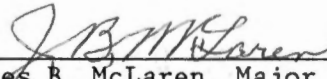


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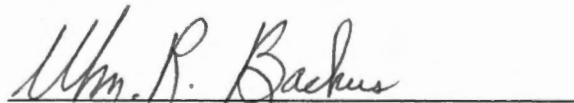
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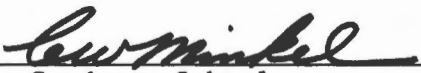








Accepted for the council:


The Graduate School

MULTIVARIATE PROCEDURES FOR EVALUATING FACTORS
AFFECTING PALATABILITY OF BEEF

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Billy Bruce Greene

March 1985

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Thesis
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The author wishes to dedicate this dissertation to his wife, Nancy Sanders Greene, to his parents, Kyle and Betty Greene, and to his brother, Rex Greene, for their love and support.

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ABSTRACT

Multiple regression, factor, and canonical correlation analyses were used to study the relationships among palatability attributes, Qualitative Descriptive flavor and aroma variables, live animal traits, and carcass variables. Data from 301 steers were analyzed to determine those factors which were most valuable in predicting palatability characteristics. Carcass weight was the most important animal characteristic found to predict juiciness, flavor, and overall desirability scores. Addition of more than one of the carcass characteristics to the regression models did not result in a large increase in the coefficients of determination and the results of the factor analysis showed that all carcass variables and slaughter weight were highly related. The number of days the cattle had received a high-energy diet was found to be the best single predictor of palatability characteristics. The strength of carcass variables in predicting change in palatability characteristics appeared to be related to their change with respect to the number of days the cattle had received a high-energy diet. Carcass characteristics, palatability attributes and quantitative descriptive analysis (QDA) factors collected from the carcasses of 108 steers were evaluated by canonical correlation analyses to evaluate the relationship among these groups of variables. Evaluation of carcass and QDA variables resulted in one significant ($P < .0001$) pair of canonical variables which related carcass fatness positively to beef-fat and negatively to milky-oily descriptor variables. Analysis of carcass and palatability variables resulted in one pair of canonical variables

describing primarily carcass weight and sensory flavor and overall desirability. Two significant ($p < .05$) canonical variables resulted from analysis of the QDA factors and palatability attributes. The first QDA canonical variable contrasted beef-fat and milky-oily flavor and aroma factors while the second QDA canonical variable was composed primarily of liver flavor. The first palatability canonical variable was highly related to the flavor and overall desirability palatability attributes while the second palatability canonical variable was related to tenderness and juiciness. Increases in palatability attributes and QDA factor were more affected by carcass fatness variables than they were by the other carcass characteristic.

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CHAPTER I

INTRODUCTION

Feeder cattle which vary greatly in live animal characteristics are subjected to a wide range of possible management systems before slaughter. This variation among animals and among management systems results in a large variation in the carcasses from these animals. The purpose of the U.S.D.A. quality grading system is to sort these carcasses into groups which will contain carcasses of similar palatability characteristics (tenderness, juiciness, and flavor of the cooked product) before they reach the retail marketplace and, eventually the consumer, as steaks and roasts. Previous research has shown significant variation among steaks and roasts within a particular quality grade, and among roasts or steaks from carcasses of different animals. Some of this variation is probably due to the nutritional intake of the animals during the finishing period and the length of the finishing period. There is, however, a significant amount of variation which has not yet been explained within quality grades in certain palatability traits of beef.

Increases in grain prices and the increasing competition between demands of the human population and of livestock feeders for grain will probably cause an increase in use of roughages in diets for finishing cattle. The results of research have shown a decline in certain palatability characteristics of beef from forage-finished animals. There is, therefore, a need to determine the effects of feeding regime, inherent characteristics of animals, and of their interaction on palatability attributes of beef. This information would permit recommendations to be

made regarding management practices producers should employ to supply the packers and, eventually, the consumers with beef that will be of acceptable eating quality.

The objectives of this study were (1) to assemble a large set of data in which uniform procedures were used to estimate carcass quality and palatability from animals which were extremely variable with respect to live-animal characteristics, animal management systems, and carcass attributes, and (2) to assess the effects of live-animal characteristics and carcass attributes on eating quality.

CHAPTER II

REVIEW OF LITERATURE

A. INTRODUCTION

The purpose of the U.S.D.A. beef quality grading system is to identify differences in characteristics of beef carcasses which are associated with beef palatability characteristics. These differences are used to allocate carcasses into grade classes according to their probable eating quality. The fact that price discrimination of wholesale and retail beef is partially based upon beef quality grade suggests that palatability is considered an important factor affecting consumer acceptance of beef.

The carcass characteristics presently used to determine beef quality are primarily physiological maturity and marbling of the cut surface of the longissimus muscle at the 12-13th rib interface. Factors, other than those now used as the basis of the beef quality grading system, which are associated with preslaughter management of cattle and factors inherent in the animals have been reported to affect beef palatability also.

The palatability factors most often associated with the eating quality of beef are tenderness, juiciness, and flavor. Beef samples have traditionally been evaluated by sensory panelists for these factors on a categorical hedonic scale. Other methods of measuring intensities of specific sensory properties of food samples have recently been used in the evaluation of beef samples.

The purpose of this review of literature is to summarize the available research reports involving factors associated with palatability

characteristics of beef. Reports concerning the methods presently used to evaluate beef samples for their eating quality will be reviewed also.

B. EFFECT OF MARBLING ON BEEF PALATABILITY

Marbling is the primary factor upon which quality grades of beef carcasses within the A maturity classification (9-30 months of age) are based. Smith et al. (1983) stated that 85% of U.S.D.A. graded beef carcasses in the United States are A maturity carcasses. Since beef carcass price discrimination is based primarily on marbling score, the beef cattle industry must assume that marbling is a predictor of beef acceptability or that variation in organoleptic properties of beef is large enough to justify the use of some characteristic to account for this variation. Marbling has been used traditionally as a beef palatability indicator, and its use continues to be convenient (Armbruster et al., 1983). In a review of the fat content of animals in relation to their eating quality by Smith and Carpenter (1976), Bull (1916) was quoted as saying "The main object in fattening is to improve the flavor, tenderness, and quality of lean meat by the deposition of fat between the muscular fibers." Hall (1910) suggested that marbling was related to tenderness and that increased tenderness in carcasses with greater degrees of marbling was due to a decrease in connective tissue elasticity as fat is deposited within the muscle. According to Smith and Carpenter (1976), Bull (1916) and Hall (1910) did not present substantiating data, and their statements about the relationship between carcass fatness and palatability were probably based on personal opinions or assumptions.

The results of more recent research have not shown the large direct relationship between marbling and palatability that was proposed by earlier meat scientists. Some studies suggested that marbling had a slight positive effect on organoleptic properties of beef while others suggested that no relationship existed.

Tuma et al. (1962), Romans et al. (1965), Berry et al. (1974) and Prost et al. (1975) found no significant correlation between marbling and tenderness. Armbruster et al. (1983), in a more elaborate study, found no significant correlation between marbling and tenderness in carcasses from either Angus or Holstein steers and found, in addition, that variation in marbling, when used as a covariate with breed, diet and housing effects, explained only 1% of the variation in tenderness in an analysis of variance. However, Campion et al. (1975) and Tatum et al. (1980) found low significant correlations between marbling and tenderness. McBee and Wiles (1967) found a linear increase in tenderness ratings with increasing levels of marbling. Campion et al. (1975) demonstrated that in order to effect a one-unit change in taste panel tenderness score (recorded on a scale of 1 to 9) marbling score would have to differ by 17 units (on a scale of 1 to 27) in beef carcasses from a number of British and exotic breeds of cattle. Huffman (1974) and Dikeman and Crouse (1975) found that the amount of variability in tenderness accounted for by variation in marbling ranged from 7% to 10%. Wellington and Stouffer (1959) concluded that factors other than marbling must have a greater influence on tenderness.

Blumer (1963) stated that marbling is negatively associated with the amount of connective tissue in muscle. Cover (1959) found that the

tenderness of the connective tissue within the muscle, evaluated on the basis of sensory panel scores, was not affected by the amount of chemical fat present. Batterman et al. (1952) determined that the amount of connective tissue did not change during the fattening process.

Breidenstein et al. (1968) suggested that the influence of marbling on tenderness resulted from its effect on two other characteristics, juiciness and flavor, which sensory panelists tend to associate with tenderness. Blumer (1963) defined juiciness of beef as the liquid detectable during the chewing of a bite of the meat. This liquid would include the flow of saliva which occurs from eating a sample of meat and, therefore, may be associated also with flavor of the sample since this would stimulate greater salivary flow. The remainder of the liquid was probably due to the moisture and the unsaturated fatty acids or fatty acids with chain lengths short enough to be in liquid form at temperatures at which a meat sample is eaten. In reviewing a number of research papers on the subject, Blumer (1963) concluded that approximately 16% of the variation in juiciness could be accounted for by variation in amount of intramuscular fat.

Wellington and Stouffer (1959) found a significant positive relationship between marbling and juiciness and concluded that increases in beef juiciness ratings given by sensory panelists were closely associated with increased levels of fatness. The coefficient of correlation between marbling and juiciness found by these researchers was small. Their analysis resulted in a coefficient of correlation of .29 ($P < .10$). In other studies (Goll et al., 1965; Campion et al., 1975; Garcia-de-Siles et al., 1977), no relationship was found between marbling and juiciness

over a fairly wide range of marbling scores and breeds of cattle. Armbruster et al. (1983) and Wellington and Stouffer (1959) found juiciness to be related to marbling ($r = .29$, $P < .01$), within Angus but not within Holsteins. The analysis of regression of juiciness on marbling by Wellington and Stouffer (1959) indicated that an increase of 14 units (scale: 1-10) in marbling would be necessary to effect one-unit change in juiciness on a scale of 1 to 9. This range in marbling was greater than the range of the scale used in that study.

In some instances, marbling has been shown to affect sensory panelists' perception of beef flavor more than it did their perception of other palatability characteristics. Moody (1983), in a review of beef flavor, concluded that fat may influence meat flavor in two ways: 1) by oxidation of principally unsaturated fatty acids and subsequent formation of carbonyl compounds in organoleptically significant amounts and 2) by volatilization of fat-soluble compounds present in fat when heated. He stated that in most research reports, the effect of marbling has been confounded with subcutaneous fat as flavor-compound precursors and the relative importance of each has not been clearly established.

Tatum et al. (1982) found that variation in marbling explained 15% of the variation in flavor, which was greater than that explained in tenderness, juiciness, or overall acceptability ratings. Smith et al. (1983) found that flavor ratings were higher for steaks that had "modest" through "moderately abundant" marbling than for steaks with less marbling, but flavor ratings were similar within this range. Steaks containing less than "small" amounts of marbling also were ranked lower in flavor. The range in these flavor ratings was only about 1.5 units (on a 1 to 9 scale),

and beef from carcasses with "traces" or greater degrees of marbling was given acceptable flavor ratings. Armbruster et al. (1983) found only a 1/2 unit difference (on a 1 to 9 scale) in flavor ratings due to differences in marbling and questioned the importance of the differences even though they were statistically significant ($P < .05$).

C. EFFECT OF SUBCUTANEOUS FAT THICKNESS ON BEEF PALATABILITY

Some researchers have suggested that subcutaneous fat thickness may be an important adjunct to marbling as an indicator of beef tenderness. In a review paper, Smith et al. (1983) proposed that thickness of subcutaneous fat is not linearly related to palatability but that there is a possible threshold level of fat thickness below which palatability is not satisfactory. Bowling et al. (1977) suggested that increased subcutaneous fat associated with grain finishing acts as an insulator to delay chilling and promotes autolysis of muscle protein. Furthermore, this delayed chilling is believed to prevent cold shortening, which improves beef tenderness. Smith et al. (1976) found that increases in thickness of subcutaneous fat in lamb carcasses, which decreased the rate at which the temperature of the carcass declined in the cooler, enhanced either the rate or the duration of autolytic enzyme activity in muscle and lessened the extent to which sarcomeres shortened during the cooling process. These factors were considered responsible for increased tenderness ratings associated with fatter lamb carcasses. Wanderstock and Miller (1948) determined that tenderness ratings increased with an increase in the amount of carcass subcutaneous fat. Bowling et al. (1977) reported that increases in fat thickness from 1.3 to 9 mm were associated with

increases in sarcomere lengths and sensory panel tenderness ratings. They found no variation in tenderness of meat from carcasses with fat thicknesses greater than 10.2 mm and suggested that increasing the fat thickness beyond this point would not improve tenderness. Merkel and Pearson (1975) reported that meat from carcasses with 12.7 mm or less fat thickness at the 12th and 13th ribs was less tender than that from carcasses with more than 12.7 mm and that the toughening effects of cold shortening are greatest in meat from carcasses with less than 12.7 mm of fat. They suggested also that toughness increases progressively as fat thickness decreases below 12.7 mm and that there were essentially no differences in tenderness of meat from cattle with 12.7 mm or more fat, regardless of how much additional subcutaneous fat (up to 31.8 mm) was present. Bowling et al. (1978) reported that 19% of the variation in sensory panel tenderness ratings could be explained by variation in fat thickness and suggested alternate chilling methods for carcasses with inadequate marbling and subcutaneous fat covering. Dolezal et al. (1982) grouped carcasses according to subcutaneous fat thickness and found that carcasses with 5.07 mm or less of fat thickness received lower palatability ratings than did those with 5.07 to 10.15 mm. Carcasses with 10.15 mm or greater had higher ($P < .05$) palatability ratings than did those with fat thicknesses between 5.07 mm and 10.15 mm. Palatability variables in this study included tenderness, flavor, and overall palatability. Juiciness was not different ($P < .05$) among the three fat-thickness groups. Tatum et al. (1982) found a general increase in palatability as subcutaneous fat thickness increased up to 7.6 mm, and no change was observed as fat thickness increased from 7.6 to 10.2 mm. They suggested that after a certain level

of subcutaneous fat thickness was reached, the effect of fat thickness on beef palatability is neither linear nor additive. However, Aberle et al. (1981) found no differences in sarcomere lengths of muscle in carcasses with different subcutaneous fat thicknesses and found little evidence of cold shortening having a significant effect on tenderness. These authors hypothesized that the lower internal temperatures of carcasses with less subcutaneous fat could reduce the activities of endogenous proteolytic enzymes which are believed to cause post mortem tenderization. However, they indicated that they did not believe that the differences in chilling rate caused by differences in subcutaneous fat thicknesses could explain all the variation in tenderness found in beef from cattle fed grain for longer periods of time. Bowling et al. (1978) concluded that cold shortening and variation in rate or extent of autolytic enzyme activity in pre-rigor muscle caused by less fatness in carcasses of grass-finished cattle could have resulted in part, but not all, of the variation in tenderness of meat between grass- and grain-finished cattle.

D. EFFECT OF FEEDING REGIME ON BEEF PALATABILITY

Beef consumption in the United States rose steadily from the 1950's through the 1960's, primarily as a result of a large supply of reasonably priced beef as a consequence of large supplies of relatively inexpensive grain (Schupp et al., 1979). Increased energy costs, competition with other countries for U.S. grain exports and the popular belief among U.S. consumers that a relationship exists between consumption of animal fat and ill health may cause future beef producers to use less grain in their beef-production systems. Schupp et al. (1979) predicted that world demand

and supply of feed grain will dictate the relative amounts of grain and forage fed to cattle in the immediate future and that U.S. beef production will depend more heavily on forages in the distant future.

Though forage-finished cattle may yield choice grade carcasses, a number of palatability problems have been encountered with the beef from such cattle. Finishing cattle on low-energy forage diets tends to have a more adverse effect on flavor than on other palatability characteristics of beef. Tenderness and juiciness ratings, however, have been found to be lower in meat from cattle finished on forages than in that from cattle fed concentrate diets in some experiments (Kropf et al., 1975; Bowling et al., 1977, 1978). Bidner (1975) and Reagan et al., (1977, 1981) reported no variation in tenderness scores of beef due to finishing cattle on a range of forage:grain ratios. Melton (1983) stated that different forages have different effects on organoleptic properties of beef refuting a simple conclusion concerning the effect of all forages on beef flavor. In general, less desirable flavor scores have been associated with beef from cattle finished on grass pastures (Bowling et al., 1977; Reagan et al., 1977; Melton et al., 1982a). Results of many studies have been similar across several types of grass, legume, or grass-legume pastures, with approximately one-point difference in average flavor score between meat from grass- and grain-finished cattle (Wanderstock and Miller, 1948; Kropf et al., 1975; Reagan et al., 1977; Harrison et al., 1978; Schroeder et al., 1980; Melton et al., 1982b).

Bowling et al. (1977) suggested that when cattle finished on various management systems are slaughtered at the same time, differences in management systems are confounded with differences in fatness of the

animals. Conversely, if forage-fed and grain-fed animals are slaughtered at a constant fat thickness, differences in age are confounded with differences in management system. Therefore, they evaluated forage-versus-grain palatability differences in beef from animals slaughtered at the same age and level of marbling but having differences in subcutaneous fat thickness. They observed consistent differences in flavor characteristics between the beef carcasses from animals finished on forage or grain diets which could not have been associated with differences in marbling. Similar results were reported by Melton et al. (1982a) and by Reagan et al. (1977). According to the results of these experiments, it seems that the flavor difference between meat from grass- and grain-finished cattle is not due to difference in fat concentration, but rather to chemical differences within the edible portion of the beef.

In a report of the results of a large study involving Angus and Hereford x Angus cattle, Schupp et al. (1979) stated that at carcass weights greater than 227 kg neither trained sensory panel judges nor consumer household sensory panelists could distinguish effectively between beef from forage-finished cattle and that from cattle fed grain for 70 days. They suggested that forage-fed cattle should not be slaughtered until they were heavy enough to produce 227-kg carcasses. This study was conducted with British breeds of cattle only, and the results possibly could be different in cattle of other breeds and biological types. Melton et al. (1982a) found that the desirability of flavor of beef from yearling cattle finished on whole-shelled corn following a spring-summer grazing period increased as the length of the finishing period increased from 0 to 84 days. They described the desirable flavor as "beef-fat" flavor and the

undesirable flavor as "sour", "dairy" or "fishy" flavor. Brown et al. (1979) reported similar descriptions of flavor of beef from grass-finished cattle. Schroeder et al. (1980) described desirable flavors of beef from grain-fed cattle as being "fatty" while those of beef from grass-fed cattle were described as "grassy". Berry et al. (1980) described desirable beef flavor as a "browned" flavor while beef with undesirable flavor characteristics had a "grassy" or "astringent" flavor.

Moody (1983) suggested flavor of meat to be the result of the two distinct responses of taste and aroma which are stimulated by a large number of chemical compounds. He suggested that the volatile compounds contained in meat are the most important chemical compounds causing these responses. These chemical compounds are derived from carbohydrates, fats, and proteins which are similar among species, with few exceptions. According to Brown et al. (1979) and Melton et al. (1982b), grass versus grain feeding did not account for the difference in the amounts of alpha amino acid compounds in beef produced by the two basic sources of feed. They did find a difference in carbohydrate concentrations in meat due to differences in diet, and Melton et al. (1982a) found that the concentration of water-soluble reducing sugars in beef increased linearly with increasing number of days that steers were fed corn.

Fatty acids are the primary precursors of carbonyl compounds which are known to affect beef flavor. Differences in concentrations of fatty acids in beef from cattle fed grass or grain have been reported. Beef from cattle finished on grass has a higher percentage of stearic acid (C18:0) and a lower percentage of oleic acid (C18:1) than does beef from cattle finished on grain (Brown et al., 1979; Melton et al., 1982b).

Schroeder et al. (1980) reported similar results and stated that a higher percentage of unsaturated fatty acids was found in beef from grain-fed steers. This finding was based primarily on decreases in concentrations of C18:0 and increases in that of C18:1 fatty acids. These researchers did not measure the differences in concentrations of linoleic acid (C18:3). Melton et al. (1982a) found a higher percentage of C18:3 in beef from grass-fed cattle and a large concentration of this fatty acid in the lipid portion of the grass that had been fed. They suggested that the concentration of C18:1 increased at the expense of C18:0 as the length of the grain feeding period increased. They hypothesized that this was due to the higher energy level of the feed rather than to differences in the composition of the grass and grain diets. Feeding cattle a high-energy rather than a low-energy concentrate diet resulted in increased concentration of C18:1 and decreased concentrations of palmitic acid (C16:0), C18:0, or both (Dinius et al., 1976). The decrease in the concentrations of C18:3 and arachidonic acid (C20:4) associated with increased grain finishing periods seemed to be the result of the diet composition and not of the energy level. Melton (1983) concluded that higher concentrations of these and other polyunsaturated fatty acids found in beef from grass-fed cattle may cause a higher intensity of undesirable flavors in that beef, such as milky-oily, grassy, and fishy flavors by thermal oxidation. These fatty acids are assumed to cause more rapid oxidative rancidity during storage of beef from grass-fed than in stored beef from grain-fed cattle. Melton et al. (1982a) found a larger concentration of two of the volatile fatty acids in beef from grain-fed animals. The concentration of acetic acid was found to increase linearly with time on a

grain diet up to 140 days. Butyric acid was found to be present in higher concentrations in beef from grain-fed cattle.

E. EFFECT OF LENGTH OF FINISHING PERIOD ON BEEF PALATABILITY

Although most research data have shown an improvement in flavor characteristics of beef from animals which have received a high-concentrate diet prior to slaughter (Tatum et al., 1980; Melton et al., 1982a), there appears to be a point beyond which longer feeding does not affect beef flavor. Aberle et al. (1981) concluded that, although feeding a high-energy diet increases palatability, the duration of this increase is short, and little benefit is obtained from longer periods of feeding. Tatum et al. (1980) serially slaughtered steers after 100, 130 and 160 days on feed and found that desirable flavor characteristics increased with time on feed from 100 to 130 days but did not increase with time on feed from 130 to 160 days. Other palatability characteristics were not found to increase in beef from cattle fed longer than 100 days, regardless of the quality grade of the carcasses. This was reported to be true in beef from choice-, good-, and standard-grade carcasses. The authors suggested that knowledge of the feeding history of cattle might be used along with, or as a substitute for, U.S.D.A. quality grade as a predictor of beef palatability.

Harrison et al. (1978) studied the effects of nutritional regime and days on feed and found no difference in palatability between beef from cattle fed 98 days on a high-concentrate ration and that from cattle fed on a high-forage ration. The high-forage ration did, however, contain 36% cracked corn. The desirable flavor characteristics associated with grain

feeding may have been present in the beef from these "forage-fed" animals due to the inclusion of corn in the forage diet. Alfalfa haylage and corn silage were used as the forage components of the diet, and other research has shown that these feeds may be substituted for corn in finishing diets for cattle without causing decreased palatability in the beef produced. Dinius et al. (1976) determined that alfalfa and other high-quality hays could be substituted for 29.4% of the corn in the diet without affecting flavor characteristics. Young and Kauffman (1978) concluded that beef from cattle fed corn silage was slightly more desirable than that from steers fed a mixture of corn and corn silage.

Zinn et al. (1970) studied shear values of beef from steers slaughtered at 30-day intervals up to 210 days on feed and found that tenderness values, expressed as an average of those from three muscles, were higher in beef from cattle fed 150 and 180 days. They concluded that the age of the animals had a greater effect on tenderness than the length of the finishing period after 180 days on feed and tended to depress tenderness values at 210 days on feed. Epley et al. (1968) found that feeding cattle beyond 139 days did not result in consistent increases or decreases in flavor intensity, flavor desirability, tenderness desirability, or overall desirability.

Crouse et al. (1978) stated that longer time on feed was associated with improved taste panel scores within a particular diet energy level and that feeding regimens that involved longer feeding periods for cattle to reach slaughter weight tended to decrease taste panel acceptability. In contrast, Burson et al. (1980) found no interaction between time on feed and diet energy density of corn and wheat concentrate diets in their

effect on palatability characteristics. Their low-energy-density ration, however, contained approximately 36% concentrate. They concluded that any effect of time on feed and diet energy density on palatability of beef in this particular study must have occurred before the start of the trial during the early growing or "preconditioning" period. The control group in this study was not slaughtered until after a feed adjustment period.

Smith et al. (1977) found no differences in palatability of beef from various biological types of cattle after 49 days of feeding a 20% or a 60% forage ration. These cattle had, however, received corn silage prior to the beginning of the feeding trial, and a longer feeding period would probably be necessary to effect a difference had the cattle been on a pasture diet. Melton et al. (1982a), in studying grazing versus all-concentrate feeding, determined that major changes in intensities of flavor descriptors occurred during the first 56 days steers were fed grain after grazing. There appeared to be little change after 84 days on feed. The authors suggested that, based on beef flavor, the length of grain finishing of cattle could be reduced to 80 to 90 days with little flavor change. Schupp et al. (1979) reported that cattle grown on grass and fed a high-concentrate finishing ration for 70 days produced beef with acceptable palatability characteristics as judged by both household and trained sensory panelists.

Aberle et al. (1981) reported that improved tenderness of beef occurred within the first 70 days cattle were fed a high-energy diet. Smith et al. (1977) and Leander et al. (1978) reported improved tenderness of beef from cattle fed 49 and 50 days, respectively, over beef from grass-fed cattle. Harrison et al. (1978) reported similar findings but

stated that beef from cattle fed 98 days was rated more tender than was that from cattle fed 49 days.

Aberle et al. (1981) stated that growth rate of cattle prior to slaughter has an important effect on meat tenderness. One hypothesis was that, in rapidly growing animals, newly synthesized collagen would represent a greater proportion of the total muscle collagen. This newly synthesized collagen would contain fewer intermolecular crosslinks which would result in less stable collagen fibers and higher solubility. Another possible effect of the rapid growth rate would be that the rate of protein breakdown and the rate of protein synthesis are elevated in rapidly growing cattle, as has been found to be the case in rats. Thus, the proteolytic enzymes would be more active, or present in larger concentrations, and would cause a greater degree of post-mortem muscle fiber breakdown. They found little evidence that cold-induced shortening caused differences in tenderness and concluded that rate of growth immediately prior to slaughter may be more important in determining tenderness of beef than is length of time on a high-energy diet, provided the high-energy diet had been fed long enough to allow maximum activation of the enzyme systems operative in rapidly growing muscle tissue.

F. EFFECT OF BIOLOGICAL TYPE AND BREED ON BEEF PALATABILITY

In general, the observed effect of biological type of cattle on palatability characteristics of beef have been small or nonexistent. Smith et al. (1977) divided crossbred cattle of several different British, exotic and dairy breeds into small- and large-frame groups and found no differences in any palatability characteristic when values were

adjusted for the effects of age and longissimus-muscle-fat endpoints. Large-type cattle had slightly lower palatability scores at a constant weight, but these differences were small. Possibly, the differences in weight reflect differences in rate of maturity of the large cattle versus that of the small cattle. Carcasses from large-type cattle were found to be less mature and to have lower marbling scores when adjusted to a constant weight.

Koch et al. (1976) studied palatability characteristics of beef from steers produced from Hereford and Angus cows and sired by Hereford, Angus, Jersey, South Devon, Limousin, Charolais, and Simmental bulls. They found tenderness scores to be significantly associated with breed of sire. Beef from Jersey and South Devon crosses was more tender, while that from Limousin and Simmental crosses was less tender. Although these differences were significant ($P < .01$), they were numerically small, and all mean scores were within the desirable range. No differences were found in juiciness and flavor characteristics among breed groups even though there were differences in marbling scores. Epley et al. (1968) studied the effects of sire and sire-by-time-on-feed interactions on palatability characteristics of beef and found the effect of sire on flavor and tenderness scores to be significant ($P < .01$). The breeds of sires used in this study were Angus, Hereford, and Polled Hereford. Furthermore, a significant interaction ($P < .01$) was found between the effect of sire and that of time on a high-energy diet with respect to tenderness ratings. This interaction was not observed in the case of flavor scores.

In a study of seven breeds and breed crosses, Ramsey et al. (1963) found steaks from Brahman steers to be less tender than those from Jersey,

Hereford, Angus, Brahman x British cross, Santa Gertrudis, and Holstein steers. Although the steaks from Angus steer carcasses contained greater amounts of marbling, those from Jersey and Hereford cattle were rated most tender. The steaks from the remaining breeds did not differ significantly ($P > .05$). When the cattle were grouped according to type, beef from British-beef-type steers was more juicy but less flavorful than beef from dairy-type steers. Steaks from the Brahman cattle ranked lower in all palatability traits studied. Although Holsteins ranked lowest in carcass quality measurements, they were intermediate between the Brahman and the British and Jersey steers in palatability ratings. Armbruster et al. (1983) found very small differences between flavor characteristics of beef from Angus and Holstein steers and no difference in juiciness. Branaman et al. (1962) found no differences in tenderness of meat from beef-type steers and that from Holstein steers, but greater degrees of juiciness and flavor of lean were associated with meat from the beef-type cattle.

In a study of British and exotic cross cattle, Koch et al. (1979) found differences in tenderness of beef among breed crosses, but no differences in other palatability characteristics were detected. Although statistically significant ($P < .05$), the actual differences among the means were small, and all means were in an acceptable range of the hedonic scale. The authors suggested that differences among breed groups in meat palatability are small when animals are of a similar age and have been raised under similar management and feeding conditions. In a study which included Zebu-cross cattle, Koch et al. (1982) found greater variation in palatability characteristics, with the primary differences being between

beef from Zebu-cross and that from exotic- or British- cross cattle. Beef from Zebu cattle ranked lower in tenderness, juiciness and flavor scores. Flavor scores had the least amount of variation, and the authors suggested that, although the differences in flavor among breeds were statistically significant ($P < .05$), they did not seem to be economically important.

G. EFFECT OF GRASS FEEDING ON COLOR OF FAT AND LEAN AND ON LEAN FIRMNESS

Some researchers have hypothesized that beef from grass-finished cattle has a less desirable color and texture of lean tissue and a yellow appearance of the fat which is assumed to be discriminated against by consumers. Hunt et al. (1953) found no difference in lean color between carcasses from grass-finished cattle and those from grain-finished cattle when the cattle were fed to equal degrees of finish. The authors stated that grass as a feed does not produce dark beef, and brightness of lean is related to degree of finish. Wanderstock and Miller (1948) found small and inconsistent differences in lean color scores between carcasses from grass-fed cattle and those from grain-fed cattle and found no relationship between lean color and muscle pH. Bull et al. (1941) concluded that cattle finished on good pasture do not have darker colored lean. Koch et al. (1976) stated that both color and texture of lean change with maturity and that deviations in color or texture from expected levels within a given degree of maturity contributed to differences in evaluation of lean quality in the study. These differences were not related to palatability characteristics.

Campion et al. (1975) found no significant correlations between texture of lean and palatability characteristics except for a low negative

coefficient of correlation ($-.11$, $P < .05$) between texture and tenderness when calculated over several sire breeds. This significant correlation could have resulted from breed differences. Tuma et al. (1962) showed that texture within a narrow range of carcass maturity was not useful as a predictor of meat palatability.

Campion et al. (1975) found significant pooled-within-sire-breed correlations of color of lean with sensory panel evaluations of tenderness, flavor, and overall acceptability. Juiciness was correlated with lean firmness on a within-sire basis, but flavor was not. Schupp et al. (1979) found no evidence of consumer discrimination against beef from forage-finished cattle on the basis of darker-colored lean.

Hunt et al. (1953) found that carcasses from grass-fattened cattle contained more yellow fat color than did those from grain-fattened cattle. The carcasses from grass-fattened cattle contained also greater concentrations of carotene, a principal source of vitamin A. They stated that, though these carcasses would not be considered desirable on the basis of carcass attractiveness, meat from them actually would be more nutritious due to the higher carotene content. No differences in palatability between meat samples from the two groups were found. Bull et al. (1941) studied a number of pasture-forage species and determined that yellow fat in carcasses resulted from the transfer of carotene from pasture forage to body fat. Yellow fat was not found to be objectionable to consumers even though these carcasses received lower quality grades due to the fat color. Malphrus (1957) determined that no flavor preference was indicated on the basis of color of fat in beef roasts. Schupp et al. (1979) studied

responses of a consumer panel with respect to fat color and found no consumer discrimination against cuts of beef with more yellow fat color.

H. HEDONIC-SCALE METHOD OF MEASURING FOOD PREFERENCES

The definition of hedonics is: characterizing or pertaining to pleasure. According to Peryam and Pilgrim (1957), hedonic rating scales have been used in food evaluation since as long ago as 1920. Since that time many types of rating scales have been used in food research, technology, and quality control. The essential components of the hedonic rating scale are the definition of a psychological continuum and the establishment of a series of successive categories of response. Its essential features are its assumption of a continuum of preference and the direct way in which it defines the categories of response in terms of like and dislike (Peryam and Pilgrim, 1957). The scale is named for the type of response it seeks to elicit. The response is assumed to be derived from feeling or is due to the continuous degrees of pleasantness or unpleasantness associated with a sensation.

Three sources of variation are believed to affect the average rating of a food. One is the interaction between judges and treatments, which can be interpreted as disagreement among people as to which treatment is preferred and by how much. Peryam and Pilgrim (1957) stated that, even though this source of variation is always present, relative preferences of panelists tend to be stable.

A second source of variation is among panelists drawn from a population. Individuals express themselves differently. Some are more enthusiastic and tend to use the high end of the scale while others are

restrained and tend to use the low end of the scale. There are differences among individuals resulting also from their like or dislike of certain foods.

A third source of variation is variation in environmental conditions or in test populations. Panelists may tend to rate some foods higher during the winter than they would during the summer. Panelists who are, for example, accustomed to eating hot chili may rate a sample differently from those who are not accustomed to eating hot chili.

Although a food scientist conducts a test to determine some fact about the food, the hedonic scale is designed to measure human behavior potential. The food itself is only one of the factors which contribute to the result. Panelists' responses may be affected by personality, long- and short-range attitudes, physical well-being, and variables which are both physiological and psychological in nature (Pilgrim, 1957).

Peryam and Pilgrim (1957) listed the advantages of the hedonic scale as: 1) its simplicity which makes it suitable for use with a wide range of populations, 2) subjects can respond meaningfully without previous experience, 3) the data can be handled by the statistics of variables, and 4) in contrast to other methods, within broad limits the results are meaningful for indicating general levels of preference.

Cover (1959) pointed out that hedonic scale ratings are valuable for detecting consumer acceptance of a product but not for detecting quantitative differences among products. She stated that a panel judge who dislikes rare meat would probably give a lower juiciness score to a rare steak because of his or her dislike for a steak that was too rare. This allowed the measurement of preferences for a particular meat sample, but

it could not be compared with any physical or chemical test for juiciness. Cover (1959) suggested that another scale should be used in which the judge rated the sample for degree of juiciness, regardless of preference. These are the types of scales which are now predominantly used in research for detecting palatability differences among meat samples. Amerine et al. (1965) stated that this type of scale which measures quantitative differences in palatability characteristics, such as juiciness and tenderness, could be used effectively by judges regardless of their preferences for rare or well-done steaks.

McDaniel and Sawyer (1981) reported that other limitations associated with categorical scaling of palatability characteristics are that such scaling is subject to several biases of human judges. Intervals between neighboring categories may be psychologically unequal, and judges may tend to lump their evaluations at the center of the scale.

I. QUANTITATIVE DESCRIPTIVE ANALYSIS

Stone et al. (1974) described quantitative descriptive analysis as a technique by which trained individuals identify and quantify, in order of occurrence, the sensory properties of a product or an ingredient. The results of such analysis permit the development of multidimensional models in a quantitative form which may be related to consumer acceptance of products and to physical and chemical properties of foods. Baten (1946) studied organoleptic properties of apples and pears on a hedonic categorical scale and on a scale anchored at each end by words, "Very poor" being placed at one end of a continuous line and "excellent" being placed at the other end. Results obtained from a comparison of the two

methods of scaling showed better detection of product differences when the scale word-anchored only at the ends was used.

Stone et al. (1974) developed an interval scale six inches in length with anchor points one-half inch from either end and, usually, but not necessarily, an anchor at the midpoint of the scale. The panel judge was requested to place a vertical mark across the line at the point which best reflected the magnitude of his or her perceived intensity of the attribute being evaluated. During training, panelists received instruction on the range of intensities of the attribute being tested. During evaluation, the word anchors were used as the optimum range of intensities. Although this method of sensory analysis has been used primarily to study other products, similar techniques have been used to assess the flavor, texture, and aroma attributes of various meat products (Chambers et al., 1981; Melton et al., 1982a, b; Galt and MacLeod, 1983).

J. STATISTICAL ANALYSIS OF SENSORY DATA

O'Mahony (1982) suggested that commonly used methods of analysis of sensory data, such as the analysis of variance, are only rough estimates of whether real differences, or similarities, exist among foods. In category scaling techniques, many judges tend to be reluctant to use the extreme ends of the scale as if psychological distances between categories on the scale are of unequal lengths. As a result, the distribution curve will be a distorted normal distribution. This may invalidate the assumptions underlying analysis of variance. When the mean evaluation of a particular product lies near the end of a categorical scale, the distribution may be skewed. Often, the variances of two distributions are unequal

when rated by a categorical scale. Thus, both basic assumptions underlying analysis of variance may not be true. O'Mahony (1982) stated that these same assumptions may be invalidated also when graphic or intensity scaling is used. The distribution may be skewed positively or negatively when the mean rating of a sample is placed close to either end of the scale. The conceptual intervals on a scale used by a judge when comparing samples are not known. Therefore, the measured length of a line that is twice as long for one sample as it is for another may not indicate that the former sample is twice as good as the latter any more than a sample given a rating of eight on a categorical scale may be assumed to be twice as good as a sample given a rating of four.

O'Mahony (1982) suggested that probability levels determined by analysis of variance of sensory data should be used only as rough estimates. Other tests such as nonparametric rank tests should be applied to sensory data along with analysis-of-variance tests. Should a trend be observed, a binomial test was suggested to determine if a significant number of judges show the indicated trend. A transformation of the data was suggested only if the experimenter believes there is something wrong with the original data. According to O'Mahony (1982), analyzing the data in several different ways should give the experimenter a clearer view of what is happening.

K. SUMMARY OF REVIEW OF LITERATURE

Although marbling is the primary factor involved in the evaluation of quality of lean in beef carcasses, within a physiological maturity group, the relationship between marbling and organoleptic properties that

indicate beef palatability is small. In general, the relationship of marbling to palatability characteristics has been found to be slightly positive. However, the results of some studies have indicated no relationship. Most research data suggest that a larger direct relationship exists between marbling and flavor and between marbling and juiciness than between marbling and tenderness.

Subcutaneous fat thickness affected beef palatability in some instances, but there was no direct linear relationship between subcutaneous fat thickness and palatability attributes. Thicker layers of subcutaneous fat appear to decrease the effect of cold shortening on muscle contraction and to increase beef tenderness, but this factor did not improve after subcutaneous fat thickness reached approximately 12 mm.

Although choice-grade carcasses can be produced from forage-finished cattle, a number of palatability problems have been encountered with beef from such cattle. The palatability attribute that is affected most in beef from forage-finished cattle is flavor. There appears to be an improvement in flavor characteristics of beef from cattle finished on grain as compared to those of beef from cattle finished on grass. The desirable characteristics of beef from grain-finished cattle are both directly and indirectly related to the diet which the cattle received prior to slaughter.

The length of time cattle have received a high-energy diet prior to slaughter has been found to affect palatability characteristics of beef produced from them. This improvement in palatability did not increase linearly over long finishing periods, and there is a period of concentrate feeding beyond which desirable palatability characteristics are not

increased. This length of time varies depending on the type and energy density of the diet and the type and breed of cattle receiving the diet.

Carcasses produced from grass-fed animals often have a less desirable color and texture of lean and a yellow appearance of the fat. Reports of research findings regarding the relationship between less desirable color and texture of lean beef and type of diet consumed by animals producing this beef have been inconsistent. Although yellow fat color and less desirable lean color and texture may affect consumer acceptance of beef at the retail meat counter, most researchers have not found a large decrease in the palatability characteristics of beef from carcasses with yellow fat and undesirable lean color and texture.

A number of problems may be encountered when using sensory panels to evaluate the desirability or acceptability of food samples. Many panelists do not use the entire rating scale; some panelists tend to use the high end of the scale while others tend to use the low end of the scale. There is often an interaction between judges and treatments in the evaluation of food samples by a sensory panel. The food itself is only one of many factors which may affect panelists' evaluation of food samples. Continuous line scales were designed to circumvent the problems associated with the categorical hedonic scale, but some problems still arise. Some panelists still tend to use one end of the scale while others tend to use the other end. One continuous scale technique is Quantitative Descriptive Analysis in which a panelist evaluates a food sample for the intensity of a particular sensory characteristic relative to some standard given the panelist during training.

Since the beef packing and retail industries continue to place emphasis on beef quality when pricing slaughter cattle and wholesale and retail beef, it seems that palatability is an important characteristic of beef. The factors presently used by U.S.D.A. graders to determine beef quality were found to be related to the palatability characteristics of beef, but this relationship was small. There is a need for continued research to determine the effect of other factors on beef palatability and to determine the relative importance of these factors in predicting the probable eating quality of beef.

CHAPTER III

EXPERIMENTAL PROCEDURE

A. SOURCE AND MANAGEMENT OF THE ANIMALS

A total of 301 Angus or Hereford steers were evaluated for various live-animal, carcass, and palatability characteristics over a three-year period. All steers were wintered on stockpiled pasture and hay when sufficient forage was not available or was covered by snow. They were then placed on spring-summer cool-season grass and clover pasture at the beginning of the spring growing season. At the end of the spring-summer grazing period, the steers were placed in a feedlot and fed a high-concentrate feedlot diet, consisting of whole-shelled corn and a protein supplement, for varying lengths of time before slaughter. Various carcass variables and palatability characteristics of the beef from each carcass were recorded after slaughter of the animals.

In the fall seasons of 1978, 1979 and 1980, a total of 60, 90 and 83 steers, respectively, were purchased at East Tennessee feeder calf sales and were transported to The University of Tennessee Plateau Experiment Station. The steers purchased in 1978 consisted of 30 Angus and 30 Hereford steers, those purchased in 1979 were Angus, and those purchased in 1980 were Hereford.

At the beginning of the spring-summer grazing period of the year following the purchase of the respective groups of steers, they were placed on predominantly fescue and clover pastures and were allowed to graze until the forage became dormant during the latter part of the

summer. The steers were randomly assigned to slaughter groups and one group was slaughtered directly off pasture while the remainder were placed in the feedlot.

Another group of 68 Angus steers which had been utilized in a cow-calf grazing trial at the Ames Plantation in West Tennessee were weaned in the fall of 1980 and were wintered on stockpiled forage and hay at that experiment station. They were allowed to graze a variety of grasses during the following spring and summer and were managed similarly to the steers which were grazed at the Plateau Experiment Station. At the end of the summer grazing season in West Tennessee, these steers were randomly assigned to slaughter groups. One group was slaughtered directly off grass, and the remainder of the cattle were transported to the 70-N unit of the Plateau Experiment Station and were placed in the feedlot.

The animals which were placed in the feedlot were allowed 14 days to adjust to the concentrate diet, which consisted of whole-shelled corn and a commercial protein supplement. Following this 14-day adjustment period, a group of cattle were sequentially slaughtered at 28-day intervals up to 140 days on feed.

B. LIVE ANIMAL DATA

Live animal weights, wither heights, and subcutaneous fat thickness measurements were recorded at the time of purchase and at the beginning of the spring-summer grazing period for the steers which were wintered at the Plateau Experiment Station. These measurements were recorded again at the end of the summer grazing period. Only those measurements recorded at the end of the grazing period were available for the steers which had been

grazed at the Ames Plantation. These measurements were recorded for all animals in the feedlot prior to the slaughter of each consecutively slaughtered group of steers.

C. CARCASS DATA

Each group of steers to be slaughtered were transported to Knoxville, Tennessee and, with the exception of the steers in the trial conducted in 1979, were slaughtered at a commercial packing house. The steers in the 1979 trial were slaughtered at the University of Tennessee, Food Technology and Science meat animal abattoir. Carcass quality and yield grade factors including marbling and percent kidney, pelvic and heart fat were determined by a U.S.D.A. grader for the steers which were slaughtered at the packing house and by a trained layperson for the cattle which were slaughtered at the university meat laboratory. Hot carcass weight, rib-eye area, and subcutaneous fat thickness were determined on carcasses from all steers. Carcass lean color, lean firmness, and fat color were determined subjectively by University of Tennessee personnel for all carcasses except those from steers which had been slaughtered in 1979.

D. PALATABILITY DATA

A loin from each steer was separated into steaks and frozen for later sensory panel analysis. A group of 10 to 14 trained taste panelists (depending on year) consisting of University of Tennessee Department of Food Technology and Science and Animal Science professors, secretaries, and graduate students evaluated the steaks for tenderness, juiciness, flavor, and overall desirability. The steaks were evaluated on a 9-point

hedonic scale with a score of 1 indicating an extremely tough, dry, unflavorful, or undesirable steak, a score of 5 indicating a steak that was acceptable in each category, and a score of 9 being assigned to an extremely tender, juicy, flavorful, or desirable steak.

E. STATISTICAL PROCEDURE

An average value of each palatability characteristic was calculated by determining a raw mean for each animal across all panelists who had evaluated the animal for these characteristics. The data were pooled across all years and locations of origin, and stepwise regression analysis was performed on the pooled data with the palatability characteristics used as dependent variables and various carcass and live-animal characteristics used as independent variables. Those variables which were deemed most important based on the stepwise regression analysis were subsequently used in various combinations to produce regression equations to account for the variation associated with the palatability characteristics. Regression analyses were performed with carcass variables and live-animal variables used as independent variables.

Results of preliminary analyses showed that differences in palatability characteristics existed among the four groups of cattle. Therefore, an analysis of the regression of the palatability characteristics on all carcass variables and on the number of days on feed was performed by year group. The residuals from this model were subjected to a discriminant analysis, with year group as the classification variable, to test for homogeneity of the variance-covariance structure of the residual values among the four palatability characteristics across years. The results of

the analysis indicated that there were year differences in the variances of the residual values. The large differences among years occurred in the residual variances of tenderness, whereas, the variances of the other palatability characteristics were very similar. Therefore, regression equations with tenderness as the independent variable were calculated by year group in subsequent analyses, and the effect of year was added to the model as an independent variable in regression equations with juiciness, flavor, and overall desirability as dependent variables. A test for parallelism was performed on the regression equations with year included in the model by testing whether a significant portion of the sums of squares was contained in the interactions between year and all other independent variables in the model. These interactions were determined not to be significant ($P > .05$) in any of the regression equations. Therefore, in constructing the equations with these palatability characteristics as dependent variables, the intercepts were adjusted for the average effect of year.

Factor analysis was performed on the carcass variables and the live-animal variables measured at the beginning of the feedlot phase of the experiment and those measured just prior to the slaughter of each consecutively slaughtered group of cattle. This analysis was performed to identify those variables which were highly associated with each other and redundant when used in multiple-regression equations and to produce factor scores for those factors deemed to be interpretable and to account for the majority of the variation in the multivariate structure. Three factors were found to contain all variables and to account for 74% of the variation in the correlation structure. Factor scores were produced for

three factors to use in subsequent multiple regression analyses of palatability characteristics. This procedure allowed most of the variation associated with these carcass and live-animal characteristics to be used without the incorporation of a large number of variables in the multiple-regression equations.

The effect of number of days on feed was then added to the regression model to determine the relationship between the palatability characteristics and the length of feedlot finishing. When the square of days on feed affected the dependent variable ($P < .10$), it was added to the model along with days on feed. Other live-animal and carcass characteristics were then added to the regression model along with days on feed to determine whether this would increase the amount of variation in palatability characteristics explained by the model.

CHAPTER IV

FACTORS AFFECTING PALATABILITY OF BEEF

A. SUMMARY

Multiple-regression and factor analyses were used to study the relationship of palatability attributes with live-animal traits and carcass variables. Performance data, body measurements, carcass variables, and sensory panel evaluations of the carcasses from 301 steers subjected to similar management and nutritional regimes over a three-year period were analyzed by stepwise regression analysis to identify variables which were most valuable in predicting palatability characteristics. With the exception of slaughter weight, live animal traits were found to be of little value in equations for predicting palatability characteristics. Variation in carcass weight, marbling, and carcass fat thickness were found to explain more of the variation associated with palatability attributes of beef than any of the other variables studied. Carcass weight was the most important variable and, when used as the independent variable in simple regression analyses, explained 18%, 37%, and 29% of the variation in juiciness, flavor, and overall desirability, respectively. Of the three carcass characteristics, carcass fat thickness had the least relationship with the palatability variables, and the variation in this variable explained 4% to 11% less variation in palatability characteristics than did carcass weight. Addition of more than one of the carcass characteristics to the regression models did not result in a large increase in the coefficients of determination and the results of

factor analysis showed that all carcass variables and slaughter weight were highly related. The number of days the cattle had received a high-energy diet and the quadratic term of this variable, in the case of flavor and overall desirability, was found to be the best single predictor of palatability characteristics. The coefficients of determination from the simple regression of juiciness on number of days on feed and the multiple regressions of flavor and overall desirability on the linear and quadratic terms of number of days on feed were .24, .43, and .34, respectively. Carcass variables were usually not important ($P > .10$) in regression equations when the number of days on feed was added to the models. The value of carcass variables in predicting change in palatability characteristics appeared to be related to their change with increases in number of days the cattle had received a high-energy diet. Variation in carcass characteristics explained 75% of the variation in number of days on feed.

B. INTRODUCTION

The purpose of a beef quality grading system is to allocate carcasses into groups according to their probable sensory desirability and the fact that price discrimination is partially based on quality grades of beef carcasses, suggests that an effective method of predicting the probable desirability of beef would be desirable. Research has indicated that the factors presently being used as indicators of beef quality grades have limited utility as predictors of palatability characteristics of beef.

Although variation in carcass maturity and marbling are related to palatability attributes, only a small portion of the variation in

organoleptic properties of beef can be explained by variation in these two carcass characteristics. The amount of variation in tenderness found to be accounted for by variation in marbling has generally ranged from 7% to 10% (Huffman, 1974; Dikeman and Crouse, 1975). Armbruster et al. (1983) found that variation in marbling, when used as a covariate with breed, diet, and housing effects explained only 1% of the variation in beef tenderness. Breidenstein et. al. (1968) suggested that the influence of marbling on tenderness is due to its effect on two other characteristics, juiciness and flavor, which sensory panelists tend to associate with tenderness. Wellington and Stouffer (1959) and Armbruster et al. (1983) found that marbling was more closely related to juiciness than to tenderness and Armbruster et al. (1983) and Smith et al. (1983) reported significant relationships between marbling and flavor.

Other factors associated with animal management prior to slaughter and inherent characteristics of the animals have been reported to have an effect on the organoleptic properties of the beef produced by the animals. Some researchers have suggested that these factors should be used along with the factors presently used as predictors of palatability characteristics of beef for use in allocating carcasses into grades according to their probable eating quality. Relationships between carcass subcutaneous fat thickness and palatability characteristics have been found to exist (Merkel and Pearson, 1975; Bowling et al., 1977; Dolezal et al., 1982). Zinn et al. (1970), Aberle et al. (1981), and Melton et al. (1982a) found that the desirable characteristics of beef increased as the cattle producing this beef were fed for longer periods of time on high-energy diets. Tatum et al. (1980) suggested that information

concerning the feeding history of cattle might be used along with, or as a substitute for, U.S.D.A. quality grades as a predictor of beef palatability.

The objectives of this study were to assemble a large data set from cattle treated similarly prior to slaughter and to determine the relative value of various live animal and carcass traits as predictors of palatability characteristics of beef and to develop equations which could account for the largest portion of the variation in these palatability characteristics.

C. EXPERIMENTAL PROCEDURE

In the fall seasons of 1978, 1979 and 1980, a total of 60, 90 and 83 steers, respectively, were purchased at East Tennessee feeder calf sales. The steers purchased in 1978 consisted of 30 Angus and 30 Hereford steers while those purchased in 1979 were Angus, and those purchased in 1980 were Herefords. The steers were allowed to graze stockpiled forage during the fall and winter and were given hay when sufficient forage was not available.

At the beginning of the spring-summer grazing period of the year following the purchase of the respective groups of cattle, the steers were placed on predominantly fescue and clover pastures and were allowed to graze until the forage became dormant during the later part of the summer. In 1980, another group of 68 Angus steers was used in a grazing study at Ames Plantation during the spring-summer season and finished for slaughter at the Plateau Experiment Station under the same management system as the groups described earlier. At the end of the grazing period the steers

were assigned to groups, and a group was slaughtered directly off pasture while the remainder were placed in the feedlot.

The remaining slaughter groups were allowed a 14 day period for adjustment to the high-energy diet, which consisted of whole-shelled corn and a commercial protein supplement, and were slaughtered at 28-day intervals up to 140 days on feed.

Live-animal weights, wither heights and subcutaneous fat thickness measurements were recorded at the end of the summer grazing period and in the feedlot prior to the slaughter of each consecutively slaughtered group of steers. Carcass quality and yield-grade factors were determined by a U.S.D.A. grader.

A loin from each steer was separated into steaks and frozen for later sensory-panel analysis. A group of 10 to 14 trained sensory panelists (depending on year) evaluated the steaks for tenderness, juiciness, flavor, and overall desirability using a 9-point hedonic scale.

An average value for each palatability characteristic was calculated by determining a raw mean for each animal across all panelists who had evaluated meat from the animal for these characteristics. The data were pooled across all years and locations of origin and stepwise regression analysis was performed on the pooled data with the palatability characteristics used as dependent variables and various carcass and live-animal characteristics used as independent variables. Variables which were deemed most important on the basis of the stepwise regression analysis were used in various combinations to produce regression equations in an attempt to account for as much as possible of the variation in the palatability characteristics.

Results of preliminary analyses showed that differences in palatability characteristics existed among the four year groups of cattle. Therefore, an analysis of the regression of the palatability characteristics on all carcass variables and number of days on feed was performed by year. The residuals from this model were subjected to a discriminant analysis, year being the classification variable, to test for homogeneity of the variance-covariance structure of the residual values among the four palatability characteristics across years. The results of the analysis indicated a difference in the variances of the residual values among groups. The large differences among groups occurred in the residual variances for tenderness, whereas, the variances were very similar for the other palatability characteristics. Therefore, regression equations with tenderness as the dependent variable were calculated by group in subsequent analyses and the effect of year was added to the model with the independent variables in regression equations for juiciness, flavor, and overall desirability as dependent variables. A test for parallelism was performed for the regression equations which included year in the model by testing whether a significant portion of the sums of squares was contained within the interactions of year with all other independent variables in the model. These interactions were determined not to be significant ($P > .05$) in any of the analyses. Therefore, in constructing the equations for prediction of these palatability characteristics, the intercepts of the equations were adjusted for the average effect of year.

Factor analysis was performed on the carcass variables and the live animal variables measured at the beginning of the feedlot phase of the experiment and those measured just prior to the slaughter of each

consecutively slaughtered group of cattle. This analysis was performed to identify variables which were highly associated with each other and redundant when used in multiple-regression equations, and to produce factor scores for those factors deemed to be interpretable and to account for the majority of the variation in the multivariate structure. Factor scores were produced for three factors to use in subsequent multiple-regression analyses of palatability characteristics.

The effect of number of days on feed was then added to the regression model to determine the relationship between the palatability characteristics and the length of feedlot finishing. When the quadratic term of days on feed was found to affect the dependent variable ($P < .10$), it was added to the model along with the linear term. Other live animal and carcass characteristics were then added to the regression model.

D. RESULTS AND DISCUSSION

1. Evaluation of Mean Palatability Scores by Year Group

Means and standard errors of the organoleptic variables by year and for the three-year pooled data are presented in Table 1. Means across years were different ($P < .05$) in the case of all palatability characteristics. The standard errors of flavor, juiciness and overall desirability were similar. Panel members were not the same persons in all years though some were represented in more than one year. Beef samples from both groups of cattle in 1981 were evaluated by the same judges, but the members making up this panel may have been different from those on the 1979 and 1980 panels. Although some panel members judged the beef samples from all groups of cattle, some panelists were present for the evaluation

TABLE 1. Means and Standard Errors of Carcass and Palatability Characteristics

Variable	YEAR GROUP ^b				OVERALL
	1979	1980	1981H	1981A	
Tenderness	5.17 ± .15 ^d	5.86 ± .12 ^e	5.76 ± .12 ^e	3.68 ± .14 ^f	5.20 ± .08
Juiciness	5.55 ± .09 ^d	6.00 ± .07 ^e	5.99 ± .07 ^e	5.97 ± .08 ^e	5.90 ± .04
Flavor	5.07 ± .10 ^d	5.35 ± .08 ^e	5.36 ± .08 ^e	5.30 ± .09 ^{de}	5.28 ± .04
Overall Desirability	5.00 ± .11 ^d	5.40 ± .09 ^e	5.34 ± .09 ^e	5.28 ± .10 ^e	5.28 ± .05
Marbling ^c	4.69 ± .18 ^d	4.97 ± .15 ^{de}	4.17 ± .15 ^f	4.76 ± .17 ^{de}	4.65 ± .08
Carcass Weight kg	253.85 ± 6.54 ^d	227.83 ± 5.31 ^e	237.58 ± 5.63 ^{de}	227.63 ± 6.15 ^e	235.62 ± 2.97
Fat Thickness mm	10.77 ± .63 ^d	8.57 ± .51 ^e	8.02 ± .54 ^e	7.64 ± .59 ^e	8.65 ± .29
Rib-Eye Area cm	64.35 ± 1.40 ^d	66.99 ± 1.14 ^{de}	67.48 ± 1.21 ^{de}	69.08 ± 1.32 ^e	67.07 ± .63
Percent Internal Fat	1.74 ± .08 ^d	1.57 ± .07 ^{de}	1.53 ± .07 ^e	1.66 ± .08 ^{de}	1.61 ± .04
N	60	90	81	68	299

^a palatability characteristics measured on a 9-point scale. 1 = extremely undesirable, 5 = acceptable, 9 = extremely desirable, etc. All means are expressed on this basis.

^b 30 Angus and 30 Hereford steers were slaughtered in 1979, 90 Angus steers were slaughtered in 1980, 81 Hereford steers were slaughtered in 1981, and 68 Angus steers were slaughtered in 1981.

^c 1 = devoid, 5 = small, 10 = abundant, etc.

^d Means superscripted with different letters are different ($P < .05$).

of only one or two groups and were replaced by new panelists for evaluation of subsequent groups. Even though the mean values were statistically different ($P < .05$), the actual differences were small, and the standard errors were similar. Except for tenderness, the range in mean values across years was about 1/2 unit on a 9-point hedonic scale. All mean values, except for tenderness mean in the 1981A group, were greater than the acceptable rating of 5.0. The higher palatability characteristic ratings observed in certain year groups did not appear to be due to increases in mean fatness of the animals (Table 1). Some groups with high mean palatability scores (eg 1981H) had low mean marbling scores, fat thicknesses, and carcass weights.

It could not be determined from data available in this study whether these differences were due to variation in environmental conditions among years, genetic differences among the respective groups of cattle, the fact that different panelists were used in different years, or to differences among panelists' evaluation of palatability characteristics. Peryam and Pilgrim (1957) stated that one of the major sources of variation affecting the average organoleptic rating of food is the tendency of panelists to express themselves differently. Some tend to use the high end of the rating scale while others tend to use the low end. Another source of variation suggested by these authors was variation in environmental conditions. Since panelists were not the same across groups and since beef from the different groups of cattle was evaluated at different times, both of these sources of variation probably influenced the results of this study.

2. Factors Affecting Tenderness

Differences in actual mean tenderness values across years were larger than differences in means of other palatability characteristics (Table 1). The tenderness standard errors also were higher than those of the other characteristics. Regression of palatability characteristics on carcass variables was performed by year, and the residual variances were tested for multivariate homogeneity. The variances were determined to be heterogeneous among years ($P < .001$), and the largest degree of heterogeneity occurred among yearly residual variances of tenderness. The coefficients of partial regression of tenderness on number of days on feed, carcass weight, marbling, and fat thickness are shown by year in Table 2. These independent variables explained more variation in tenderness than did any combination of variables used in the regression analyses. The residual standard deviations and coefficients of determination (R^2 values) shown in Table 2 suggest the inconsistency of these variables as predictors of tenderness in different years or groups. The residual variance of the 1981A group was approximately 5 times greater than that of the 1980 group. Examination of the coefficients of partial regression on the independent variables suggests that the effect of the independent variables are very different among the four groups.

3. Factors Affecting Juiciness

Since the residual variances from the regression of juiciness, flavor, and overall desirability on carcass characteristics were less heterogeneous and since the coefficients of partial regression were similar across years, the data were pooled across years and the fixed effect

TABLE 2. Coefficients of Partial Regression of Tenderness on Carcass Characteristics by Year Group

Variable	Year Group ^a			
	1979	1980	1981H	1981A
Intercept	4.55	5.36	4.82	5.52
Days on Feed	.007	.005	.002	.012
Carcass Weight	-.004	-9x10 ⁻⁵	.002	-.002
Marbling	.316	.077	.071	.434
Fat Thickness	-.007	-.020	-.010	.013
R ²	.18	.10	.09	.04
RSD ^b	1.04	.77	.81	1.71
EDF ^c	55	85	76	63

^a30 Hereford and 30 Angus steers were slaughtered in 1979, 90 Angus steers were slaughtered in 1980, 81 Hereford steers were slaughtered in 1981, and 68 Angus steers were slaughtered in 1981.

^bResidual Standard Deviation.

^cError Degrees of Freedom.

of year was included in the model in subsequent regression analyses involving these characteristics. Coefficients of partial regression from various equations where carcass characteristics and number of days on feed were used to predict juiciness are shown in Table 3. Year affected juiciness ratings in all models ($P < .001$), and the intercepts for each equation is adjusted for the effect of year. However, more of the variation in juiciness was associated with variation in carcass weight, marbling, fat thickness, and days on feed than was associated with variation among years. In simple regression analyses, an increase in these carcass variables was associated with an increase in juiciness ratings ($P < .001$), but coefficients of determination were small. Variation in carcass weight explained more variation in juiciness than did variation in any other individual carcass characteristic ($R^2=.18$), fat thickness explained the least ($R^2=.14$) and marbling was slightly less important than carcass weight.

Since the cattle in this study were grown on grass prior to being placed in the feedlot, an increase in carcass weight is probably an indicator of an increase in fat due to grain feeding. All cattle were of British breeding, were fairly homogeneous with respect to type, and were treated similarly on pasture and in the feedlot (except for length of finishing). Therefore, this increase in carcass weight may have been a better indicator of the effective length of the finishing period than was marbling or fat thickness. Fat thickness accounted only for fat deposited subcutaneously, while the change in carcass weight may have more accurately described the increase in total fat deposition. Marbling is partially controlled by genetic factors and may not increase in all

TABLE 3. Effects of Sequentially Adding Carcass Variables and Days on Feed to the Model for Predicting Juiciness

Intercept ^a	Partial Regression Coefficients				R ²	RSD ^c
	DOF ^b	Carcass Weight	Marbling	Fat Thickness		
4.75		.005***			.18	.63
5.11			.160***		.17	.63
5.48				.040***	.14	.64
4.78		.003**	.081*		.19	.62
4.81		.004**		.007	.18	.63
5.14			.131**	.001	.17	.63
4.74		.003*	.088*	-.005	.19	.62
5.42	.006***				.24	.61
5.45	.006***	.001			.24	.61
5.40	.006***		.009		.24	.61
5.47	.007***			-.014	.24	.61
5.38	.007***		.035	-.018	.24	.61
5.42	.006***	-.000	.011		.24	.61
5.38	.007***	.001		-.016	.24	.61
5.33	.007***	.001	.033	-.019	.24	.61

^aIntercept adjusted for average effect of year.

^bDays on feed.

^cResidual Standard Deviation.

***P<.001, **P<.01, *P<.05.

animals at a similar rate when they consume a high-energy diet. According to Greene (1982), marbling increased at a decreasing rate during a 140 day-finishing period on a high-energy diet, but carcass weight increased linearly during that period.

Various combinations of the carcass variables in multiple-regression equations did not significantly improve the explanation of variation in juiciness. Adding subcutaneous fat thickness to a model containing either carcass weight or marbling did not increase the R^2 value (Table 3). In general, the addition of marbling to models containing carcass weight explained an additional 1% of the variation in juiciness ($P < .05$). Variation in number of days on feed explained a higher percentage of the variation in juiciness ($R^2=.24$) than did variation in any individual or combination of variables. Number of days on feed was the best single predictor of palatability variables throughout the study. The effects of various carcass characteristics on juiciness were not important in the presence of days on feed. Therefore, it appears that carcass characteristics are more reliable as predictors of the length of time on feed or degree of finish than as predictors of consumer acceptability of meat taken from the carcasses providing these data.

The pooled within-year coefficients of correlation among the variables used here are shown in Table 4. The coefficients of simple correlation between number of days on feed and any of the three carcass variables and between members of pairs of carcass variables were all greater than .75. Thus, the high degree of association among the independent carcass variables tended to make unlikely any significant increase in the amount of variation in juiciness explained by regression models containing more

TABLE 4. Pooled Within-Year Coefficients of Correlation Among Days on Feed, Live-Animal and Carcass Characteristics, and Palatability Attributes

	Initial Weight	Initial Back- Fat	Initial Wither Height	Final Weight	Final Back- Fat	Final Wither Height	Carcass Weight	Marbling	Fat Thickness	Rib Eye Area	Percent Internal Fat	Tenderness	Juiciness	Flavor	Overall Desirability
Days on Feed	-.08	-.03	-.04	.76	.25	-.11	.83	.77	.78	.70	.72	.23	.43	.64	.57
Overall Desirability	-.15	-.08	-.03	.44	.18	-.04	.50	.44	.43	.45	.40	.45	.74	.92	
Flavor	-.11	-.04	-.01	.51	.24	-.01	.58	.53	.50	.51	.46	.35	.59		
Juiciness	-.16	-.07	-.09	.31	.12	-.10	.33	.34	.30	.31	.26	.39			
Tenderness	-.07	-.08	-.12	.19	.07	-.08	.17	.18	.18	.20	.16				
Percent Internal Fat	.05	.20	.03	.63	.31	-.28	.72	.65	.72	.53					
Rib-Eye Area	.23	.11	.10	.78	.27	-.05	.83	.63	.61						
Fat Thickness	.06	.30	.01	.73	.25	-.09	.80	.78							
Marbling	.01	.09	.01	.71	.25	-.08	.76								
Carcass Weight	.32	.16	.25	.94	.25	-.12									
Final Wither Height	-.08	-.08	-.01	-.17	.31										
Final Backfat	-.10	-.04	-.10	.10											
Final Weight	.45	.21	.33												
Initial Wither Height	.68	.18													
Initial Backfat	.39														

*p = .01. Coefficients >.11 are significant (p<.05).

than one carcass variable. The effect of carcass variables on juiciness appeared to be primarily a result of their change due to additional days on feed.

The coefficient of regression of juiciness on carcass weight was .005. Individual values of carcass weight ranged from approximately 120 to 350 kg, a range of 230 kg. Thus, the maximum difference in the predicted juiciness scores for meat from these carcasses would be 1.2 units on the 9-point hedonic scale. The coefficient of regression of juiciness on marbling was .160, and the range in marbling score was 8 units on a 10-point scale. An increase of 8 units of marbling would increase the predicted juiciness rating only 1.28 units on the 9-point scale. Therefore, the increase in juiciness due to increased levels of carcass weight or marbling was small. Wellington and Stouffer (1959) suggested that marbling would have to increase 14 units on a scale of 1 to 27 to effect a 1 unit change in juiciness on a 9 point scale. These results support the hypothesis that panelists tend to use the center of the rating scale when evaluating beef from carcasses of individual animals.

4. Factors Affecting Flavor

The coefficients of partial regression shown in Table 5 suggest the existence of a relationship between flavor and the various carcass characteristics similar to those observed between juiciness and these characteristics. When these variables were used in simple regression equations, carcass weight explained a larger percentage (37%) of the variation in flavor than either marbling (28%) or fat thickness (26%). The amount of variation in juiciness explained by regression on all carcass variables

TABLE 5. Effects of Sequentially Adding Carcass Variables and Days on Feed to the Model for Predicting Flavor

Intercept ^a	DOF ^b	Partial Regression Coefficients				R ²	RSD ^d
		DOF ^{2c}	Carcass Weight	Marbling	Fat Thickness		
3.10			.009***			.37	.61
3.95				.284***		.28	.65
4.57					.075***	.26	.67
3.13			.007***	.088*		.38	.61
3.16			.009***		.006	.37	.61
4.02				.200***	.031**	.30	.65
3.08			.007***	.097*	-.007	.38	.61
4.54		.010***				.43	.58
3.82		.014***				.45	.57
4.32		.016***				.43	.58
4.45		.018***		.035		.43	.58
4.31		.017***			-.007	.44	.58
3.82		.014***		.055	-.014	.45	.58
3.73		.015***		-.002		.46	.57
3.68		.015***			-.023*	.46	.57
				.027	-.026		

^aIntercept adjusted for average effect of year.

^bDays on feed.

^cDays on feed squared

^dResidual Standard Deviation

***P<.001, **P<.01, *P<.05.

was only 1% greater than that explained by regression on carcass weight alone.

Melton et al. (1983) reported a high positive association between desirable flavor characteristics of grain-fed beef and the length of time the animals were fed high-energy diets after grazing pasture. This is supported by the pooled within-year coefficients of correlation shown in Table 4. The number of days on feed was slightly more highly correlated with carcass weight than with marbling or subcutaneous fat thickness, but all coefficients of correlation of individual carcass variables with days on feed were fairly high. Both the linear ($P < .001$) and the quadratic terms ($P < .01$) for days on feed were related to flavor although juiciness was found to increase only linearly with an increase in number of days on feed.

The linear and the quadratic terms of the number of days on feed explained approximately 6% more variation in flavor than did carcass weight. Tatum et al. (1980), Aberle et al. (1981), and Melton et al. (1982a) found also that there was a point of diminishing returns beyond which additional grain finishing did not enhance the flavor characteristics of beef. This seemed to be true in this study since flavor improved rapidly in beef from cattle fed for the short periods. As the length of finishing reached longer periods (84 days or more), the rate of increase in flavor decreased. Melton et al. (1982a) associated this phenomenon with a dilution effect and(or) exchange of undesirable fatty acids with desirable fatty acids deposited in adipose tissue of beef during the period the cattle were fed a grass diet. These desirable fatty acids enhance the flavor characteristics of beef during finishing on a

grain diet. After a certain length of grain finishing, these undesirable flavor characteristics were probably not detectable due to the dilution effect and(or) exchange of undesirable fatty acids for desirable fatty acids in the adipose tissue. Carcass weight was significantly associated with flavor ($P < .01$) even in the presence of the linear and quadratic terms for number of days on feed. This may have been due to the fact that the heavier animals within a slaughter group deposited more adipose tissue during the grain-feeding period. This increase in deposition of adipose tissue would have resulted in greater dilution and(or) exchange of the fatty acids and resulted in the indirect relationship between increased carcass weight and desirable flavor characteristics.

As was observed in the case of juiciness, the number of days the animals were fed a high-energy diet after termination of the grazing period was a better predictor of flavor than any combination of carcass characteristics. In general, marbling and fat thickness were not important ($P > .05$) when used as independent variables in multiple regression equations containing the linear and quadratic terms for days on feed.

The percentage of the variation in flavor explained by the various regression models was greater than the percentage of the variation in juiciness explained by the same models. One possible explanation is that flavor was more directly proportional to the length of the finishing period, and juiciness was more closely associated with intramuscular fat or marbling (Blumer, 1963). The amount of intramuscular fat in carcasses of animals slaughtered following shorter finishing periods may have been sufficient to produce enough detectable liquid to cause the meat to be rated acceptable by sensory panelists. The mean marbling scores shown in

Table 6, however, were fairly low (average slight or less) in the carcasses from the groups of cattle fed grain for less than 84 days. These carcasses would be considered inadequate in the beef packing industry with respect to degree of marbling. Another possible explanation is that the panelists were not able to differentiate between degrees of juiciness as well as they were able to differentiate between degrees of flavor and overall desirability. The mean palatability characteristic scores of animals slaughtered after varying numbers of days on feed (Table 6) suggest that all palatability characteristics, except juiciness, were slightly unacceptable at 0 days on feed. All other palatability scores continued to be lower than those for juiciness at all levels of days on feed. The difference between the mean flavor and overall desirability scores of beef at 0 and 140 days on feed were 1.43 and 1.35 units, respectively, while the range in juiciness scores was only .79 units. For some reason, the panelists in this study tended to rate juiciness higher than other palatability characteristics. This suggests that they were able to detect smaller differences in juiciness of beef associated with increased lengths of the finishing period and increased carcass fatness than they were able to detect in other palatability characteristics.

5. Factors Affecting Overall Desirability

Similar results were obtained from the regression of overall desirability on carcass variables and the linear and quadratic terms for the number of days on feed (Table 7). All carcass variables were related to overall desirability ($P < .001$) when used separately in regression models. Variation in carcass weight explained a slightly higher proportion of the

TABLE 6. Means and Standard Errors of Palatability and Carcass Characteristics by Days on Feed

	Days on Feed					
	0	28	56	84	112	140
Tenderness ^a	4.87 + .15	4.93 + .15	5.01 + .15	5.19 + .15	5.27 + .16	5.60 + .19
Juiciness ^a	5.49 + .08	5.60 + .08	5.81 + .08	6.07 + .08	6.19 + .09	6.28 + .10
Flavor ^a	4.49 + .08	4.88 + .08	5.28 + .08	5.62 + .08	5.71 + .08	5.92 + .10
Overall desirability ^a	4.56 + .09	4.81 + .09	5.25 + .09	5.60 + .09	5.69 + .10	5.91 + .11
Marbling ^b	3.06 + .12	3.86 + .12	4.43 + .13	5.24 + .12	5.71 + .13	6.27 + .15
Carcass Weight kg	176.59 + 3.95	207.26 + 3.98	224.49 + 4.06	257.89 + 4.02	278.87 + 4.22	302.42 + 4.91
Fat Thickness mm	3.50 + .42	5.40 + .42	7.97 + .43	11.05 + .43	12.94 + .45	13.97 + .52
Rib-Eye Area cm	55.74 + 1.09	63.28 + 1.09	65.01 + 1.12	69.12 + 1.11	74.78 + 1.16	78.98 + 1.35
Percent Internal Fat	1.03 + .06	1.33 + .06	1.37 + .06	1.87 + .06	2.10 + .06	2.34 + .07
N	55	54	52	53	48	37

^aPalatability characteristics measured on a 9-point hedonic scale. 1 = extremely undesirable, 5 = acceptable, 9 = extremely desirable and all means for these variables are expressed on this basis.

^b1 = devoid, 5 = small, 10 = abundant, etc.

TABLE 7. Effects of Sequentially Adding Carcass Variables and Days on Feed to the Model for Predicting Overall Desirability

Intercept ^a	DOF ^b	Partial Regression Coefficients				R ²	RSD ^d
		DOF ^{2c}	Carcass Weight	Marbling	Fat Thickness		
3.59			.048***			.29	.72
4.55				.274***		.24	.74
4.61					.070***	.20	.75
3.30			.006***	.108*		.30	.71
3.33			.008***		.008	.28	.71
4.07				.206***	.025 ^t	.25	.73
3.24			.006***	.118*	-.007	.30	.71
3.99		-4x10 ^{-5t}				.34	.68
4.10		-3x10 ^{-5t}	.002**			.35	.69
4.37		-3x10 ^{-5t}		.033 ^t		.35	.68
4.51		-3x10 ^{-5t}			-.010	.35	.68
4.36		-3x10 ^{-5t}		.061	-.019	.35	.68
4.09		-3x10 ^{-5t}	.002	.012		.35	.68
4.01		-4x10 ^{-5t}	.003		-.023 ^t	.36	.68
3.94		-3x10 ^{-5t}	.003	.042	-.027 ^t	.36	.68

^aIntercept adjusted for average effect of year.

^bDays on feed.

^cDays on feed squared.

^dResidual Standard Deviation.

***P<.001, **P<.01, *P<.05, ^tP<.10.

variation in overall desirability than did the other carcass characteristics. Adding marbling to the model containing carcass weight increased the coefficient of determination only 1%. The contribution of fat thickness was small ($P > .10$) in the presence of carcass weight. Marbling and fat thickness did not explain as much of the variation in overall desirability as did carcass weight alone.

The linear and quadratic terms for number of days on feed explained more variation in overall desirability than did carcass weight. However, carcass weight contributed to the regression model ($P < .01$) in the presence of days on feed and its quadratic term, similar to the effect observed in the regression of flavor on these variables. Marbling made a small contribution ($P < .10$) in the presence of the linear and quadratic terms for days on feed. In either case, the increase in R^2 value was only 1% above that obtained by including the linear and quadratic terms of days on feed only in the model.

The contribution of the quadratic term for the number of days on feed was small ($P < .10$) but it was sufficiently important to be included in the model. Overall desirability appeared to be intermediate to juiciness and flavor in its response to an increase in days on feed. The quadratic term of days on feed explained less of the variation in overall desirability than it did in flavor but more than in juiciness. Theoretically, overall desirability can be considered a composite score which is influenced by the other palatability characteristics.

The purpose of the overall desirability variable is to allow panelists to evaluate the beef sample according to their own likes and dislikes. If they prefer a less juicy or a less tender steak, a sample

which has a slightly unacceptable score for tenderness and juiciness may be rated higher in overall desirability. If a panelist likes the flavor associated with beef from grass-fed animals, he may rate a beef sample low for flavor but higher for overall desirability. The coefficients of correlation of overall desirability with flavor, juiciness, and tenderness suggest a fairly high relationship of this variable with all other palatability characteristics except tenderness. Tenderness was not highly correlated with any of the variables in this study, but its correlation with overall desirability was higher than that with any other variable. On the basis of the positive coefficients of correlation between overall desirability and other palatability traits, it seems that panelists considered those steaks which were more tender and juicy and had a more desirable flavor score to be more desirable overall. The greatest positive relationship existed between overall desirability and flavor ($r=.92$).

Analysis of regression of overall desirability on other palatability characteristics (Table 8) showed that a large portion of the variation in overall desirability was dependent on variation in flavor, juiciness, and tenderness ($R^2=.90$). Both the raw and the standard coefficients of partial regression show that variation in flavor exhibited a greater influence on the variation in overall desirability scores than did variation in juiciness and tenderness.

6. Factor Analysis

Since the results of the regression and correlation analyses seemed to indicate a high degree of relationship among the independent carcass

TABLE 8. Mean Squares, Coefficient of Determination, and Raw and Standard Coefficients of Partial Regression of Overall Desirability on Flavor, Juiciness, and Tenderness

	Mean Square	Coefficient of Partial Regression	Standard Coefficient of Partial Regression
Intercept ^a		-1.27	
Year	.21*		
Flavor	68.28***	.784***	2.280***
Juiciness	9.23***	.336***	.876***
Tenderness	1.89***	.077***	.410***
Residual	.07		
EDF ^b	292		
R ²	.90		
RSDC	.26		

^aIntercept adjusted for average effect of year.

^bError degrees of Freedom.

^cResidual Standard Deviation.

***P<.001, *P<.05.

variables and addition of more than one variable to regression equations did not result in a large increase in the amount of variation explained in the palatability variables, a factor analysis was performed using live-animal variables and carcass characteristics to determine the relationships among these variables and to condense the information contained in a large number of variables into a smaller number of factors. These factors were then used in multiple-regression equations to explain a larger portion of the variation in the palatability characteristics with a small number of independent variables in the model. The results of the factor analysis of the pooled data across years are shown in Table 9. A factor analysis was initially performed by year; but the results were found to be consistent across years, and the data were pooled for the final analysis. Factors with eigenvalues greater than 1 were retained in the final analysis. Three factors were extracted, and no variables seemed to be split between two factors nor did any variable load as a unique factor.

All carcass variables and final live-animal weight had high loadings on the first factor (FACTOR1). The high degree of multicollinearity that exists among the carcass variables probably explains why the addition of more than one variable to the multiple-regression equations did not significantly increase the R^2 value. The addition of more than one carcass variable to the regression equation was redundant.

Carcass weight had the highest rotated-factor loading (.918) while rib-eye area had the lowest (.797). All variables had high loadings, and the highest loadings were associated with the three carcass variables used in the previous regression analyses. In addition, final weight also was

TABLE 9. Factor Analysis of Live-Animal and Carcass Characteristics

	Factor Loadings		
	FACTOR1	FACTOR2	FACTOR3
Initial Weight	.089	.916	-.067
Initial Backfat	.138	.628	.092
Initial Wither Height	.025	.858	-.011
Final Weight	.854	.321	-.201
Final Backfat	-.181	.022	.795
Final Wither Height	.240	.008	.815
Carcass Weight	.918	.283	-.018
Marbling	.866	-.127	.076
Fat Thickness	.888	.023	.001
Rib-Eye Area	.797	.167	.136
Percent Internal Fat	.820	.027	.018
Eigenvalues	4.77	1.97	1.37
Cumulative Portion	.43	.61	.74

closely related to FACTOR1. Since final weight is closely related to carcass weight, the two variables would be expected to load heavily on the same factor. FACTOR1 explained 43% of the variation in the correlation structure.

All initial variables (initial weight , initial backfat thickness, and initial wither height) measured at the beginning of the feedlot phase of each experiment, had high loadings on the second factor (FACTOR2). This factor appeared to contain the variance associated with initial animal measurements. Initial weight had the highest loading on FACTOR2, followed by initial wither height and initial backfat thickness. Initial weight was the most important initial live-animal variable in the prediction of palatability characteristics. FACTOR2 explained an additional 18% of the variation in the multivariate structure.

Final backfat thickness and final wither height, just prior to slaughter, loaded heavily on the third factor (FACTOR3). It seems that final backfat thickness should be associated with FACTOR1 since it is a measure of live-animal fat thickness just prior to slaughter. It would be expected to be the same measurement as carcass fat thickness since both were assumed to be measured at the same location on the animal (at the 12th-13th rib and three-fourths the distance of the longissimus dorsi from its dorsal end). Several sources of variation, however, may cause differences in these two variables. Probably, fat thickness was not measured on the live animal at the same location that it was measured on the carcass because of the inability of the technician to see this location on the live animal but located it by palpation. The edge of the longissimus muscle is often not smooth and subcutaneous fat thickness measurements

made only small distances from the correct location, either medially or laterally, could be quite variable. Subcutaneous fat in the beef animal is deposited in layers, and this may cause an erroneous reading of the ultrasonic measuring device. When an animal is slaughtered, part of the subcutaneous fat may be removed with the hide. Thus, the measured fat thickness on the carcass may be less than the actual thickness of subcutaneous fat found on the animal prior to slaughter. Finally, the individual fat-thickness measurements taken on the carcasses in this study were adjusted by the U.S.D.A. grader for more or less than average thicknesses of fat cover over the entire carcass. The coefficient of correlation between final backfat thickness and carcass-fat thickness was only .25. Although the coefficient of correlation between final backfat thickness and final wither height was small ($r=.31$), these two variables were more closely related to each other than to any other variable in the analysis. This factor (FACTOR3) consisting of variables measured on the live animal prior to slaughter explained an additional 13% of the variation in the multivariate structure for a total of 74% of the variance explained by the three factors which consisted of on-feed, preslaughter, and carcass variables.

Mean squares due to regression of the palatability characteristics on the three factors are shown in Table 10. Year was added to the model as a fixed effect. As would be expected from the previous regression analyses, FACTOR1 (consisting primarily of carcass variables and final live-animal weight) was the most important factor in accounting for the variation in palatability characteristics ($P < .001$). The initial live-animal characteristic factor (FACTOR 2) seemed to be more important

TABLE 10. Mean Squares, Coefficients of Determination, and Residual Standard Deviations in Analysis of Regression of Palatability Characteristics on Factor Scores

	Palatability Characteristic		
	Juiciness	Flavor	Overall Desirability
Year	4.29***	3.07***	3.66***
FACTOR1	14.26***	48.50***	45.68***
FACTOR2	3.03***	1.60*	3.57**
FACTOR3	.12	1.02 ^t	.17
Residual	.36	.34	.49
R ²	.26	.42	.35
RSD ^a	.60	.60	.70

^aResidual Standard Deviation

***P<.001, **P<.01, *P<.05, ^tP<.10.

in the regression model for prediction of juiciness ($P < .001$) than it was in the case of flavor ($P < .05$) and overall desirability ($P < .01$). FACTOR3 was not important ($P > .10$) in the regression analyses of any palatability characteristic but approached significance in the prediction of flavor ($P < .10$). Examination of the coefficients of determination of the three respective palatability characteristics shows that the amount of variation in these characteristics explained by variation in the factor scores was very similar to the amount explained by number of days on feed in the regression analyses. Thus, days on feed predicted changes in palatability characteristics as well as the carcass and live-animal variables.

7. Estimation of Number of Days on Feed from Carcass Characteristics

Since number of days on feed appears to be the most important variable in predicting palatability, a regression analysis was performed to determine how well carcass variables could estimate the number of days that the animals which produced the carcasses had been fed. Standard coefficients of partial regression are shown in Table 11 to indicate the relative importance of the carcass variables in the equation. Carcass weight, fat thickness and marbling made large contributions to the estimation of the number of days on feed ($P < .001$), and all variables were important. Percent internal fat made a smaller contribution ($P < .05$) but was considered also to be an important variable. All of the important carcass variables, except for carcass weight, were direct measures of fatness. Carcass weight was probably a primary indicator of body fat deposition during the finishing period of the cattle in this study since

TABLE 11. Mean Squares, Coefficient of Determination, and Coefficients of Partial Regression of Number of Days on Feed on Carcass Characteristics

	Mean Square	Standard Coefficient of Partial Regression
Intercept ^a		-87.64
Year	4424.50***	
Carcass Weight	33246.13***	.827***
Fat Thickness	6897.96***	.666***
Marbling	11929.07***	1.524***
Percent Internal Fat	3335.57*	.599*
Residual	555.51	
EDF ^b	291	
R ²	.75	

^aIntercept adjusted for average effect of year.

^bError Degrees of Freedom

***P<.001, *P<.05.

they had been grown on grass before being placed in the feedlot. On the basis of the standard coefficients of partial regression, marbling made the largest contribution to the estimation of number of days on feed during which the cattle received a high-energy diet. As carcass weight in the data increased, days on feed increased by a lesser amount than was the case with marbling; and percent internal fat made the smallest contribution. Variation in the carcass variables explained 75% of the variation in days on feed. The major value of the carcass variables in determining palatability characteristics of beef appears to be their indication of the length of time the animals were fed a high-concentrate diet.

CHAPTER V

RELATIONSHIP OF QUANTITATIVE DESCRIPTIVE FACTORS, CARCASS
CHARACTERISTICS, AND PALATABILITY ATTRIBUTES IN BEEF

A. SUMMARY

Carcass characteristics, palatability attributes and quantitative-descriptive analysis (QDA) factors collected from the carcasses of 108 steers were evaluated by canonical correlation analyses to evaluate the relationship among these groups of variables, between individual variables within the groups and between theoretical canonical variables from each group.

Evaluation of carcass and QDA variables resulted in one significant ($P < .0001$) pair of canonical variables. They were C1 which described carcass fatness and Q1 which contrasted beef-fat and milky-oily flavor and aroma. Carcass variables highly correlated with Q1 were marbling ($r=.58$), rib-eye area ($r=.55$), and percent internal fat ($r=.51$). Milky-oily flavor and aroma were negatively correlated with C1 ($r=-.54$ and $-.52$, respectively) and beef-fat flavor and aroma was positively related to C1 ($r=.57$ and $.36$, respectively). Analysis of carcass and palatability variables resulted in one pair of canonical variables C2 (describing primarily weight) and P1 (sensory flavor and overall desirability). Coefficients of correlation between carcass characteristics and P1 were all positive and intermediate in magnitude ($r=.45$ to $.57$). Juiciness, flavor, and overall desirability were positively related to C2 ($r=.39$ to $.58$). Two correlated pairs of canonical variables (Q2-P2, Q3-P3) resulted from analysis of the

QDA factors and palatability attributes. Q2 contrasted beef-fat and milky-oily flavor and aroma factors while Q3 was composed primarily of liver flavor. P2 was highly related to the flavor and overall desirability palatability attributes while P3 was more closely related to tenderness and juiciness. Palatability attributes most highly related to Q2 were flavor and overall desirability, and QDA factors highly correlated with P2 were milky-oily flavor and aroma and beef-fat flavor. Increases in palatability attributes and QDA factors were more affected by carcass fatness, which was related to the length of time the animals were fed a high-energy density diet, than they were by any other carcass characteristic.

B. INTRODUCTION

The U.S.D.A. Agricultural Marketing Service has defined lean-beef-carcass-quality factors as those factors which are associated with tenderness, juiciness, or flavor of the beef from these carcasses (Pierce, 1973). Pierce (1974) stated that U.S. beef carcass grades were designed to identify differences in those carcass characteristics which are associated with palatability factors. The characteristics used to determine quality grade are marbling and firmness of the cut surface of the longissimus muscle at the 12-13th rib interface and physiological maturity of the carcass.

Results from extensive studies have shown that the quality determining factors used by the U.S.D.A. to establish carcass grades do have an effect on the palatability of beef, but the amount of variation in palatability explained by these factors has generally been small. According to

Smith et al. (1983), 85% of all U.S.D.A. graded beef is within the A maturity classification, and marbling is, therefore, the major factor determining carcass quality grade. The proportion of the variation in beef palatability attributable to variation in marbling is small (Blumer, 1963; Tatum et al., 1982) and the relationships between marbling and palatability traits have been reported to range from small positive coefficients of correlation (Tatum et al., 1980; Armbruster et al., 1983) to non-significant correlations (Romans et al., 1965; Garcia-de-Siles et al., 1977).

There is some evidence that subcutaneous fat thickness has an effect on beef palatability (Bowling et al., 1977; 1978, Dolezal et al., 1982). Tatum et al. (1982) suggested that subcutaneous fat thickness affects palatability up to a certain subcutaneous fat thickness and that the effect is neither linear nor additive after this fat thickness is reached.

According to Moody (1983), flavor is one of the most important quality attributes of beef, and it is a result of both taste and aroma. Stone et al. (1974) described quantitative descriptive analysis as a technique by which trained individuals identify and quantify, in order of occurrence, the sensory properties of a product or an ingredient. These QDA techniques have been used to assess the flavor, texture and aroma attributes of various beef products (Chambers et al., 1981; Melton et al., 1982a; Galt and MacLeod, 1983).

The purpose of these analyses was to determine the simultaneous relationships of U.S.D.A. quality and yield characteristics with QDA flavor and aroma factors and with palatability attributes determined by sensory panel evaluation.

C. EXPERIMENTAL PROCEDURE

A description of the management of the cattle producing the beef samples used in this analysis from the time of purchase through slaughter, and a detailed description of methods used in collection of carcass and palatability data are presented in Chapter III, page 31.

Quantitative-descriptive-analysis data were available for beef samples from the animals slaughtered in 1980 and from the two groups slaughtered in 1981. Tests of homogeneity of the variance-covariance structure of the QDA, palatability attributes, and carcass variables showed that the 1980 variances were different from those in 1981 ($P < .001$). The two groups slaughtered in 1981, however, had homogeneous variances between the two groups of variables ($P > .10$). Therefore, subsequent analyses were performed on data pooled from the two groups.

The QDA panel was composed of six individuals who were able to discriminate, in a trio test, between the flavors of grass-fed and grain-fed beef three times in succession (Melton et al., 1982b). Flavor descriptors that distinguished between grass-fed and grain-fed beef were then chosen during a panel group discussion. Panelists considered beef-fat aroma and flavor a desirable characteristic of grain-fed beef and a milky-oily flavor and aroma and a sour flavor as undesirable characteristics associated with grass-fed beef. These characteristics were defined also as a dairy-like flavor which resulted in a puckering and dry feeling in the mouth. The QDA variables used in this study were beef-fat flavor, milky-oily flavor, beef-fat aroma, milky-oily aroma, liver flavor, sour flavor, and raw flavor.

Individual samples of beef were evaluated for the intensity of each aroma and(or) flavor component by all panelists. Panelists recorded their evaluation of each sample by placing a vertical mark on a 150 mm horizontal line. The mark was placed at the point which was perceived to be the degree of intensity of the stimulus from a particular sample. The value of the rating of each sample by each panelist was the length of the line between the extreme left end of the line and the mark placed on the line by the panelist. Thus, a higher rating for a sample of beef would indicate a greater intensity of the stimulus. Values of each characteristic for each sample were averaged across panel members and subsequent analyses were performed on these average values.

Canonical-correlation analyses were performed on the data to determine the relationships among groups of variables rather than relationships between members of pairs of individual variables or relationships between any one dependent variable and a group of independent variables. The three groups of variables used in the analysis were carcass variables, QDA factors and palatability attributes measured on a 9-point hedonic scale. Relationships of QDA factors and palatability attributes with carcass variables and relationships of the QDA factors with palatability variables were determined.

D. RESULTS AND DISCUSSION

1. Relationship between Carcass Variables and QDA Variables

Means of all variables used in the analyses are shown in Table 12. Examination of the minimum and maximum levels of fat thickness shows a wide range of these values among the carcasses. Marbling scores ranged

TABLE 12. Means, Standard Errors, Minimum, and Maximum Values of Palatability and Carcass Variables Used in the Analysis

Variable	Mean ^a	Standard Error	Minimum Value	Maximum Value
<u>Carcass Variables</u>				
Marbling ^b	4.56	0.12	2.00	7.60
Fat Thickness mm	7.80	0.42	0.80	20.32
Carcass Weight kg	230.14	4.75	132.27	336.82
Rib-Eye Area cm	68.68	1.05	43.86	98.69
Percent Internal Fat	1.62	0.06	0.50	3.50
<u>QDA Factors</u>				
Beef-Fat Aroma	66.42	0.87	43.30	85.30
Milky-Oily Aroma	63.10	0.97	39.00	86.58
Beef-Fat Flavor	70.85	1.22	41.80	95.08
Milky-Oily Flavor	66.55	1.32	37.33	102.00
Liver Flavor	36.25	0.53	25.17	53.92
Sour Flavor	47.66	0.86	30.50	71.00
Raw Flavor	30.73	0.88	16.75	64.43
<u>Palatability Attributes^d</u>				
Tenderness	4.42	0.17	1.00	7.00
Juiciness	5.97	0.06	4.18	7.08
Flavor	5.33	0.07	3.42	7.20
Overall Desirability	5.32	0.07	3.60	6.90

^aN = 108.

^b 1 = Devoid, 5 = Small, 10 = Abundant, etc.

^cEvaluated by six trained QDA panelists on a 150 mm scale.

^dEvaluated by 14 sensory panelists on a 9-point hedonic scale.

from practically devoid to moderate, which correspond to quality grades of low standard to high choice, respectively. Except for tenderness, scores for QDA factors and palatability attributes were not located at the extreme ends of the scales.

The highest coefficient of simple correlation between the members of any pair of variables from the two groups was that between carcass weight and beef-fat flavor ($r=.52$, Table 13). Since these cattle had reached approximately three-fourths of their logical slaughter weight on a grass diet before being placed in the feedlot on a high-concentrate ration, an increase in body weight was primarily a result of an increase in fat deposition. Therefore, an increase in carcass weight was closely related to an increase in carcass fatness and other carcass characteristics except rib-eye area. Perhaps the reason carcass weight was more closely related to flavor than was marbling was because carcass weight increased linearly as the length of time the animals were fed a grain diet increased, and, after 84 days on the high-energy diet, marbling increased at a decreasing rate (Greene, 1982). Tatum et al. (1980) and Melton et al. (1982a) reported that intensities of desirable flavor characteristics in beef increased with increases in the length of time the animals producing the beef were fed a high-energy diet. Since the cattle in this study were serially slaughtered after varying lengths of feedlot finishing, carcass weight was probably the characteristic which had the closest relationship with the length of this finishing period. The cattle were all of British breeding, and variation in carcass weight within each slaughter group was less than that among the serially slaughtered groups.

TABLE 13. Coefficients of Correlation Among Carcass Characteristics, Palatability Attributes, QDA Variables, and the Number of Days on Feed

	Days on Feed	Overall Desirability	Flavor	Juiciness	Tenderness	Raw Flavor	Sour Flavor	Liver Flavor	Milky- Oily Flavor	Beef- Fat Flavor	Milky- Oily Aroma	Beef- Fat Aroma	Percent Internal Fat	Rib- Eye Area	Carcass Weight	Fat Thickness
Marbling	.81	.51	.51	.41	-.02	.22	.02	.01	-.42	.49	-.43	.30	.70	.63	.77	.80
Fat Thickness	.75	.50	.49	.38	.04	.18	.11	.07	-.30	.38	-.30	.24	.74	.56	.78	
Carcass Weight	.82	.55	.57	.35	.03	.16	-.04	-.06	-.49	.52	-.44	.34	.68	.82		
Rib-Eye Area	.68	.46	.49	.27	.08	.03	.08	-.13	-.46	.46	-.40	.30	.47			
Percent Internal Fat	.66	.45	.44	.36	.07	.18	.02	.03	-.38	.47	-.40	.34				
Beef-Fat Aroma	.37	.32	.32	.32	.11	-.07	-.27	.02	-.75	.81	-.77					
Milky-Oily Aroma	-.53	-.43	-.45	-.33	-.04	.03	.34	.03	.85	-.79						
Beef-Fat Flavor	.62	.52	.53	.38	.08	.02	-.31	.04	-.87							
Milky-Oily Flavor	-.62	-.51	-.56	-.33	-.07	.05	.36	.05								
Liver Flavor	-.04	-.06	-.12	-.08	-.03	.02	-.10									
Sour Flavor	-.02	.09	.05	.06	.03	.32										
Raw Flavor	.20	.23	.17	.29	-.07											
Tenderness	.08	-.02	.02	-.02												
Juiciness	.44	.66	.54													
Flavor	.46	.86														
Overall Desirability	.44															

*n = 108. Coefficients >.19 are significant (p<.05).

The coefficient of canonical correlation between the first canonical carcass characteristic variable and the first canonical QDA variable was .66 ($P < .001$). This first canonical pair is made up of a linear combination of the carcass variables (C1) which has the largest correlation with a linear combination of the QDA variables (Q1). Thus, the correlation is between the two hypothetical canonical variables which were derived from linear combinations of the variables in the respective groups. Although five pairs of canonical variables were generated, only the first pair were significantly correlated ($P < .05$). This canonical correlation ($r=.66$) was greater than any of the simple correlations between members of pairs of individual variables of the respective groups (Table 13). The canonical coefficient of determination (R^2) for the first canonical pair (C1 and Q1) was .44 (Table 14). This value represents the squared coefficient of multiple correlation between the individual variables in each group and their opposite canonical variable. For example, a regression model which contained the QDA canonical variable Q1 as the dependent variable and the individual carcass variables as the independent variables would result in an R^2 value of .44. Conversely, a regression model with the carcass canonical variable C1 as the dependent variable and the individual QDA variables as the independent variables would result in an R^2 value of .44 also. Thus, the canonical R^2 value is the squared coefficient of multiple correlation between the two groups of variables. In another regression model which included beef-fat flavor as the dependent variable and all carcass variables as independent variables, the R^2 value was .33. The relationship between all variables in the two groups taken simultaneously results in a canonical R^2 value of .44 (Table 14) which was only an

TABLE 14. Canonical Pair Coefficients of Correlation Between Carcass and QDA Variables, Carcass and Palatability Variables, and QDA and Palatability Variables^a

Analysis Number	Canonical Pair	Canonical Correlation	Adjusted Canonical Correlation	Canonical R-Squared	PROB>F
1	C1 with Q1 ^b	.66	.61	.44	.0001
2	C2 with P1 ^c	.58	.53	.35	.0001
3	Q2 with P2 ^d	.66	.57	.44	.0001
3	Q3 with P3 ^e	.53	.41	.28	.05

^aOther canonical variables were generated for both groups of variables during the analysis of each pair of variable groups. Only the first canonical variable pair made a significant contribution ($P < .05$) to the analysis of carcass characteristics with QDA factors and carcass characteristics with palatability attributes. The first and second canonical variable pairs were both significant in the analysis of QDA factors with palatability attributes.

^bCarcass characteristics (C1) with QDA factors (Q1).

^cCarcass characteristics (C2) with palatability attributes (P1).

^dQDA factors (Q2) with palatability attributes (P2).

^eQDA factors (Q3) with palatability attributes (P3).

increase of .11 in the R^2 value. Therefore, more of the total variation in the QDA factors was accounted for in this canonical correlation analysis.

The standard canonical coefficients (loadings) of the carcass variables on the first carcass canonical variable (C1) are shown in Table 15. The highest loadings were for the variables which were primarily measures of carcass fatness. Marbling had the largest standard canonical coefficient (.53) and the highest correlation with the canonical variable C1 ($r=.88$). A positive relationship between marbling and flavor characteristics of beef was reported by Breidenstein et al. (1968) and Armbruster et al. (1983) who found gross coefficients of correlation of .19 and .16, respectively. However, in this study the coefficient of simple correlation was higher (.40, Table 13). The higher correlation found here may be due to the fact that the animals were of similar breeding and physiological age and were fed the same diet prior to slaughter while those in the studies mentioned above were a more diverse group and were fed different finishing diets.

The loading of fat thickness on the C1 canonical carcass variable was negative, but it had a positive coefficient of correlation with C1. In a previous multiple-regression analysis of these data, multiple regression of the dependent palatability attributes on carcass weight, marbling, and fat thickness resulted in a negative coefficient of partial regression of fat thickness as an independent variable. Tatum et al. (1982) developed a response surface model for the effects of marbling and subcutaneous fat thickness on overall palatability characteristics of beef samples and found that overall palatability increased linearly with increasing levels

TABLE 15. Raw and Standard Canonical Coefficients and Coefficients of Correlation of the Carcass Variables with the First Carcass and QDA Canonical Variates (Analysis 1).

Carcass Characteristic	Carcass Canonical Variable Cl ^a		Coefficients of Correlation of the Carcass Characteristics With	
	Raw Canonical Coefficient	Standard Canonical Coefficient	Cl ^a	Ql ^b
Marbling	.42	.53	.88	.58
Fat Thickness	-.11	-.47	.66	.44
Carcass Weight	.01	.44	.89	.59
Rib-Eye Area	.02	.24	.83	.55
Percent Internal Fat	.50	.33	.77	.51

^aFirst carcass canonical variable related to QDA factors.

^bFirst QDA canonical variable related to carcass characteristics.

of marbling, but these increases were consistent across all levels of fat thickness. All other carcass variables had positive standard canonical loadings on the carcass variable C1. Fat thickness had the lowest coefficient of correlation with C1 ($r=.66$).

Carcass weight resulted in a positive canonical loading and had a high positive coefficient of correlation with the C1 variable. This correlation was greater than any other correlation between an individual carcass variable and the C1 canonical variable.

Rib-eye area and percent internal fat had lower standard canonical loadings but high coefficients of correlation with C1. All variables were highly related to length of finishing period (Table 13). Therefore, an increase in rib-eye area would be partially a function of length of finishing, as would increases in weight and fat. The observation that the correlations between carcass weight and variables describing flavor were larger than those between other carcass variables and flavor variables may have been due to the fact that carcass weight was more closely related to the number of days on feed than were other variables.

The QDA factors, beef-fat flavor and aroma and milky-oily flavor and aroma, made a major contribution to the first canonical QDA variable Q1 (Table 16). The coefficients of correlation between beef-fat flavor and aroma and Q1 were positive and those between milky-oily flavor and aroma and Q1 were negative. Thus, the Q1 variable was primarily a contrast between these two flavor and aroma sensory descriptors. Melton et al. (1982b) reported an increase in beef-fat flavor and aroma and a decrease in milky-oily or dairy flavor and aroma when cattle were fed a high-concentrate diet for longer periods of time. Since these cattle were

TABLE 16. Raw and Standard Canonical Coefficients and Coefficients of Correlation of the QDA Variables with the First Carcass and QDA Canonical Variates (Analysis 1)

QDA Factor	Canonical QDA Variable Q1a		Coefficient of Correlation of the Individual QDA Factors with	
	Raw Canonical Coefficient	Standard Canonical Coefficient	Q1a	C1b
Beef-Fat Aroma	-.06	-.59	.55	.36
Milky-Oily Aroma	-.05	-.48	-.78	-.52
Beef-Fat Flavor	.07	.93	.86	.57
Milky-Oily Flavor	-.01	-.14	-.81	-.54
Liver Flavor	-.02	-.09	-.12	-.08
Sour Flavor	.03	.30	.001	.001
Raw Flavor	.01	.10	.23	.14

aFirst QDA canonical variable related to carcass characteristics.

bFirst carcass canonical variable related to QDA factors.

grown on a pasture diet and fed for varying lengths of time in the feedlot, it is logical that a greater intensity of the beef-fat variables and a lower intensity of the milky-oily characteristics were associated with the canonical variable C1, which was primarily composed of carcass fat variables. The results of other research (Berry et al., 1980; Schroeder et al., 1980; Melton et al., 1982a,b) however, suggested that an increase in desirable flavor constituents has a close association with the type of diet the animals received during fattening.

Beef-fat flavor had the highest standard loading on the canonical QDA variable Q1 and the highest correlation with the Q1 variable of any of the QDA factors. Beef-fat aroma had a negative canonical loading on Q1 even though the coefficient of correlation was positive between these two variables. Of these four QDA factors, however, beef-fat aroma had the lowest coefficient of correlation with the Q1 variable. Both milky-oily flavor and aroma had negative canonical loadings and highly negative coefficients of correlation with the QDA variable Q1.

Liver, sour, and raw flavors made small contributions to the Q1 variable relative to the contributions made by the beef-fat and milky-oily variables. Melton et al.(1982a) found a positive simple correlation between liver flavor and beef-fat flavor and a negative simple correlation between sour flavor and beef-fat flavor similar to those observed in this study (Table 13, page 77). The correlations of these two variables (sour flavor and liver flavor) with the Q1 variable, which describes overall beef-fat characteristics, however, resulted in the reverse effect. An explanation for this occurrence was not determined but neither variable

had a large effect on the determination of the Q1 canonical variable. The contribution of raw flavor to the Q1 canonical variable was low also.

Coefficients of correlation between each individual carcass variable and the Q1 canonical variable were all high and positive. Fat thickness had the lowest correlation with Q1 ($r=.44$). The high correlation among the individual carcass variables could explain why only one canonical pair (C1 and Q1) were significantly correlated. This resulted in a large portion of the information within the carcass-variable variance-covariance structure which was related to the flavor descriptor variables being accounted for by one canonical variable (C1) which described carcass fatness. The coefficients of correlation between the individual QDA factors and the canonical carcass variable again had positive relationships with beef-fat variables and negative relationships with milky-oily variables.

2. Carcass Characteristics and Palatability Attributes

The coefficient of correlation between the first canonical pair derived from the carcass characteristics (C2) and the palatability attributes (P1). was .58 ($P < .001$, Table 14, page 79). As was the case with the relationship of the carcass characteristics and the QDA factors, only the first canonical pair (C2 and P1) resulted in a significant coefficient of correlation ($P < .05$).

Carcass weight was the primary variable in the relation of the linear combination of carcass characteristics (C2) to the linear combination of the palatability attributes (P1, Table 17). These results imply that carcass weight was probably the characteristic which was most highly

TABLE 17. Raw and Standard Canonical Coefficients and Coefficients of Correlation of the Carcass Characteristics with the First Carcass and Palatability Canonical Variates (Analysis 2)

Variable	Carcass Canonical Variable C2 ^a		Coefficients of Correlation of the Carcass Characteristics with	
	Raw Canonical Coefficient	Standard Canonical Coefficient	C2 ^a	Pl ^b
Marbling	.19	.24	.86	.51
Fat Thickness	.02	.07	.85	.50
Carcass Weight	.01	.61	.97	.57
Rib-Eye Area	.01	.07	.81	.48
Percent Internal Fat	.17	.11	.77	.45

^aFirst carcass characteristic canonical variable related to palatability.

^bFirst palatability attribute canonical variable related to carcass characteristics.

related to length of grain finishing, as was assumed from the results of the QDA. Of the remaining carcass characteristics, marbling and fat thickness had the highest coefficients of correlation with the carcass canonical variable (C2). Each individual carcass characteristic, however, was highly correlated with the other carcass characteristics (Table 13, page 77) as well as with the carcass canonical variable (C2, Table 17).

Flavor and overall desirability were very highly correlated with the canonical palatability variable (P1) ($r=.99$ and $.97$, respectively, Table 18). These results suggest that the carcass quality and yield characteristics have a greater influence on flavor than on tenderness and juiciness. The coefficient of simple correlation between flavor and overall desirability ($r=.96$, Table 13, page 77) was much higher than the correlation between members of any other pair of palatability variables. Panelists appeared to place more emphasis on beef flavor than on either tenderness or juiciness when rating a beef sample for overall desirability. Moody (1983) stated that flavor was one of the most important quality attributes of beef. It is evident from the standard canonical loadings and the correlations of the two groups with their respective canonical variables that all the carcass variables were fairly highly associated with flavor. Both the carcass characteristics and flavor were highly related to length of finishing period.

Tenderness ratings had a low coefficient of correlation ($r=.02$) with the palatability canonical variable (P1). Tenderness did not have a large coefficient of correlation with any of the palatability attributes (Table 13, page 77). The results of other research have shown tenderness to have

a very small relationship with marbling (Romans et al., 1965; Walter et al., 1965; Breidenstein et al., 1968). Wellington and Stouffer (1959) stated that factors other than marbling affected beef tenderness to a greater extent. Apparently, these factors were not included in the present study. Tuma et al. (1962) found that animal age had a greater influence on tenderness than did other carcass characteristics. Since all of the carcasses in this study were within the A maturity classification, physiological maturity was not included in this analysis. Although results of other studies (Bidner et al., 1975; Harrison et al., 1978) have shown subcutaneous fat thickness to affect tenderness, fat thickness in this study was not highly correlated with tenderness (Table 13, page 77) even though fat thickness ranged from .8 to 20 mm (Table 12, page 75). Tenderness was not closely related to any of the carcass characteristics in this analysis.

The coefficient of correlation of juiciness with the canonical palatability variable (P1) was intermediate to those of flavor and tenderness, and juiciness made some contribution to P1. Juiciness has been associated by others with an increase in fatness, especially intramuscular fat, and should be related to the carcass characteristics included in this study.

Carcass weight, marbling, and fat thickness had similar coefficients of correlation with the palatability canonical variable (P1) to correlations between members of pairs of the individual carcass characteristics and the QDA canonical variable (Q2, Table 18). Rib eye area and percent kidney fat resulted in slightly lower coefficients of correlation with the P1 canonical variable than did the other carcass characteristics.

TABLE 18. Raw and Standard Canonical Coefficients and Coefficients of Correlation of the Palatability Variables with the First Carcass and Palatability Canonical Variates (Analysis 2)

Palatability Attribute	Palatability Canonical Variable Pl a		Coefficients of Correlation of the Palatability Attributes with	
	Raw Canonical Coefficient	Standard Canonical Coefficient	Pl a	C2b
Tenderness	-.01	-.02	.02	.01
Juiciness	.36	.21	.67	.39
Flavor	1.28	.95	.99	.58
Overall Desirability	-.10	-.07	.97	.57

aFirst palatability attribute canonical variable related to carcass characteristics.

bFirst carcass characteristic canonical variable related to palatability attributes.

Flavor and overall desirability had the highest coefficients of correlation with the C2 carcass canonical variable. Breidenstein et al. (1968) concluded that flavor and juiciness were more influenced by marbling than was tenderness and that an increase in flavor and juiciness caused panelists to give steaks higher tenderness ratings. They found coefficients of correlation of tenderness with flavor and juiciness to be .60 and .55, respectively. There was no apparent correlation of tenderness with flavor and juiciness in this study (Table 13, page 77). Tenderness was not related to the P1 palatability canonical variable ($r=.02$) nor the C2 carcass canonical variable, ($r=.01$, Table 18). Juiciness had a fairly high coefficient of correlation with the C2 carcass canonical variable. Other researchers have shown juiciness to be closely associated with marbling, which made the major contribution to the C2 canonical variable (standard canonical loadings). Armbruster et al. (1983) found marbling to be highly associated with juiciness ($r=.29$, $P < .01$), whereas tenderness was not found to be correlated with marbling.

3. QDA Factors and Palatability Attributes

Two significant canonical variable pairs (Q2-P2 and Q3-P3) existed between organoleptic properties of beef based on QDA analysis and the palatability attributes based on the hedonic scale. The first canonical pair (Q2 and P2) had a coefficient of correlation of .66 ($P < .001$) and a canonical R^2 value of .44 (Table 14, page 79). The absolute values of the coefficients of correlation between the individual QDA variables and their first canonical variable (Q2, Table 19) were high for the beef-fat and the milky-oily factors. The beef-fat factors were positively

TABLE 19. Raw and Standard Canonical Coefficients and Coefficients of Correlation of the QDA Variables with the First and Second Palatability and QDA Canonical Variates (Analysis 3)

	Standard Canonical Coefficients		Coefficients of Correlation of QDA Factors with			
	Q2 ^a	Q3 ^b	Q2 ^a	Q3 ^b	P2 ^c	P3 ^d
Beef-Fat Aroma	-.45	-.74	.37	-.16	.25	-.08
Milky-Oily Aroma	-.08	.35	-.60	.13	.40	.07
Beef-Fat Flavor	.45	.31	.72	.08	.48	.04
Milky-Oily Flavor	-.87	-.64	-.77	-.11	-.51	-.06
Liver Flavor	-.20	.75	-.08	.55	-.06	.29
Sour Flavor	.43	.32	.08	.07	.05	.04
Raw Flavor	.26	-.70	.28	-.43	.19	-.23

^aFirst QDA factor canonical variable related to palatability attributes.

^bSecond QDA factor canonical variable related to palatability attributes.

^cFirst palatability canonical variable related to QDA factors.

^dSecond palatability canonical variable related to QDA factors.

correlated, and the milky-oily variables were negatively correlated with the QDA canonical variable Q2. The flavor factors had the highest coefficients of correlation with beef-fat flavor and milky-oily flavor ($r=.72$ and $-.77$, respectively). Beef-fat aroma had the lowest correlation of these four variables ($r=.37$) and had a negative standard canonical loading.

The remaining three of the seven individual QDA variables made little contribution to the QDA canonical variable (Q2). Liver flavor was negatively associated ($r=-.08$) and raw and sour flavor were positively associated ($r=.28$ and $.08$, respectively) with the Q2 canonical variable.

The coefficients of correlations of the individual palatability attributes with their canonical variable (P2) were high for flavor and overall desirability (Table 20). These two attributes were closely associated with each other ($r=.96$, Table 13, page 77). They were more closely related with each other than with any other palatability attribute. These results suggest that panelists place more emphasis on flavor in determining overall acceptability of a meat sample than on tenderness or juiciness. However, the fact that the score sheet was designed such that a sample was first rated for tenderness followed by juiciness, flavor, and overall desirability in that order. This could possibly have influenced the overall desirability score since flavor was evaluated just prior to the evaluation of overall desirability. The magnitude of the influence of the order of the variables on the evaluation sheet on overall desirability could not be determined in this study. Juiciness contributed to the first palatability canonical variable (P1) having a .66 coefficient of correlation with it.

TABLE 20. Raw and Standardized Canonical Coefficients and Coefficients of Correlation of the Palatability Variables with the First and Second Palatability and QDA Canonical Variates (Analysis 3)

	Standard Canonical Coefficient		Coefficients of Correlation of Palatability Attributes with			
	P2a	P3b	P2a	P3b	Q2c	Q3d
Tenderness	.03	.35	-.07	.23	-.05	.12
Juiciness	.19	-1.52	.66	-.48	.43	-.25
Flavor	1.01	-2.19	.99	.10	.66	.05
Overall Desirability	-.13	3.33	.96	.12	.64	.06

^aFirst palatability attribute canonical variable related to QDA factors.

^bSecond palatability attribute canonical variable related to QDA factors.

^cFirst QDA factor canonical variable related to palatability attributes.

^dSecond QDA factor canonical variable related to palatability attributes.

The palatability canonical variable (P2) was more highly correlated with the beef-fat and milky-oily descriptor variables than with the liver-flavor, sour-flavor, and raw-flavor variables. The coefficients of correlation between individual palatability attributes and the QDA canonical variable (Q2) were highest for flavor and overall desirability. Tenderness was negatively correlated with P2 ($r = -.05$). The high degree of association between desirable flavor characteristics and the QDA canonical variable (Table 20) would be expected since the QDA factors are assumed to be descriptors of flavor and aroma stimuli. The flavor attribute was positively associated with beef-fat flavor and aroma and negatively associated with milky-oily flavor and aroma. These results are consistent with those found by Melton et al. (1982a,b) who compared beef from grass-fed versus beef from grain-fed cattle with respect to these same descriptor variables. They found that beef-fat flavor and aroma were more characteristic of beef from grain-fed cattle and milky-oily flavor and aroma were more characteristic of with beef from grass-fed cattle. Since carcass characteristics in this study are largely a function of number of days on a high-energy diet, the results from the three studies are in agreement.

The coefficient of correlation between the second canonical pair (P3 and P4) was .34 ($P < .05$) with a cumulative canonical R^2 value for the two canonical variate pairs of .75 (Table 14, page 79) The largest coefficients of correlation between the second QDA canonical variable (Q3) and the individual QDA factors were those between the Q3 canonical variable and liver and raw flavors ($r = .55$ and $-.43$, respectively, Table 19). The beef-fat and milky-oily factors were not closely related to this canonical

variable. This was logical since most of the variation in the two variables was associated with the first QDA canonical variable (Q2).

The palatability canonical variable (P3, Table 20) had higher coefficients of correlation with juiciness and tenderness than with flavor and overall desirability. This correlation with tenderness ($r=.23$) was higher than any single or multiple correlation of tenderness with other individual variables or canonical variables in this study. These results indicate that a decrease in raw flavor and an increase in liver flavor corresponded with a decrease in juiciness and an increase in tenderness. Beef which is cooked to a greater degree of doneness may contain less moisture and extractable juice derived from short chain volatile fatty acids and, thus, cause the beef samples to be less juicy. The positive loadings for liver flavor and tenderness on the Q3 and P3 canonical variables are more difficult to interpret.

As was found with the correlation between the QDA variables and the Q1 canonical variable, liver flavor and raw flavor had a high degree of association with the P2 canonical variable, and juiciness and tenderness had the highest coefficients of correlation with the Q3 canonical variable.

CHAPTER VI

SUMMARY

Multiple regression, factor, and canonical correlation analyses were used to study the relationships among palatability attributes, Qualitative Descriptive flavor and aroma variables, live animal traits, and carcass variables. Data from 301 steers were analyzed to determine those factors which were most valuable in predicting palatability characteristics. Carcass weight was the most important animal characteristic found to predict juiciness, flavor, and overall desirability scores. Addition of more than one of the carcass characteristics to the regression models did not result in a large increase in the coefficients of determination and the results of the factor analysis showed that all carcass variables and slaughter weight were highly related. The number of days the cattle had received a high-energy diet was found to be the best single predictor of palatability characteristics. The strength of carcass variables in predicting change in palatability characteristics appeared to be related to their change with respect to the number of days the cattle had received a high-energy diet. Carcass characteristics, palatability attributes and quantitative descriptive analysis (QDA) factors collected from the carcasses of 108 steers were evaluated by canonical correlation analyses to evaluate the relationship among these groups of variables. Evaluation of carcass and QDA variables resulted in one significant ($P < .0001$) pair of canonical variables which related carcass fatness positively to beef-fat and negatively to milky-oily descriptor variables. Analysis of carcass and

palatability variables resulted in one pair of canonical variables describing primarily carcass weight and sensory flavor and overall desirability. Two significant ($p < .05$) canonical variables resulted from analysis of the QDA factors and palatability attributes. The first QDA canonical variable contrasted beef-fat and milky-oily flavor and aroma factors while the second QDA canonical variable was composed primarily of liver flavor. The first palatability canonical variable was highly related to the flavor and overall desirability palatability attributes while the second palatability canonical variable was related to tenderness and juiciness. Increases in palatability attributes and QDA factor were more affected by carcass fatness variables than they were by the other carcass characteristic.

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APPENDIX

TABLE A1. Mean Squares^a of the Regression of Tenderness on Carcass Characteristics by Year Group

Source	Year Group ^b		
	1979	1980	1981A
Days on Feed	1.64	1.16	3.41
Carcass Weight	.61	.00	.20
Marbling	3.08	.48	5.16
Fat Thickness	.03	.26	.05
Residual	1.07	.60	2.92

^aNo mean squares were significant at the .10 level of significance.

^b30 Angus and 30 Hereford steers were slaughtered in 1979, 90 Angus steers were slaughtered in 1980, 81 Hereford steers were slaughtered in 1981, and 68 Angus steers were slaughtered in 1981.

TABLE A2. Mean Squares of the Regression of Juiciness on Days on Feed and Carcass Characteristics

Year	Source				Residual	EDFa
	Days on Feed	Carcass Weight	Marbling	Fat Thickness		
4.64***		15.92***			.39	294
3.45***			14.76***		.40	294
4.45***				11.00***	.41	294
4.00***		2.80**	1.64*		.39	293
4.68***		5.03**		.12	.40	293
3.56***			4.11**	.35	.40	293
3.74***		2.49*	1.57*	.05	.39	292
3.72***	24.16***				.37	294
3.51***	8.25***	.00			.37	293
3.69***	9.41***		.02		.37	293
3.21***	13.70***			.56	.37	293
4.22***	9.83***		.24	.77	.37	293
3.44***	6.63***	.01	.03		.37	292
3.10***	8.71***	.06			.37	292
2.80***	7.36***	.02	.20	.78	.37	291

^aError Degrees of Freedom.

***P<.001, **P<.01, *P<.05.

TABLE A3. Mean Squares of the Regression of Flavor on Days of Feed and Carcass Characteristics

Year	Source					Fat Thickness	Residual	EDFa
	Days on Feed	Days on Feed Squared	Carcass Weight	Marbling				
3.50***			61.29***				.37	294
2.12**				46.17***			.43	294
3.29***					39.40***		.45	294
2.85***			17.04***	1.92*			.34	293
3.53***			21.99***		.10		.38	293
2.47***				9.62***	2.85**		.42	293
2.62***			14.29***	1.92*	.10		.37	292
1.74**	16.11***	1.37**					.34	293
2.22***	8.74***	2.49***	2.93**				.33	292
1.72**	12.11***	2.51**		.30			.34	292
2.25**	14.56***	2.75**			.13		.34	292
1.32**	12.46***	2.63**		.59	.42		.34	291
2.19***	8.21***	2.49**	2.63**	.00			.33	291
1.79***	9.90***	2.78**	4.08***		1.28*		.33	291
1.60**	9.18***	2.72**	3.62***	.13	1.41*		.33	290

^aError Degrees of Freedom.

***P<.001, **P<.01, *P<.05.

TABLE A4. Mean Squares of the Regression of Overall Desirability on Days on Feed and Carcass Characteristics

Year	Source					Residual	EDF ^a
	Days on Feed	Days on Feed Squared	Carcass Weight	Marbling	Fat Thickness		
4.77***			52.17***			.51	294
2.69***				42.89***		.54	294
4.38***					34.60***	.57	294
3.75***			12.19***	2.90*		.50	293
4.83***			17.77***		.19	.51	293
3.09***				10.16***	1.87 ^t	.54	293
3.47***			10.43***	2.82*	.11	.50	292
2.64***	12.22***	1.37 ^t				.46	293
2.71***	7.61***	1.29 ^t	1.08**			.46	292
2.57***	9.11***	1.27 ^t		1.26 ^t		.46	292
2.08**	11.91***	1.49 ^t			.39	.46	292
1.84**	9.96***	1.40 ^t		.72	.86	.46	291
2.84***	6.89***	1.26 ^t	.85	.03		.46	291
2.48***	8.74***	1.51 ^t	1.97*		1.28 ^t	.46	291
2.12**	7.87***	1.44 ^t	1.58 ^t	.33	1.58 ^t	.46	290

^aError Degrees of Freedom.***P<.001, **P<.01, *P<.05, ^tP<.10.

TABLE A5. Mean Squares for the Regression of Juiciness on Live-Animal Characteristics and Days on Feed

Year	Source			Residual	EDFa
	Days on Feed	Final Weight	Initial Weight		
3.01***			2.30*	.44	279
5.15***		11.10***		.40	265
5.00***		20.49***	11.59***	.36	264
3.46***	8.99***	0.00		.37	264
3.15***	20.15***		1.52*	.37	278
3.86***	.86	2.12*	3.45**	.27	263

aError Degrees of Freedom

***P<.001, **P<.01, *P<.05.

TABLE A6. Effects of Sequentially Adding Live-Animal Variables and Days on Feed to the Model for Predicting Juiciness

Intercept ^a	Partial Regression Coefficients			R ²	RSD ^b
	Days on Feed	Final Weight	Initial Weight		
6.82			-.003*	.10	.66
4.61		.003***		.17	.64
6.38		.004***	-.007***	.26	.60
6.24	.003	.003*	-.005**	.27	.60

^aIntercept adjusted for average effect of year.

^bResidual Standard Deviation.

***P<.001, **P<.01, P<.05.

TABLE A7. Mean Squares for the Regression of Flavor on Live-Animal Characteristics and Days on Feed

Year	Source				Residual	EDF ^a
	Days on Feed	Days on Feed Squared	Final Weight	Initial Weight		
1.96*				.94	.56	279
4.22***			42.01***		.42	265
5.08***			61.69***	20.80***	.34	264
1.56**	14.49***	2.72**		.14	.34	277
2.70***	4.74***	2.49**	6.20***	4.56***	.32	262

^aError Degrees of Freedom.

***P<.001, **P<.01, *P<.05.

TABLE A8. Effects of Sequentially Adding Live-Animal Variables and Days on Feed to the Model for Predicting Flavor

Intercept ^a	Partial Regression Coefficients				R ²	RSD ^b
	Days on Feed	Days on Feed Squared	Final Weight	Initial Weight		
5.91				-.002	.05	.75
2.85			.006***		.31	.65
5.22			.008***	-.010***	.43	.58
4.48	.012***	5x10 ⁻⁵ **	.005***	-.006***	.47	.57

^aIntercept adjusted for average effect of year.

^bResidual Standard Deviation

***P<.001, **P<.01.

TABLE A9. Mean Squares for the Regression of Overall Desirability on Live-Animal Characteristics and Days on Feed

Year	Source		Initial Weight	Residual	EDFa
	Days on Feed	Days on Feed Squared	Final Weight		
2.15*			2.85*	.67	279
5.25***			36.17***	.55	265
5.52***			59.45***	.45	264
3.42***	3.06**	1.39 ^t	6.64***	.44	262

^aError Degrees of Freedom.

***P<.001, **P<.01, *P<.05, ^tp<.10.

TABLE A10. Effects of Sequentially Adding Live-Animal Variables and Days on Feed to the Model for Predicting Overall Desirability

Intercept ^a	Partial Regression Coefficients				R ²	RSD ^b
	Days on Feed	Days on Feed Squared	Final Weight	Initial Weight		
6.34				-.003*	.06	.82
3.01			.005***		.23	.74
			.008***	-.011***	.37	.67
5.35	.009**	3x10 ^{-5t}	.005***	-.008***	.39	.67

^aIntercept adjusted for average effect of year.

^bResidual Standard Deviation.

***P<.001, **P<.01, *P<.05, ^tP<.10.

VITA

Billy Bruce Greene was born July 9, 1957 in Morristown, Tennessee. He received his primary and secondary education in Hancock County, Tennessee. He graduated from Hancock County High School in Sneedville, Tennessee in June 1975.

In September of 1975, he entered Berea College in Berea Kentucky and graduated from that school with a Bachelor of Science degree in Agriculture in June, 1979.

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