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Prediction of Beef Palatability Factors and Relationships Between Live and Carcass Traits

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PREDICTION OF BEEF PALATABILITY FACTORS AND RELATIONSHIPS BETWEEN LIVE AND CARCASS TRAITS

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BETWEEN LIVE AND CARCASS TRAITS

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser | Date

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RJB

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDIX TABLES

INTRODUCTION

The agricultural industry of South Dakota is primarily based on the beef cow and her products. Cattle feeders had 275,000 head of cattle and calves on feed on July 1, 1970, a 2 percent increase over July 1, 1969. South Dakota has about 1,719,000 beef cows which is 38 percent more than a decade ago. The state can continue to increase beef production in many ways such as retaining more cows to produce feeders, increasing calving percentage, using crossbreeding, or feeding cattle to heavier weights. Increased carrying capacity through irrigation and management may be another avenue to increased production.

In 1949, 63 pounds of beef was the annual per capita consumption. By 1959 it was 81 pounds and increased to 112 pounds in 1969. Beef is providing more nutrition than ever before and some people believe this country will need 33 percent more beef by 1980.

Although increased beef tonnage will be required to satisfy increasing demands, maintenance, improvement and standardization of beef quality are also necessary during the next decade. Manufacturers of meat substitutes will capitalize on the ability to standardize palatability characteristics. Quality and palatability indicators in the live animal and the carcass must be identified and utilized by the beef industry to maintain and improve its position in the main dish market. Presently, tenderness is the variable having the most influence on consumer quality evaluation of beef. Therefore, indicators of tenderness in the live animal and carcass should be identified and utilized.

Past research has shown that shear tenderness was correlated with taste panel tenderness, but many times only zero order correlations were obtained. Where large variations in maturity occurred, taste panel tenderness could be more easily related or correlated with shear tenderness. Limitations still remain in the effectiveness of taste panel and fundamental mechanical tests to be highly correlated, because physiology, psychology, and the mechanical processes are involved in sensory evaluation. Many times the "mechanical system" and the "human system" are not fully understood by the researcher which limits the consistency of correlations between the two systems. Some experts believe the applications of engineering techniques are needed to evaluate the texture of solid food materials such as beef. A new approach probably should be used for evaluating beef tenderness where objective physical measurements have been proven to be useful. These measures should give more fundamental data than most of the conventional, poorly defined tests of the past used under narrow differences in beef quality.

The prediction of beef palatability from a number of conventional live and carcass traits was the primary objective of this study. The ability to predict or evaluate beef quality is quite difficult within the narrow ranges of this study.

Market cattle have changed slowly over the years. Cattle reach market weight at younger ages. In addition, more emphasis is placed on trimmer, younger cattle having much less waste fat. Along with trimness, tenderness is the important contemporary beef palatability factor. Many researchers believe color, texture, and firmness of lean are indicators of quality. Muscle fiber diameter, muscle fiber waviness, and muscle fiber length have been considered to be factors involved in tenderness of beef. The above factors have often failed to reflect the variation in tenderness of the more uniform, younger carcasses.

Various systems used to measure or predict beef quality in the carcass have been developed, but none have a high degree of accuracy. The combination of traits, utilizing marbling as a major indicator supported by carcass maturity and conformation, has evolved as the current carcass quality grading system. Recent reported data from various researchers showed that the present grading system does not always reflect beef palatability. Tenderness has not always been highly correlated with the carcass grade which is largely determined by the level of marbling.

Many different measures have been suggested to measure beef quality, but none are much better predictors of quality than the present quality system. A tender-o-meter, recently developed by a well known packing company, measures the tenderness of the fresh ribeye surface. Moreover, biophysical and biochemical changes within the muscle cells before and after slaughter probably are the factors most important in determining beef palatability. Measures of these changes could be more important than those presently used. Other undeveloped systems measuring levels of hormones or natural substances that may reflect muscle changes have also been considered. The eventual correct beef quality measure will probably contain these factors that more precisely represent the human sensations involved in detecting quality.

The present beef quality grading system could benefit from some adjustments or elimination of certain quality standards. This study will show that beef palatability will not always be consistently predicted between groups of cattle within the narrow ranges of this study. Because beef quality cannot be easily predicted, the present monetary value of quality grades could be shifted toward cutability grades. If a more sensitive beef quality evaluation system is not found, we should concentrate our efforts and economic values in an area where differences in carcass value are more easily detected. Comparison and prediction of beef quality and quantity traits in this study will suggest where a few changes can be made.

REVIEW OF LITERATURE

The palatability of beef has long been a concern of animal scientists and those involved in producing the fresh beef product. Since palatability is a qualitative trait, the industry usually has resorted to subjective techniques to evaluate a carcass or cut. Subjective traits most often used are flavor, tenderness, juiciness, and texture. Beef palatability is associated with tenderness to a greater extent than pork or lamb palatability.

Variation in tenderness may be related to many different characteristics of any given animal. Usually, as the animal matures, the palatability and tenderness scores become less desirable. Barbella et al. (1939), Harrison et al. (1949), Hiner and Hankins (1950), and Lowe and Kastelic (1961) have shown differences in palatability due to age of animal. However, McBee and Wiles (1967), Palmer et al. (1965), and Romans, Tuma and Tucker (1965) reported only small differences in tenderness or palatability when using carcasses in the range of 12 to 36 months of age.

Differences in breeds offer some variation in palatability. One of the classical studies was done by Barbella et al. (1939). The researchers observed tenderness differences among the seven different breeding groups used in their study. Later two groups of researchers, Carpenter et al. (1955) and Cartwright et al. (1958), found differences between breeds and between lines within breeds. Palmer (1963) found highly significant differences for tenderness due to sires, breed of sire, and sires within breed. The Warner-Bratzler shear and trained taste panel members were used as the methods of evaluation. Palmer (1963) found breed of sire had a pronounced effect on tenderness. Meat from Angus, Hereford, and Shorthorn progeny was significantly more tender than that from progeny of Brahman and Brahman x Shorthorn sires. He noted that 36.7, 36.3, 37.4, and 56.8 percent of the Angus, Brahman, Hereford, and Shorthorn progeny, respectively, were better than average in tenderness.

Alsmeyer et al. (1959) have listed several factors that influence tenderness or palatability of beef. The following chart shows the factors studied:

Percent of Tenderness
Variability Accounted for by Factors Studied

Factors	Panel Tenderness Variability %
Percent of Brahman breeding	12.1
Carcass grade	9.2
Animal slaughter age	5.0
Carcass outside finish	3.1
Carcass conformation	2.6
Marbling	1.1

Percent of Brahman breeding accounted for 12.1 percent of the variability in tenderness by taste panel. Carcass grade (U.S.D.A.) explained only 9.2 percent followed by the other less important variables.

Zinn et al. (1961) evaluated the U.S.D.A. Beef Grading Methods utilizing 48 Hereford and 48 Angus steers. Quality and quantity data were recorded on all steers on test. The average slaughter weight was 920 pounds with an average carcass grade of high good. The gross simple correlation coefficients are as follows:

Traits	Correlation Coefficient
Carcass conformation - cutout	-.50
Dual grading, est. - cutout	-.46
Loin eye area - cutout	-.61
Fat thickness over 12th rib - cutout	-.54
Marbling score - carcass grade	0.89
Marbling score - tenderness	-.08

This report indicated that the correlation coefficient of marbling with tenderness is very low. Ninety-nine percent of the variation in tenderness is due to factors other than marbling. They also showed that the correlation coefficient of marbling with grade accounts for about 80 percent of the variation in carcass quality grade. Marbling is the most important of the several factors used by the federal grader in establishing quality grades of market steers.

Epley et al. (1968) used steers from the progeny of 12 sires to study the effects of sire, length of feeding, and sire x length of feeding upon flavor, tenderness and overall desirability. Two hundred steers were fed in five lots. The first lot was marketed at 139 days and the others followed at 28-day intervals. A laboratory and consumer taste panel sampled the steaks and found inconsistent increases and decreases in flavor intensity, flavor desirability, tenderness desirability, or overall desirability. Epley *et al*. concluded that sire and sire x length of time on feed effects upon palatability appear to be worthy of further consideration.

Stringer *et al*. (1968) studied the quantitative and qualitative carcass characteristics of the same steers. They found an overall decrease in rate of gain and an overall increase in dressing percent when steers were fed extended periods of time. After 195 days on feed the mean carcass quality grade did not improve. Some differences in quantitative and qualitative carcass traits among progeny of various sires were significant. An increase in percent trimmed fat and a decrease in percent retail cuts were the most significant effects on extending the feeding period from 139 to 251 days.

Ramsey *et al*. (1967) studied the effects of breed on muscle fiber diameter and the relationships among palatability measures and selected production and carcass traits. Brahman and Charolais had larger muscle fiber diameters in the *Longissimus dorsi* and *Semimembranous* muscles than Angus, Hereford, and Jersey steers. Smaller muscle fibers tended toward more tender rib roasts, loin steaks, and round steaks. Breed differences were not detected for the percent of wavy muscle fibers in this study. Ramsey *et al*. (1967) also found larger fiber diameters in the warm carcass as compared to samples taken from the same carcasses chilled 48 hours. On a within breed basis, simple correlation coefficients indicated small relationships between either fiber diameter or percent of wavy fibers and production, carcass, or palatability traits. Some of the following relationships showed more significance: (1) percent ether extract of the Longissimus dorsi, tenderness of shear, and juiciness of loin steaks were negatively related with fiber diameter; (2) muscle fiber diameter to tenderness relationship appeared to be independent of ether extract of the Longissimus dorsi, animal age, and body weight; (3) the amount of marbling in the Longissimus dorsi had little effect on palatability measures; and (4) percent wavy fibers in the Longissimus dorsi samples taken from the warm body and the Semimembranous samples were negatively related to muscle tenderness, juiciness, and flavor. However, these relationships were much lower when the fiber characteristics of the Longissimus dorsi sampled after chilling were analyzed.

The extremes of maturity were related to significantly different sarcomere lengths in the Longissimus dorsi and those differences were associated with palatability characteristics in a study by Cooper et al. (1968). They demonstrated that fiber diameter was associated with sarcomere length and tenderness, and that muscle bundle size increased markedly with maturity and could be estimated visually with some accuracy.

Mullins and associates (1969) reported two factors which may cause tenderness or lack of tenderness in meat. These factors are (1) the distribution and molecular state (structure) of connective tissues and (2) the state of contraction expressed in the repeating units (sarcomere) of muscle fibrils (contracting elements of individual muscle cells). McClain et al. (1965) reported that varying amounts of connective tissues failed to show any significant contribution toward explaining tenderness differences.

The animal age-fiber diameter relationship probably has an effect on tenderness according to Tuma et al. (1962). Fiber diameter increased with age, but they found little relationship between fiber diameter and tenderness within age groups. Before removing the effect of animal age, the Longissimus dorsi area at the 12th rib and the total lean in the carcass were related to fiber diameter.

Other workers have found a relationship between fiber diameter and palatability factors in beef. Hiner et al. (1953) showed that meat having small fibers was more tender than meat with larger fibers. Joubert (1956) showed that total musculature of lamb had a relationship with muscle fiber diameter. Joubert demonstrated that muscle fibers increased in size until their maximum growth capacity was reached. Tuma et al. (1962) speculated from these facts that "if fiber diameter to total musculature relationship holds true for beef cattle, it may be that selection for 'meat type' animals would have an influence on tenderness."

Brady (1937) found a nonsignificant relationship between fiber diameter and shear force as a measure of tenderness when working with beef muscles. At about the same time, Satorius and Child (1938) found that cooking caused a decrease in muscle fiber diameter. Also, extensibility of muscle fibers was affected by cooking and this factor may have increased the resistance to shear as measured by the Warner-Bratzler shear device.

Satorius and Child (1938) demonstrated that size of muscle fibers and fibers per bundle was significantly correlated with texture and tenderness scores. They found that the smaller the fiber and more fibers per bundle, the finer the texture and the more tender the meat.

Deatherage (1963) reported at the Campbell Soup Symposium the following effects of age and protein on tenderness:

1. Tenderness is a function of all the proteins of the muscle cell itself as well as of the connective tissue.

2. Heat coagulation of the muscle proteins contributes to tenderness or toughness as well as shortening the collagen fibers.

3. The toughening of well done steak was due to coagulation of muscle proteins but without hydrolysis of collagenous connective tissue and that prolonged boiling or braising caused tenderness by preferentially hydrolyzing connective tissue to allow separation of coagulated fibers.

4. In some meat coagulation of muscle cells was dominant in causing toughness and in others connective tissue was the dominant factor.

5. Some animals yielded meat that was never very tough and this could be a reflection of feeding, management, or breeding.

6. Some meat on aging never became acceptably tender.

7. Post-mortem tenderization involved very subtle changes in proteins within the muscle cell itself and that these changes produced meat of different character of tenderness than that resulting from hydrolysis by added enzymes.

Deatherage (1963) found a low correlation between marbling and tenderness in studies of Holstein and Hereford beef.

Cover and Hostetler (1958) carried on work dealing with the effect of carcass grade and fatness on tenderness of meat from steers of known history. They mentioned that if an exact indicator of tenderness was available it might be incorporated in the carcass grade standards. Results showed tenderness ratings were as high from meat from some carcasses in the lower grades as for meat from other carcasses in the higher grades. Coefficients of correlation were low for tenderness with carcass grade, separable fat, and ether extract. Correlation coefficients were not consistent in sign. The highest correlation was r = 0.33 when tenderness was compared with carcass grade and fatness. This accounted for only 11 percent of the total variation in tenderness.

Palmer et al. (1958) reported in a study of 32 steers that tenderness correlated -.178 with ether extract percentage of the aged muscle. Wellington (1954) studied steers under controlled feeding conditions producing a wide variation in fat content and found no influence of nutrient intake level on muscle tenderness.

Wellington and Stouffer (1959) studied beef marbling and its estimation. They thoroughly investigated its influence on tenderness and juiciness. These researchers calculated simple correlation coefficients between various fat indices as follows:

Simple Correlation

Source of Variation[a]	Marbling Score r	Percent Ether Extract of Rib Eye r	Outside Fat Thickness r
Carcass grade	0.784	0.769	0.694
Marbling score		0.793	0.551
Ether extract of rib eye - %			0.633

[a] All are significant at 1 percent level.

Wellington and Stouffer (1959) also ran simple correlations for the relationship between indices of fat and certain palatability factors. They found that all correlations were low as shown below.

Marbling differences accounted for only 7 percent of the tenderness variability detected by this panel. The panel observed that as the degree of marbling increased there was a significant increase in the juiciness of the beef.

Breidenstein et al. (1968) studied 60 heifer and cow carcasses that were selected on the basis of maturity (A, B, E) and marbling (slight, modest, slightly abundant and abundant) 1-day post-mortem. They found palatability to be associated with muscle texture, firmness, and color. Ether extract increased progressively with increasing marbling score but did not statistically affect either shear force or panel tenderness. However, the abundant marbling level had the lowest shear force values and highest panel tenderness scores of all marbling

Simple Correlation

Source of Variation	Coefficient of Correlation r	Percentage of Variation Accounted For $r^2 \times 100$
Marbling score versus		
Tenderness by shear	-.080	0.6
Tenderness by panel	0.263**	6.9
Juiciness by panel	0.188*	3.5
Ether extract versus		
Tenderness by shear	0.031	0.1
Tenderness by panel	0.171	3.0
Juiciness by panel	0.296**	8.8
External fat covering versus		
Tenderness by shear	0.046	0.2
Tenderness by panel	0.053	0.3
Juiciness by panel	0.158	2.5

** Significant at 1 percent level.
* Significant at 5 percent level.

groups. Maturity did not affect juiciness and flavor, but marbling was an important consideration. These researchers also found conflicting results when comparing the Longissimus dorsi and Semimembranosus muscles. Some of the gross correlation coefficients for the evaluations used in the study are shown below.

Gross Correlation Coefficients for Subjective Measurement of Fresh Muscle Properties and Evaluation of Cooked Muscle

Muscle	Marbling Distribution L. D.[a]	Muscle Firmness L. D.[a]	Muscle Texture L. D.[a]	Subj. Color L. D.[a]
Shear force	0.09	0.07	0.49**	0.33*
Panel tenderness score	-.04	-.34**	-.37**	-.25
Panel juiciness score	0.17	-.56**	0.09	0.06
Panel flavor score	0.16	-.65**	0.10	-.05
Panel general opinion score	0.04	-.48**	-.22	-.22
Muscle firmness	-.23	--	-.16	--
Subjective color	--	--	0.30*	--
Ether extract (fresh)	0.26*	-.55**	0.30*	-.18

[a] Longissimus dorsi.
** $P < .01$.
* $P < .05$.

Busch (1968) obtained heritability estimates for carcass quality traits using some of the cattle in this study and others used earlier in the original project. Overall improvement of beef quality would be small through selection even if it could be accurately evaluated in the live animal. The heritability estimates obtained by Busch (1968) were as follows:

Heritability Estimate

Trait	Heritability Estimates
Carcass grade	0.34
Marbling	0.31
Lean color	0.19
Lean firmness	0.29
Tenderness	0.00

METHODS OF PROCEDURE

Source of the Data

South Dakota State University and state-wide ranchers cooperated on a major beef breeding project between the years 1959 to 1968. Eighteen ranches located throughout the state produced the Hereford steers. About half of the steers were sired by bulls owned by the South Dakota Agricultural Experiment Station which were leased to the ranchers. The remaining bulls were raised by purebred breeders and purchased by the cooperators. It was felt the ranchers represented the majority of climate and management conditions under which calves were raised in the state.

Feeding and Management Practices

At weaning, or approximately 205 days of age, selected calves were shipped to Brookings to be placed in a commercial type feedlot. The management of the steers changed slightly from year to year as described by Busch (1968). The steers were fed a high energy ration supplemented with free choice alfalfa hay, salt and mineral and were implanted with diethylstilbestrol during the feeding period. When the average weight of a ranch group of steers was near 1,000 pounds, the group was marketed. Wholesale cuts or whole carcasses were returned to the South Dakota State University Meat Lab for sampling and data collection.

Production and Carcass Traits Studied

Initial Age. The initial age represents the weaning age of the steers when placed in dry lot at Brookings.

Days on Feed. This value represents the length of feeding period at Brookings.

Members of the Animal Science staff subjectively scored the animals just prior to slaughter for the following traits:

Final Condition. The amount of finish on the animals was scored in a range from 1 to 14 with 1 being low condition.

Final Conformation. Each animal was evaluated and scored on a coding system from 1 to 17 where 1 denoted undesirable conformation.

Estimated Live Maturity. A coding system from 1 to 7 was used by evaluators to place a maturity value on each animal. Average maturity was 4 and young was 1.

Estimated Live Percent Cutability. The staff members estimated the various factors used in the cutability prediction equation developed by Murphy et al. (1960). Each steer's estimated cutability score was calculated from the estimated data.

Final Weight and Dressing Percent. Prior to being trucked from Brookings to a slaughter plant, a 12-hour period without feed and water was used to get a final shrunk weight. The shrunk weight was used in calculating dressing percent as follows:

$$\text{Dressing percent} = \frac{(0.975 \times \text{Hot carcass wt.})}{\text{Live wt. (12-hour shrink)}}$$

Chilled carcass weight was calculated by multiplying 0.975 times the hot carcass weight which adjusted for shrink during the cooling period.

Final Market Grade. A packer grader scored each animal to the one-third grade on a scale from 1 to 24. A rating of 24 indicates a high prime grade.

The U.S.D.A. Meat Grading Service evaluated all carcasses slaughtered. A representative of the service also put a subjective score on these carcasses for the following traits:

Marbling Score. The estimated marbling level is a reflection of the intramuscular fat of the Longissimus dorsi muscle.

Carcass Maturity. The carcass age was evaluated using the degree of ossification of vertebra, lean color, and the shape of the ribs.

Lean Color. Color scores were determined on the rib eye at the 12th rib with a range from very dark red to dark pink. The range was from 1 to 7, respectively.

Carcass Quality Grade. Maturity and marbling were major factors considered in determining the carcass quality grade. Lean firmness and color may also influence the quality grade. The range in data reported here was 13 to 24 or low standard to high prime, respectively.

Carcass Conformation. Each one-third grade represented a degree of conformation. The range was 13 to 24 with high prime conformation being 24.

Carcass Grade. The grader adjusted the carcass quality grade for carcass conformation to comply with grade standards. The range was the same as the carcass quality grade.

The objective or quantitative carcass traits were also among those studied. Rib-eye area and fat thickness were used in the cutability equation. Chilled carcass weight, which is mentioned earlier, is also part of the cutability equation.

Fat Thickness. The fat thickness was calculated by averaging three measurements over the rib eye on the acetate tracing. The method described by Naumann (1951) was used.

Rib-eye Area. A polar compensating planimeter was used to measure the area of the Longissimus dorsi muscle from an acetate tracing of the cross section cut between the 12th and 13th rib.

Carcass Cutability. Fat thickness, kidney fat percent, chilled carcass weight, and rib-eye area were utilized in the equation developed by Murphy et al. (1960) to obtain the estimated percent of boneless retail cuts from the chuck, rib, loin, and round.

Shear Tenderness. Steaks were taken from the area of the 12th rib about ten days after the steers were slaughtered and were frozen until the tenderness evaluation was made. The steak samples were thawed at room temperature and cooked with dry heat at 325° F. to an internal temperature of 150° F. Three cores, 1 inch in diameter, were removed from the medial, central and lateral areas of the Longissimus dorsi muscle. Two shear values were obtained on each of the cores with a Warner-Bratzler shearing device. The average of all six values was the shear tenderness reported for each animal. Tenderness was measured as pounds of force required to shear the 1 inch core, therefore, a lower value indicates more tender meat. This trait was measured on all cattle in this study.

Taste Panel Tenderness, Flavor, and Juiciness. A research taste panel was used in 1963 to evaluate all three factors from the same rib steak sample. Panel members were selected from the Animal Science staff.

Chemical Analysis - Percent Moisture, Fat, and Protein. One boneless rib-eye steak removed anterior to the 12th rib was used for proximate chemical analysis.

Histological Analysis. Muscle fiber diameters of the Longissimus dorsi were measured on part of the steers in this study using a modification of the Brady (1937) method. Muscle fiber length and muscle fiber waviness were evaluated at the same time.

Statistical Procedures

Simple correlations were obtained for all traits and multiple regression analyses were obtained by a stepwise method. The same program gave all means and standard deviations for the traits.

The complete study involved 578 time-constant steers and 52 weight-constant steers. The time-constant steers were divided into three different experiments because each group of steers had a slight variation in the amount of data available. Quality traits, including quality grade, shear tenderness, and tenderness, juiciness, and flavor as indicated by panel were analyzed using multiple regression techniques. Other traits subjected to multiple regression analysis included carcass cutability and muscle fiber diameter. Within each experiment, three multiple regression analyses were completed for selected traits using live data only, carcass data only, and all data combined, respectively.

Experiment 1. Five hundred seventy-eight steers were involved in this phase of the study. These steers were from the years 1962 to 1967. The data available permitted multiple regression analyses as indicated below:

Data Used in Multiple Regression Analysis

Trait	Type of Data Used		
	All	Carcass	Live
Shear tenderness	X	X	X
Carcass cutability	X	X	X
Carcass quality grade	X	X	X

Experiment 2. Two hundred forty-six steers comprised the second study. Muscle fiber diameter, muscle fiber waviness, muscle fiber length, and estimated live maturity were available on the

smaller group of animals in addition to the data used in experiment 1. The regression analyses performed were as follows:

Data Used in Multiple Regression Analysis

Trait	Type of Data Used: All	Carcass	Live
Shear tenderness	X	X	X
Carcass cutability	X	X	X
Carcass quality grade	X	X	X
Muscle fiber diameter	X		

Experiments 3 and 4. Sixty time-constant and 52 weight-constant cattle were used in the third and fourth experiments. The weight-constant cattle had similar treatment, but each animal was marketed at a specific predetermined weight. Taste panel results in addition to the experiment 2 data were analyzed. Traits predicted and data used in the analyses are shown below.

Data Used in Multiple Regression Analysis

Trait	Type of Data Used: All	All Data Without Taste Panel	Carcass	Live
Shear tenderness	3 4[a]	3 4	3 4	3 4
Carcass cutability	3 4	3 4	3 4	3 4
Taste panel tenderness		3 4	3 4	3 4
Taste panel flavor		3 4	3 4	3 4
Taste panel juiciness		3 4	3 4	3 4

[a] 3 = time-constant cattle, 4 = weight-constant cattle.

RESULTS

Experiment 1

Data on 24 variables from each of 578 cattle were used in the analyses described in the Methods of Procedure. The means and standard deviations are presented in table 1 along with the units of each trait. Simple correlation coefficients of all traits are presented in appendix table 1. Selected traits were correlated with all other traits and are presented in table 2.

Carcass quality grade, carcass cutability, and shear tenderness were predicted with multiple regression by the stepwise method where the reduction of sum of squares determined the rank of steps. Tables 3, 4, and 5 show the order of steps and the sum of squares reduced by each step or trait. All steps are ranked according to the percentage of sum of squares reduced. Tables 6, 7, and 8 show the prediction of carcass quality, carcass cutability, and shear tenderness when the data were broken into three groups as all data, carcass data, and live data. The multiple correlation coefficient, R, and the proportion of variation accounted for, R^2, are also listed at the bottom of each table. Tables 6, 7, and 8 also show the multiple regression coefficients which could be used in a practical situation to predict carcass quality, carcass cutability, or shear tenderness.

Experiment 2

The second experiment consisted of 246 steers. Standard deviations, means, and the units of measure for the 29 traits are

TABLE 1. MEANS AND STANDARD DEVIATIONS FOR TRAITS USED IN STUDY (N = 578)

Variable	No.	Means	S.D.	Units
Initial age	1	220.0	27.7	Days
Days on feed	2	252.0	24.7	Days
Rate of gain	3	2.32	0.270	Pounds per day
Dressing percent	4	60.75	2.910	Percent
Final conformation	5	11.9	1.91	Integer, 3 to 17, average 10
Final condition	6	9.8	2.04	Integer, 0 to 14, average 7
Carcass conformation	7	19.5	1.15	Integer, 19 = Choice -, 20 = Choice
Carcass grade	8	18.3	1.56	Integer, 18 = Good +, 19 = Choice -
Live market grade	9	19.3	1.21	Integer, 19 = Choice -, 20 = Choice
Tenderness	10	16.0	4.12	Pounds
Marbling score	11	4.9	1.06	Integer, 4 = slight, 5 = small
Live percent cutability	12	49.28	1.272	Percent
Carcass cutability	13	49.45	1.997	Percent
Loin eye area	14	10.67	1.662	Square inches
Fat thickness	15	0.51	0.157	Inches

TABLE 1 CONTINUED

Variable	No.	Means	S.D.	Units
Carcass maturity	16	22.6	1.84	Integer, 22 = A +, 23 = A
Lean firmness	17	4.8	0.87	Integer, 4 = slightly soft, 5 = moderately firm
Lean color	18	4.6	0.82	Integer, 4 = cherry red, 5 = light cherry red
Carcass quality grade	19	18.2	1.72	Integer, 18 = Good +, 19 = Choice -
Percent moisture	20	72.63	3.347	Percent
Percent fat	21	3.86	1.824	Percent
Percent protein	22	21.72	1.384	Percent
Chilled carcass weight	23	607.9	57.33	Pounds
Live weight	24	991.4	90.91	Pounds

TABLE 2. SIMPLE CORRELATION COEFFICIENTS FOR TRAITS STUDIED (N = 578)

Traits	Carcass quality grade	Shear tenderness	Marbling score	Carcass cutability	Live market grade
Initial age	0.07	0.28	0.11	0.18	0.26
Days on feed	0.26	-.14	0.09	0.25	0.28
Rate of gain	0.39	0.01	0.33	0.10	0.50
Dressing percent	0.38	0.22	0.19	0.58	0.61
Final conformation	-.19	-.22	-.08	-.64	-.29
Final condition	-.18	-.26	-.04	-.70	-.34
Carcass conformation	0.48	0.42	0.27	0.45	0.62
Carcass grade	0.96	-.12	0.86	0.27	0.42
Live market grade	0.38	0.13	0.21	0.30	1.00
Shear tenderness	-.20	1.00	-.13	0.10	0.13
Marbling score	0.84	-.13	1.00	0.04	0.21
Live percent cutability	-.02	-.22	-.01	0.06	-.32
Carcass cutability	0.25	0.10	0.04	1.00	0.30
Loin eye area	-.29	-.12	-.01	-.44	-.42
Fat thickness	0.24	0.00	0.26	-.41	0.38

TABLE 2 CONTINUED

Traits	Carcass quality grade	Shear tenderness	Marbling score	Carcass cutability	Live market grade
Carcass maturity	0.36	-.02	0.14	0.39	0.37
Lean firmness	0.52	-.19	0.40	0.14	0.08
Lean color	0.39	-.05	0.39	0.14	0.21
Carcass quality grade	1.00	-.20	0.84	0.25	0.38
Percent moisture	-.16	0.06	-.19	0.11	-.06
Percent fat	0.07	-.21	0.30	-.58	-.36
Percent protein	0.06	0.24	-.13	0.52	0.39
Chilled carcass weight	0.32	0.09	0.26	0.00	0.59
Final weight	0.32	0.06	0.23	0.06	0.61

TABLE 3. RANK AND PROPORTION OF SUM OF SQUARES REDUCED BY EACH VARIABLE WHEN PREDICTING SHEAR TENDERNESS BY STEPWISE MULTIPLE REGRESSION (N = 578)

Trait	All data		Carcass data		Live data	
	S.S. reduced	Rank	S.S. reduced	Rank	S.S. reduced	Rank
Initial age	0.078	1			0.078	1
Days on feed	0.011	7			0.005	5
Rate of gain	0.001	12			0.007	4
Dressing percent	0.061	3				
Final conformation	0.000	20			0.001	7
Final condition	0.001	14			0.027	3
Carcass conformation	0.004	11	0.002	12		
Carcass grade	0.032	4	0.069	3		
Live market grade	0.002	13			0.001	8
Marbling score	0.008	9	0.006	6		
Live percent cutability	0.013	5			0.023	2
Carcass cutability	0.001	15	0.000	13		
Loin eye area	0.002	16	0.002	10		
Fat thickness	0.002	17	0.000	14		

TABLE 3 CONTINUED

Trait	All data S.S. reduced	All data Rank	Carcass data S.S. reduced	Carcass data Rank	Live data S.S. reduced	Live data Rank
Carcass maturity	0.001	19	0.002	11		
Lean firmness	0.000	23	0.008	4		
Lean color	0.009	8	0.002	9		
Carcass quality grade	0.051	2	0.048	2		
Percent moisture	0.006	10	0.008	5		
Percent fat	0.001	18	0.008	7		
Percent protein	0.011	6	0.057	1		
Chilled carcass weight	0.001	22	0.004	8		
Final weight	0.000	21			0.008	6
R	0.543		0.464		0.387	
R^2	0.295		0.215		0.149	

TABLE 4. RANK AND PROPORTION OF SUM OF SQUARES REDUCED BY EACH VARIABLE WHEN PREDICTING CARCASS QUALITY GRADE BY STEPWISE MULTIPLE REGRESSION METHOD (N = 578)

	All data		Carcass data		Live data	
Trait	S.S. reduced	Rank	S.S. reduced	Rank	S.S. reduced	Rank
Initial age	0.001	9	0.000	8	0.020	3
Days on feed	0.000	20			0.074	2
Rate of gain	0.001	10			0.150	1
Dressing percent	0.000	22				
Final conformation	0.001	12			0.001	8
Final condition	0.000	15			0.000	7
Carcass conformation	0.067	2	0.067	2		
Live market grade	0.003	8			0.010	5
Tenderness	0.008	5	0.008	5		
Marbling score	0.707	1	0.707	1		
Live percent cutability	0.000	14			0.004	6
Carcass cutability	0.003	7	0.003	7		
Loin eye area	0.006	6	0.006	6		
Fat thickness	0.001	11				

TABLE 4 CONTINUED

	All data		Carcass data		Live data	
Trait	S.S. reduced	Rank	S.S. reduced	Rank	S.S. reduced	Rank
Carcass maturity	0.025	3	0.025	3		
Lean firmness	0.018	4	0.018	4		
Lean color	0.000	21				
Percent moisture	0.000	19				
Percent fat	0.000	13				
Percent protein	0.000	17				
Chilled carcass weight	0.000	16				
Final weight	0.000	18			0.021	4
R	0.918		0.914		0.529	
R^2	0.844		0.835		0.280	

TABLE 5. RANK AND PROPORTION OF SUM OF SQUARES REDUCED BY EACH VARIABLE WHEN PREDICTING CARCASS CUTABILITY BY STEPWISE MULTIPLE REGRESSION METHOD (N = 578)

Trait	All data		Carcass data		Live data	
	S.S reduced	Rank	S.S reduced	Rank	S.S reduced	Rank
Initial age	0.002	13			0.000	8
Days on feed	0.000	17			0.056	2
Rate of gain	0.001	18			0.014	4
Dressing percent	0.025	4				
Final conformation	0.005	10			0.000	7
Final condition	0.493	1			0.493	1
Carcass conformation	0.133	3	0.159	3		
Carcass grade	0.000	21	0.045	4		
Live market grade	0.003	12			0.001	5
Tenderness	0.001	14				
Marbling score	0.001	16	0.000	12		
Live percent cutability	0.000	22			0.000	6
Loin eye area	0.037	7	0.000	13		
Fat thickness	0.102	2	0.110	2		

TABLE 5 CONTINUED

Trait	All data S.S. reduced	All data Rank	Carcass data S.S reduced	Carcass data Rank	Live data S.S. reduced	Live data Rank
Carcass maturity	0.000	20	0.002	10		
Lean firmness	0.000	19	0.004	9		
Lean color	0.004	11	0.011	6		
Carcass quality grade	0.007	8	0.001	11		
Percent moisture	0.000	23	0.006	7		
Percent fat	0.006	9	0.342	1		
Percent protein	0.001	15	0.028	5		
Chilled carcass weight	0.007	5	0.005	8		
Final weight	0.017	6			0.005	3
R	0.920		0.841		0.754	
R^2	0.846		0.707		0.569	

TABLE 6. SELECTED MULTIPLE CORRELATION COEFFICIENTS USED IN PREDICTING CARCASS QUALITY GRADE FROM ALL DATA, CARCASS TRAITS, AND LIVE ANIMAL TRAITS (N = 578)

Trait	All data	Carcass data	Live data
Marbling score	1.137	1.235	
Carcass conformation	0.290	0.303	
Carcass maturity	0.143	0.161	
Lean firmness	0.263		
Tenderness	-.039		
Rate of gain			2.464
Days on feed			0.019
Initial age			0.010
Live weight			-.005
Intercept	3.094	2.572	3.891
R	0.908	0.894	0.514
R^2	0.825	0.799	0.265

TABLE 7. SELECTED MULTIPLE CORRELATION COEFFICIENTS USED IN PREDICTING SHEAR TENDERNESS FROM ALL DATA, CARCASS TRAITS, AND LIVE ANIMAL TRAITS (N = 578)

Trait	All data	Carcass data	Live data
Initial age	0.028		0.021
Dressing percent	0.327		
Carcass grade	1.893	2.631	
Percent protein		0.627	
Carcass quality grade	-2.384	-2.818	
Live percent cutability			-.573
Final condition			-.378
Intercept	-1.251	5.509	43.261
R	0.471	0.417	0.357
R^2	0.222	0.174	0.127

TABLE 8. SELECTED MULTIPLE CORRELATION COEFFICIENTS USED IN PREDICTING CARCASS CUTABILITY FROM ALL DATA, CARCASS TRAITS, AND LIVE ANIMAL TRAITS (N = 578)

Trait	All data	Carcass data	Live data
Final condition	-.411		-.674
Fat thickness	-5.052	-6.423	
Carcass conformation	0.458	0.460	
Dressing percent	0.384		
Chilled carcass weight	-.038		
Live weight	0.019		-.005
Loin eye area	0.421		
Carcass quality	0.114		
Percent fat		-.331	
Carcass grade		0.332	
Days on feed			0.025
Rate of gain			1.408
Percent protein		0.297	
Intercept	21.340	32.516	51.342
R	0.906	0.827	0.753
R^2	0.822	0.683	0.567

presented in table 9. The cattle were part of the first experiment and the steers were slaughtered during 1963, 1964, and 1965. Estimated live maturity, muscle fiber diameter, muscle fiber waviness and muscle fiber length were the additional traits available which permitted these cattle to be studied separately.

Appendix table 2 shows the correlation matrix containing all simple correlation coefficients in this experiment. Table 10 lists a selected number of simple correlation coefficients for the important beef quality traits and carcass cutability.

Tables 11, 12, and 13 show the sum of squares reduced by each step of the multiple regression analysis and the rank of the variables. R and R^2 are also listed at the bottom of each rank.

Tables 14, 15, 16, and 17 list the multiple correlation coefficients of shear tenderness, carcass cutability, carcass quality grade, and fiber diameter. The multiple correlation coefficients listed represent prediction equations that utilize the high ranking traits.

<u>Experiment 3</u>

The data from 60 steers slaughtered in 1963 were analyzed in this experiment because taste panel data were available. The steers were part of experiment 1. Means and standard deviations are presented in table 18.

Simple correlation coefficients of the 29 traits are presented in appendix table 3. Live animal traits correlated with marbling score and tenderness are shown in table 19. Similar coefficients with carcass traits are found in table 20. Important simple

TABLE 9. MEANS AND STANDARD DEVIATIONS FOR TRAITS USED IN STUDY (N = 246)

Variable	No.	Means	S.D.	Units
Initial age	1	229.0	25.5	Days
Days on feed	2	251.0	25.5	Days
Rate of gain	3	2.32	0.269	Pounds per day
Dressing percent	4	60.68	1.523	Percent
Final conformation	5	11.6	1.07	Integer, 3 to 17, average 10
Final condition	6	9.9	1.36	Integer, 0 to 14, average 7
Carcass conformation	7	19.7	0.71	Integer, 19 = Choice -, 20 = Choice
Carcass grade	8	18.6	1.30	Integer, 18 = Good +, 19 = Choice -
Live market grade	9	19.2	0.91	Integer, 19 = Choice -, 20 = Choice
Tenderness	10	15.0	2.71	Pounds
Marbling score	11	5.2	0.96	Integer, 4 = slight, 5 = small
Live percent cutability	12	49.49	0.735	Percent
Carcass cutability	13	49.52	1.451	Percent
Loin eye area	14	10.66	1.013	Square inches
Fat thickness	15	0.56	0.158	Inches

TABLE 9 CONTINUED

Variable	No.	Means	S.D.	Units
Carcass maturity	16	22.5	0.83	Integer, 22 = A +, 23 = A
Lean firmness	17	4.9	0.73	Integer, 4 = slightly soft, 5 = moderately firm
Lean color	18	4.8	0.76	Integer, 4 = cherry red, 5 = light cherry red
Carcass quality grade	19	18.6	1.30	Integer, 18 = Good +, 19 = Choice -
Estimated live maturity	20	4.24	0.865	Integer, 1 to 7, average 4
Percent moisture	21	72.51	1.743	Percent
Percent fat	22	4.19	1.407	Percent
Percent protein	23	21.48	0.870	Percent
Muscle fiber diameter	24	56.23	6.558	Microns
Muscle waviness	25	2.7	1.28	Integer
Muscle fiber length	26	2.3	0.71	Integer
Chilled carcass weight	27	608.3	56.11	Pounds
Live weight	28	989.0	84.99	Pounds

TABLE 10. SIMPLE CORRELATION COEFFICIENTS OF IMPORTANT BEEF CARCASS AND LIVE ANIMAL TRAITS (N = 246)

Trait	Carcass quality grade	Shear tenderness	Marbling score	Carcass cutability	Live market grade	Muscle fiber diameter
Initial age	0.14	0.07	0.10	-.22	0.16	0.00
Days on feed	-.36	-.01	-.23	-.10	-.10	0.20
Rate of gain	0.43	0.02	0.38	-.22	0.42	-.14
Dressing percent	0.04	0.17	0.08	-.11	0.04	0.00
Final conformation	-.01	-.09	0.02	-.13	0.30	0.00
Final condition	-.09	0.05	-.04	-.30	0.32	0.04
Carcass conformation	0.27	0.28	0.35	-.04	0.35	-.08
Carcass grade	0.99	-.09	0.88	0.01	0.18	-.06
Live market grade	0.17	0.11	0.19	-.41	1.00	-.04
Tenderness	-.08	1.00	-.08	-.11	0.11	0.12
Marbling score	0.90	-.08	1.00	-.07	0.19	0.00
Live percent cutability	-.22	-.18	-.23	0.52	-.57	0.00
Carcass cutability	0.01	-.11	-.07	1.00	-.41	-.04
Loin eye area	0.26	-.17	-.22	0.27	0.22	-.02

TABLE 10 CONTINUED

Trait	Carcass quality grade	Shear tenderness	Marbling score	Carcass cutability	Live market grade	Muscle fiber diameter
Fat thickness	0.09	0.13	0.14	-.77	0.48	-.02
Carcass maturity	0.52	-.20	0.32	0.23	-.05	-.23
Lean firmness	0.36	-.02	0.35	-.12	-.11	-.02
Lean color	0.52	-.18	0.43	0.08	0.13	-.06
Carcass quality grade	1.00	-.08	0.90	0.01	0.17	-.06
Estimated live maturity	0.09	0.09	0.09	-.11	0.00	-.02
Percent moisture	-.26	0.15	-.28	0.02	-.02	-.04
Percent fat	0.47	-.20	0.49	-.14	0.06	0.04
Percent protein	-.41	0.17	-.38	-.01	-.08	0.01
Muscle fiber diameter	-.06	0.12	0.00	-.04	-.04	1.00
Muscle waviness	0.06	-.01	0.02	0.08	0.08	-.21
Muscle fiber length	-.03	0.11	-.04	0.22	0.06	-.05
Chilled carcass weight	0.25	0.18	0.26	-.44	0.50	-.04
Final weight	0.18	0.15	0.20	-.44	0.47	-.04

TABLE 11. RANK AND PROPORTION OF SUM OF SQUARES REDUCED BY EACH VARIABLE WHEN PREDICTING SHEAR TENDERNESS BY STEPWISE MULTIPLE REGRESSION METHOD (N = 246)

Trait	All data S.S. reduced	All data Rank	Carcass data S.S. reduced	Carcass data Rank	Live data S.S. reduced	Live data Rank
Initial age	0.001	22			0.000	9
Days on feed	0.004	14			0.004	6
Rate of gain	0.000	27			0.008	5
Dressing percent	0.011	11				
Final conformation	0.015	9			0.018	2
Final condition	0.000	23			0.015	3
Carcass conformation	0.002	15	0.000	17		
Carcass grade	0.000	26	0.001	16		
Live market grade	0.000	25			0.003	7
Marbling score	0.002	19	0.003	14		
Live percent cutability	0.011	7			0.033	1
Carcass cutability	0.002	17	0.009	9		
Loin eye area	0.011	6	0.011	6		
Fat thickness	0.000	24	0.002	15		

TABLE 11 CONTINUED

Trait	All data S.S. reduced	All data Rank	Carcass data S.S. reduced	Carcass data Rank	Live data S.S. reduced	Live data Rank
Carcass maturity	0.029	3	0.029	3		
Lean firmness	0.017	5	0.017	5		
Lean color	0.006	12	0.007	10		
Carcass quality grade	0.001	18	0.006	12		
Estimated live maturity	0.001	21			0.001	8
Percent moisture	0.006	13	0.006	11		
Percent fat	0.040	1	0.040	1		
Percent protein	0.014	8	0.010	7		
Muscle fiber diameter	0.011	10	0.011	8		
Muscle fiber waviness	0.002	20	0.004	13		
Muscle fiber length	0.011	4	0.011	4		
Chilled carcass weight	0.051	2	0.051	2		
Final weight	0.006	15			0.003	4
R	0.503		0.465		0.290	
R^2	0.253		0.216		0.084	

TABLE 12. RANK AND PROPORTION OF SUM OF SQUARES REDUCED BY EACH VARIABLE WHEN PREDICTING CARCASS QUALITY GRADE BY STEPWISE MULTIPLE REGRESSION METHOD (N = 246)

Trait	All data		Carcass data		Live data	
	S.S. reduced	Rank	S.S. reduced	Rank	S.S. reduced	Rank
Initial age					0.005	3
Days on feed	0.005	5			0.044	2
Rate of gain					0.189	1
Final conformation	0.001	9			0.004	6
Final condition					0.003	5
Carcass conformation	0.003	3	0.003	3		
Live market grade					0.000	9
Tenderness	0.001	10				
Marbling score	0.801	1	0.801	1		
Live percent cutability	0.001	14			0.003	4
Carcass cutability			0.000	11		
Loin eye area	0.001	12	0.001	6		
Fat thickness	0.001	11	0.001	10		
Carcass maturity	0.061	2	0.061	2		

TABLE 12 CONTINUED

Trait	All data S.S. reduced	All data Rank	Carcass data S.S. reduced	Carcass data Rank	Live data S.S. reduced	Live data Rank
Lean firmness	0.001	13	0.001	9		
Lean color	0.003	6	0.002	5		
Estimated live maturity					0.003	8
Percent moisture			0.000	13		
Percent fat	0.003	4	0.003	4		
Percent protein			0.000	12		
Muscle fiber diameter			0.000	15		
Muscle fiber waviness	0.002	7	0.001	8		
Muscle fiber length	0.002	8	0.002	7		
Chilled carcass weight			0.000	14		
Final weight					0.001	7
R	0.941		0.936		0.502	
R^2	0.886		0.876		0.252	

TABLE 13. RANK AND PROPORTION OF SUM OF SQUARES REDUCED BY EACH VARIABLE WHEN PREDICTING CARCASS CUTABILITY AND MUSCLE FIBER DIAMETER BY STEPWISE MULTIPLE REGRESSION METHOD (N = 246)

	Carcass cutability						Muscle fiber diameter	
	All data		Carcass data		Live data		All data	
Trait	S.S. reduced	Rank	S.S. reduced	Rank	S.S. reduced	Rank	S.S. reduced	Rank
Initial age	0.015	5			0.062	3	0.004	8
Days on feed	0.002	10			0.036	2	0.019	3
Rate of gain	0.002	11			0.000	7	0.000	20
Dressing percent	0.000	17					0.006	6
Final conformation	0.001	13			0.002	6	0.003	15
Final condition	0.000	22			0.000	8	0.000	21
Carcass conformation	0.000	15	0.001	7			0.002	12
Carcass grade	0.000	27	0.000	14			0.000	25
Live market grade	0.002	9			0.018	4	0.002	14
Tenderness	0.000	24					0.008	5
Marbling score	0.000	20					0.001	17
Live percent cutability	0.000	25	0.000	10	0.274	1	0.001	22
Carcass cutability							0.000	24

TABLE 13 CONTINUED

Trait	Carcass cutability						Muscle fiber diameter	
	All data		Carcass data		Live data		All data	
	S.S. reduced	Rank	S.S. reduced	Rank	S.S. reduced	Rank	S.S. reduced	Rank
Loin eye area	0.125	2	0.125	2			0.003	11
Fat thickness	0.599	1	0.599	1			0.000	23
Carcass maturity	0.018	4	0.018	4			0.051	1
Lean firmness	0.013	6	0.011	5			0.005	7
Lean color	0.000	19	0.000	12			0.001	16
Carcass quality grade	0.000	26	0.000	13			0.009	4
Estimated live maturity	0.000	21			0.000	9	0.000	26
Percent moisture	0.000	16	0.001	9			0.001	18
Percent fat	0.000	18	0.000	16			0.001	19
Percent protein	0.001	12	0.000	11			0.004	10
Muscle fiber diameter	0.000	23	0.000	15				
Muscle fiber waviness	0.002	8	0.006	6			0.039	2
Muscle fiber length	0.000	14	0.001	8			0.000	27

TABLE 13 CONTINUED

	Carcass cutability						Muscle fiber diameter	
	All data		Carcass data		Live data		All data	
Trait	S.S. reduced	Rank	S.S. reduced	Rank	S.S. reduced	Rank	S.S. reduced	Rank
Chilled carcass weight	0.082	3	0.082	3			0.002	13
Final weight	0.004	7			0.009	5	0.005	9
R	0.932		0.920		0.633		0.411	
R^2	0.869		0.846		0.401		0.169	

TABLE 14. SELECTED MULTIPLE CORRELATION COEFFICIENTS USED IN PREDICTING SHEAR TENDERNESS FROM ALL DATA, CARCASS TRAITS, AND LIVE ANIMAL TRAITS (N = 246)

Trait	All data	Carcass data	Live data
Percent fat	-.504	-.423	
Chilled carcass weight	0.011	0.011	
Carcass maturity	-.679	-.565	
Muscle fiber length	0.542		
Lean firmness	0.541		
Live percent cutability			-.537
Final conformation			-.749
Final condition			0.437
Intercept	21.758	22.831	45.979
R	0.384	0.346	0.255
R^2	0.147	0.119	0.065

TABLE 15. SELECTED MULTIPLE CORRELATION COEFFICIENTS USED IN PREDICTING CARCASS CUTABILITY FROM ALL DATA, CARCASS TRAITS, AND LIVE ANIMAL TRAITS (N = 246)

Trait	All data	Carcass data	Live data
Fat thickness	-5.970	-5.970	
Loin eye area	0.701	0.701	
Chilled carcass weight	-.009	-.009	
Carcass maturity	0.237	0.237	
Live percent cutability			0.807
Days on feed			-.022
Initial age			-.019
Live market grade			-.263
Intercept	45.827	45.827	24.400
R	0.908	0.908	0.624
R^2	0.824	0.824	0.390

TABLE 16. SELECTED MULTIPLE CORRELATION COEFFICIENTS USED IN PREDICTING CARCASS QUALITY GRADE FROM ALL TRAITS, CARCASS TRAITS, AND LIVE ANIMAL TRAITS (N = 246)

Trait	All data	Carcass data	Live data
Marbling score	1.101	1.101	
Carcass maturity	0.411	0.411	
Rate of gain			1.705
Days on feed			-.012
Intercept	3.607	3.607	17.578
R	0.928	0.928	0.482
R^2	0.861	0.861	0.233

TABLE 17. SELECTED MULTIPLE CORRELATION COEFFICIENTS USED IN PREDICTING MUSCLE FIBER DIAMETER FROM ALL DATA (N = 246)

Trait	All data
Carcass maturity	-1.134
Muscle fiber waviness	-1.137
Days on feed	0.041
Intercept	74.647
R	0.330
R^2	0.109

TABLE 18. MEANS AND STANDARD DEVIATIONS OF TRAITS STUDIED FOR N = 60 AND N = 52

Variable	No.	N = 60 Means	N = 60 S.D.	N = 52 Means	N = 52 S.D.	Units
Initial age	1	229.0	16.81	222.0	15.0	Days
Days on feed	2	274.0	0.0	242.0	60.0	Days
Rate of gain	3	2.22	0.23	2.21	0.23	Pounds per day
Dressing percent	4	60.83	1.42	59.88	2.04	Percent
Final conformation	5	11.8	1.01	10.9	1.22	Integer, 3 to 17, average 10
Final condition	6	10.4	1.03	9.0	1.62	Integer, 0 to 14, average 7
Carcass conformation	7	19.6	0.56	20.1	1.20	Integer, 19 = Choice -, 20 = Choice
Carcass grade	8	17.8	1.18	17.8	1.47	Integer, 18 = Good +, 19 = Choice -
Live market grade	9	19.2	0.89	18.5	1.79	Integer, 19 = Choice -, 20 = Choice
Tenderness	10	15.4	3.00	16.1	3.71	Pounds
Marbling score	11	4.8	0.70	4.4	1.26	Integer, 4 = slight, 5 = small
Carcass cutability	12	48.40	1.09	50.22	1.47	U.S.D.A. percent
Loin eye area	13	10.22	1.00	10.43	1.22	Square inches
Fat thickness	14	0.59	0.13	0.59	0.17	Inches
Carcass maturity	15	21.8	0.40	21.8	0.79	Integer, 22 = A +, 23 = A

TABLE 18 CONTINUED

Variable	No.	N = 60 Means	N = 60 S.D.	N = 52 Means	N = 52 S.D.	Units
Lean firmness	16	5.1	0.72	5.4	0.74	Integer, 4 = slightly soft, 5 = moderately firm
Lean color	17	4.4	0.70	5.2	0.98	Integer, 4 = cherry red, 5 = light cherry red
Estimated live maturity	18	4.36	0.907	4.18	0.633	Integer, 1 to 7, average 4
Taste panel tenderness	19	3.60	1.22	3.37	0.97	Integer, pounds
Taste panel flavor	20	3.32	0.93	3.06	0.48	Integer, pounds
Taste panel juiciness	21	3.60	0.98	3.55	0.59	Integer, pounds
Percent moisture	22	72.48	1.46	73.05	1.47	Percent
Percent fat	23	4.35	1.75	4.16	1.47	Percent
Percent protein	24	21.92	0.73	21.72	0.61	Percent
Muscle fiber diameter	25	58.37	8.33	55.89	5.85	Microns
Muscle fiber waviness	26	2.4	0.94	2.8	0.99	Integer
Muscle fiber length	27	2.0	0.70	2.0	0.93	Integer
Chilled carcass weight	28	613.8	55.70	560.0	74.53	Pounds
Final weight	29	1012.9	79.62	933.1	102.60	Pounds

TABLE 19. SIMPLE CORRELATIONS BETWEEN LIVE ANIMAL TRAITS, TENDERNESS, AND MARBLING SCORE

	Initial age	Days on feed	Rate of gain	Final confor-mation	Final condition	Live market grade	Live percent cuta-bility
			Tenderness				
N = 246	0.07	-.01	0.20	-.09	0.05	0.11	-.18
N = 578	0.28	-.14	0.01	-.22	-.26	0.13	-.22
N = 60	0.10	0.00	0.19	-.06	0.09	-.03	--
N = 52	0.06	-.03	-.02	-.04	-.03	-.06	--
			Marbling Score				
N = 246	0.10	-.23	0.38	0.02	-.04	0.19	-.23
N = 578	0.11	0.09	0.32	-.08	-.04	0.22	-.01
N = 60	0.05	0.00	0.14	0.20	0.20	-.02	--
N = 52	-.13	0.76	-.24	0.44	0.61	0.28	--

TABLE 20. SIMPLE CORRELATIONS BETWEEN CARCASS TRAITS, TENDERNESS, AND MARBLING SCORE

	Dressing percent	Carcass confor-mation	Carcass grade	Carcass cuta-bility	Loin eye area	Fat thickness	Carcass maturity	Lean firmness
				Shear Tenderness				
N = 246	0.17	0.28	-.09	-.11	-.17	-.13	-.20	-.02
N = 578	0.22	0.03	-.12	0.10	-.12	0.00	-.02	-.19
N = 60	0.13	-.06	-.10	0.03	0.35	-.12	-.32	-.09
N = 52	-.21	0.04	0.01	-.14	-.11	0.18	-.11	0.10
				Marbling Score				
N = 246	0.08	0.35	0.88	-.07	0.21	0.14	0.32	0.35
N = 578	0.19	0.27	0.86	0.04	-.01	0.26	0.14	0.40
N = 60	0.17	0.04	0.84	-.13	0.22	0.17	0.29	0.48
N = 52	0.50	0.55	0.87	-.51	0.46	0.42	-.05	0.51

TABLE 20 CONTINUED

	Lean color	Carcass quality grade	Percent moisture	Percent fat	Percent protein	Chilled carcass weight	Muscle fiber diameter
			Shear Tenderness				
N = 246	-.18	-.08	0.15	-.20	0.17	0.18	0.12
N = 578	-.05	-.20	0.06	-.21	0.24	0.09	--
N = 60	-.28	--	0.27	-.31	0.18	0.13	0.01
N = 52	-.30	--	0.04	-.05	0.09	-.11	0.11
			Marbling Score				
N = 246	0.43	0.90	-.28	0.49	-.38	0.26	0.00
N = 578	0.39	0.84	-.19	0.30	-.13	0.26	--
N = 60	0.25	--	-.47	0.51	-.09	0.23	0.14
N = 52	-.02	--	-.68	0.65	-.19	0.67	0.55

correlation coefficients between carcass traits and taste panel traits can be seen in table 21. Carcass quality grade, shear tenderness, taste panel tenderness, taste panel flavor, taste panel juiciness, and carcass cutability were predicted when all data without other taste panel results were used. Multiple regression prediction equations are presented within the text of the discussion.

<u>Experiment 4</u>

Taste panel data were available on 52 weight-constant steers grown under conditions similar to those described for the time-constant steers. The weight-constant cattle were marketed at various market weight levels, and carcass and quality data were obtained.

The means, standard deviations, and units of measures for each trait are presented in table 18. Prediction equations are presented in the discussion of the results. Simple correlation coefficients of all traits are presented in appendix table 4. The selected correlations of experiment 4 are also presented in tables 19, 20, and 21 along with the data from experiment 3.

TABLE 21. SIMPLE CORRELATIONS OF TASTE PANEL TRAITS WITH IMPORTANT CARCASS TRAITS

	Tenderness	Marbling score	Carcass cutability	Fat thickness	Carcass maturity	Lean firmness	Lean color	Taste panel tenderness	Taste panel flavor	Taste panel juiciness	Muscle fiber diameter	Chilled carcass weight
					Taste Panel Tenderness							
N = 60	0.27	-.26	0.08	-.04	-.04	-.31	-.02	1.00	0.81	0.79	-.08	0.01
N = 52	0.34	0.20	-.41	0.40	0.02	0.38	-.01	1.00	0.77	0.72	0.11	0.42
					Taste Panel Flavor							
N = 60	-.01	-.23	0.01	-.01	0.04	-.15	0.00	0.81	1.00	0.87	-.04	-.11
N = 52	0.17	0.13	-.08	0.15	0.07	0.28	0.02	0.77	1.00	0.72	0.10	0.03
					Taste Panel Juiciness							
N = 60	-.04	-.16	-.09	0.12	0.12	-.14	0.03	0.79	0.87	1.00	-.02	-.07
N = 52	0.18	0.23	-.46	0.27	-.06	0.28	0.02	0.72	0.72	1.00	0.15	0.14

DISCUSSION

The main objective of this study was to evaluate the ability to predict carcass quality traits using live and carcass traits, carcass traits only, and live traits only in prediction equations. In general, results from this study follow the trends of past research. Carcass quality traits had low simple correlation coefficients, and the carcass quantity traits generally had higher simple correlation coefficients with other traits (tables 2, 10, 19, 20, and 21). Because of the low simple correlation coefficients, prediction equations developed by multiple regression only accounted for a small portion of variation in any one quality trait.

Means and standard deviations of most traits were similar between experiments (tables 1, 9, and 18). Smaller standard deviations indicated more uniformity for that particular group of cattle.

All simple correlation coefficients are presented in tables 1 to 4 in the appendix. Tables 2 and 10 contain simple correlation coefficients of each trait predicted by multiple regression with all other traits studied in experiments 1 and 2 (N = 578 and N = 246).

Beef Quality Versus Live Animal Traits

Beef quality estimation has always been part of live animal evaluation. The present study showed that beef quality could not be accurately predicted or correlated with the observed live animal traits. Only those traits containing a part-whole relationship such as final weight and chilled carcass weight demonstrated simple correlation coefficients above 0.45.

The highest simple correlation coefficients between marbling and live traits were less than 0.38 for the two large groups of cattle. When shear tenderness was correlated with live market grade, the simple correlation coefficients ranged from -.06 to 0.13 for all four experiments. The data showed little correlation between the objective shear tenderness evaluation and the other live animal traits. Table 19 shows the simple correlation coefficients from the four experiments where tenderness and marbling were correlated with the live animal traits. Tenderness and initial age have the highest correlation in experiment 1, but the simple correlation coefficient was only 0.28. This would indicate that as tenderness decreased initial age increased. Final condition had a simple correlation coefficient of -.26 with tenderness from experiment 1 (N = 578). Tenderness increased as the animal increased in external condition at market age. Final conformation and live percent cutability were both correlated with tenderness at -.22. Therefore, tenderness increased as final conformation and live percent cutability increased.

Simple correlation coefficients for many pairs of traits varied in size and sign between the four experiments. Usually the coefficients were of zero order. For example, simple correlation coefficients of tenderness with live market grade, an indicator of carcass grade, ranged from -.06 to 0.13 in the four experiments as can be seen in table 19.

Marbling score taken at the 12th rib revealed low simple correlation coefficient values with live traits for the time constant cattle. Days on feed and marbling score resulted in a 0.76 simple correlation coefficient for the weight-constant cattle, indicating that the longer the cattle were on feed the more marbling could be observed in the rib eye. A wider range, -.24 to 0.38, in simple correlation coefficients for rate of gain and marbling score occurred between the weight-constant steers and steers from N = 246, respectively. Rate of gain would not be a suitable predictor of marbling from this set of data. Final conformation and final condition revealed low simple correlation coefficients with marbling in the time constant cattle, -.08 to 0.20. The weight-constant cattle, however, had simple correlation coefficients of 0.44 and 0.61 when marbling was related to final conformation and final condition.

Generally speaking, marbling and tenderness were not highly correlated with traits studied in the first three experiments where a part-whole relationship did not exist. Live animal traits were not highly correlated with either marbling or shear tenderness, indicating a low probability of accurate meat quality prediction from the live animal. Beef palatability is probably more closely related to the biochemical and biophysical changes within the muscle, and, therefore, external appearance may not reflect hidden muscle characteristics.

Beef Quality Versus Carcass Traits

Tenderness, the primary beef palatability factor, was not highly correlated with any one particular carcass trait as shown in table 20. The simple correlation coefficients ranged from -.32 to 0.28. The negative simple correlation above suggests that as carcass maturity increased in experiment 3 tenderness increased. Steers from the other experiments also followed the trend with simple correlation coefficients of -.20, -.02, and -.11 for tenderness and maturity. Simple correlation coefficients of -.19 (N = 60) and 0.09 (N = 52) existed between marbling score and shear tenderness as can be seen in appendix tables 3 and 4. The data indicated that tenderness is not easily predicted from the amount of visible marbling in the *Longissimus dorsi* muscle.

Marbling score and carcass traits generally revealed higher simple correlation coefficients than did carcass traits and shear tenderness as shown in table 20. Whenever marbling was part of a carcass trait and a part-whole relationship did exist, the simple correlation coefficients were biased. An example would be carcass quality grade where marbling is a determining factor of carcass quality.

Carcass conformation had relatively little effect on tenderness. Simple correlation coefficients ranged from -.06 to 0.28 for all experiments. Carcass grade showed a range of -.12 to 0.01 for simple correlation coefficients with shear tenderness. Carcass cutability, rib-eye area, chilled carcass weight, carcass quality grade, lean firmness, fat thickness, and dressing percent accounted for very little of the variation in tenderness.

Percent moisture, fat, and protein had similar low simple correlation coefficients with shear tenderness. Percent fat of the Longissimus dorsi muscle and tenderness were correlated from -.05 to -.31. As fat increased in the rib-eye muscle, so did tenderness. Percent water and shear tenderness simple correlation coefficients ranged from 0.04 to 0.27 in the study, indicating as water increased the tenderness of the meat decreased. The simple correlation coefficients for percent protein and tenderness were in a range from 0.09 to 0.24. Therefore, as percent protein of the Longissimus dorsi muscle increased, tenderness decreased.

Muscle fiber diameter also had low simple correlation coefficients with shear tenderness ranging from 0.01 to 0.12. Brady (1937) found a nonsignificant relationship between fiber diameter and shear tenderness. Hiner et al. (1953) showed that muscles having small fibers were more tender than those with larger fibers. The present study does not support the above finding.

Marbling and dressing percent were not related in the first three experiments as demonstrated by the low simple correlation coefficients in table 20. However, a simple correlation coefficient of 0.50 did exist between marbling and dressing percent in experiment 4, the small weight-constant group. Carcass conformation correlated with marbling in a range from 0.04 to 0.55 over the four experiments. Simple correlation coefficients of rib-eye area, fat thickness, and carcass maturity with marbling score were all low, and the values were inconsistent between experiments as shown in table 20. Sizes of simple correlation coefficients were in the low to medium range, 0.35 to 0.51, when lean firmness of the rib eye was related with marbling score. More variation was shown in simple correlation coefficients between marbling score and lean color, -.02 to 0.43. Percent fat of the rib eye increased with increased marbling as indicated by a simple correlation coefficient interval from 0.30 to 0.65. Percent moisture decreased as marbling increased. The protein content of the Longissimus dorsi muscle was irregular in degrees of correlation with marbling score. Also, fiber diameter showed no significant correlation with marbling in the first and third experiments. A simple correlation coefficient of 0.55 existed between marbling and muscle fiber diameter in the fourth experiment or the weight-constant steers as shown in table 20.

The weight-constant steers were randomly allotted to four weight groups. As each steer reached the specified weight, it was slaughtered. The time-constant cattle were slaughtered when each ranch group averaged 1,000 pounds. As a result, the weight-constant steers tended to have higher frequencies at extreme weights.

Prediction Equation by Multiple Regression Stepwise Method

Shear tenderness, the most universally accepted measure of beef palatability, was analyzed by stepwise multiple regression analysis in all four experiments. The variables used in the analyses were ranked on the amount of the shear tenderness sum of squares each variable accounted for. The multiple correlation coefficients, R, and the cumulative portion of the sum of squares accounted for, R^2, were calculated at each step. Prediction equations using the multiple regression coefficients and intercepts computed at each step were also produced.

The most reliable prediction equations in this study were probably developed from experiment 1, since it is the largest, N = 578. Table 3 lists the proportion of the shear tenderness sum of squares reduced by and the rank of each variable in the multiple regression analyses of experiment 1. Three different analyses were performed using all data, live data and carcass data, and, therefore, three lists of results are shown in most tables. Table 7 contains the multiple correlation coefficients and intercepts for shear tenderness prediction equations from experiment 1. Although only 29 percent of the total variation in shear tenderness was accounted for by the 23 variables used, it should be noted that carcass grade and quality grade were high in the ranking. When only the four highest rankings of the 23 variables were used, 22 percent of the shear sum of squares was accounted for (table 7).

Table 11 lists the proportion of the shear tenderness sum of squares reduction and the rank of each of 27 variables used in experiment 2 (N = 246). The parameters used for three short shear tenderness prediction equations derived from all data, carcass data and live data in experiment 2 are arrayed in table 14.

The rank and proportion of the sum of squares attributed to each variable in experiment 2 (tables 11, 12, and 13) are much different from the same values shown in table 3 for experiment 1. The same table demonstrates that the cumulative portion of the sum of squares accounted for, R^2, was lower in all three multiple regression analyses of shear data in experiment 2 than in experiment 1. The two short shear tenderness prediction equations developed from all data in experiments 1 and 2 are stated below. The multiple correlation coefficient, R, and the proportion of the shear tenderness sum of squares accounted for, R^2, by each equation are also quoted.

N = 578, shear tenderness I = -1.251 + 0.028 x initial age - 2.384 x carcass quality grade + 0.327 x dressing percent + 1.893 x carcass grade ($R = 0.471$, $R^2 = 0.222$)

N = 246, shear tenderness II = 21.758 - 0.504 x percent fat + 0.011 x chilled carcass weight - 0.679 x carcass maturity + 0.542 x muscle fiber diameter ($R = 0.384$, $R^2 = 0.147$)

Although the multiple correlation coefficients, R, were of the same order of magnitude, the same variables were used with the addition of muscle fiber characteristics in experiment 2, and the data in experiment 2 are a subsample of experiment 1, not one trait was used in the prediction equation of both experiments. The inconsistent relative predictive value of traits in the analyses of shear tenderness is probably due to the low simple correlation between tenderness and other traits and the low multiple correlation coefficients resulting from the combination of traits. Because of the poor relationship between other traits and tenderness, chance determines the relative proportion of the shear sum of squares each accounts for in a given set of data.

The multiple regression analysis program did not adjust the sum of squares for interactions which occurred between traits. As a result, minor discrepancies occur between rank and proportion of the sum of squares accounted for in tables 3, 11, 12, and 13 as well as other multiple regression tables.

Multiple regression analysis results for carcass quality grade were similar to shear tenderness results using live data. In experiments 1 and 2 the proportion of the sum of squares accounted for, R^2, were 0.28 and 0.25, respectively (tables 4 and 12). However, when carcass data were available, marbling, conformation, and carcass maturity did predict carcass grade as would be expected. Multiple correlation coefficients for carcass quality grade using all data in experiments 1 and 2 exceeded 0.9.

If quality, measured by shear tenderness or carcass quality grade, is important, the producer should be able to predict quality from live traits for selection purposes. Using the traits in this study, effective selection in the live herd would be impossible since only 15 to 25 percent of the variation in quality traits was accounted for in the live animals. Availability of carcass traits studied here would not improve the ability of the producer to select for tenderness. The inconsistent ranking of tenderness predictive capacity of the traits does not identify traits upon which to base a selection program.

All data from experiment 2 were used in the multiple regression analysis of fiber diameter (table 13). The components of a short prediction equation for fiber diameter appear in table 17. Only a small portion of the variation ($R^2 = 0.169$) in fiber diameter was related to the 27 variables used in the study.

Carcass cutability, a quantity trait, was also subjected to the stepwise multiple regression analysis. The sums of squares and rankings appear in tables 5 and 13 for experiments 1 and 2, respectively. The multiple correlation coefficients, R, and the portion of variation accounted for, R^2, are much higher for cutability than for tenderness and about the same as carcass quality grade when all data were used. However, the R^2 values for cutability were approximately double those of quality grade when only live data were used. The ranking of variables did vary widely in the live data between experiments 1 and 2.

The data used in the above experiments were not adjusted for weight or age differences when predicting carcass cutability. The multiple regression equations were developed to demonstrate the differences in predictability between quantity and quality traits.

Multiple Regression Analysis for Experiments 3 and 4

Sixty time-constant cattle provided the data for experiment 3. Taste panel data were available as measures of beef palatability.

Similar data were available from 52 weight-constant steers which were analyzed separately as experiment 4.

The prediction equation below was developed from multiple regression analysis for shear tenderness on the time-constant cattle, experiment 3, when all data except taste panel scores were used.

N = 60, shear tenderness III = 50.618 - 1.997 x carcass maturity + 5.079 x rate of gain - 0.651 x percent fat ($R = 0.527$, $R^2 = 0.278$)

Experiment 4, the weight-constant steers, resulted in the following prediction equation for shear tenderness from regression analysis without taste panel data:

N = 52, shear tenderness IV = 61.818 + 2.217 x muscle fiber length - 2.121 x lean color - 0.934 x dressing percent + 0.939 x carcass grade ($R = 0.750$, $R^2 = 0.563$)

Although the predictive capacity of shear tenderness was greater in experiment 4 ($R^2 = 0.563$) than in other experiments, variables used such as lean color and dressing percent would seem to be unlikely predictors of tenderness.

Taste panel tenderness was difficult to predict from data used in both experiments when other taste panel data were not included. The following prediction equation using data from experiment 3 was developed:

N = 60, taste panel tenderness III = 4.586 - 0.526 x lean firmness - 0.372 x muscle fiber waviness + 0.090 x shear tenderness + 0.027 x estimated live maturity ($R = 0.515$, $R^2 = 0.266$)

Calculation of the prediction equation for taste panel tenderness using data from weight-constant steers in experiment 4 showed these results:

N = 52, taste panel tenderness IV = 12.669 - 0.239 x carcass cutability + 0.062 x shear tenderness + 0.410 x lean firmness - 0.126 x percent fat (R = 0.587, R^2 = 0.345)

Taste panel juiciness has often been associated with the amount of marbling within the Longissimus dorsi muscle. Using all data except other taste panel data, the resulting multiple regression equation for experiment 3 was:

N = 60, taste panel juiciness III = -.812 - 0.479 x final condition + 0.520 x live market grade - 0.252 x muscle fiber waviness (R = 0.462, R^2 = 0.214)

Live market grade and final condition are estimates of fat distribution which in turn have been used as indicators of beef quality, but the above traits accounted for only 21 percent of the total variation in juiciness.

The weight-constant cattle, experiment 4, showed a different set of traits in a multiple regression equation predicting taste panel juiciness.

N = 52, taste panel juiciness IV = 17.285 - 0.245 x carcass cutability - 0.001 x final weight (R = 0.504, R^2 = 0.254)

Taste panel flavor, a trait difficult to define, was not easily predicted from the data available on the steers within experiment 3. Final condition and live market grade were the most important traits but accounted for less than 25 percent of the total variation in taste panel flavor. The following equation was calculated without other taste panel data:

N = 60, taste panel flavor III = 0.251 - 0.470 x final condition + 0.451 x live market grade - 0.294 x muscle fiber waviness ($R = 0.496$, $R^2 = 0.246$)

The taste panel flavor data from the weight-constant steers were analyzed and the R^2 and R values were similar to the time-constant experiment values. However, the traits within the multiple regression equation were much different. The prediction equation was as follows for experiment 4:

N = 52, taste panel flavor IV = 0.549 + 0.176 x lean firmness + 0.166 x muscle fiber diameter - 0.135 x muscle fiber waviness + 0.007 x initial age ($R = 0.216$, $R^2 = 0.465$)

The eight prediction equations from experiments 3 and 4 cited above include a total of 26 variables. Seventeen different traits were used in the equations. One trait, muscle fiber waviness, was used four times; another, lean firmness, was used three times and four other traits were used in two equations. Marbling did not appear in any of the eight prediction equations for quality. It is clear that no one trait or group of traits used in this study is effective in predicting beef quality characteristics. Combining that observation with the range in variation in quality traits accounted for by the eight equations, 21.4 percent to 56.3 percent, demonstrates that, collectively, the traits studied were not good indicators of quality.

Carcass cutability, a quantity trait, was easier to predict from multiple regression equations. Almost 90 percent of the variation in cutability was accounted for in experiment 3. The prediction equation below was the result of multiple regression analysis of all data:

N = 60, carcass cutability III = 50.523 - 5.692 x fat thickness + 0.519 x loin eye area - 0.007 x chilled carcass weight ($R = 0.947$, $R^2 = 0.897$)

Fat thickness, initial age, marbling score, loin eye area, and chilled carcass weight accounted for 80 percent of the variation in carcass cutability in experiment 4.

N = 52, carcass cutability IV = 57.437 - 2.543 x fat thickness + 0.021 x initial age - 0.356 x marbling score + 0.567 x loin eye area - 0.010 x chilled carcass weight ($R = 0.898$, $R^2 = 0.806$)

Initial age and marbling score are traits within this equation but are not found in the equation for experiment 3. Weight and age differences may have a definite effect upon the outcome of the multiple regression analysis for carcass cutability.

Carcass cutability, the estimated percent retail cuts, was calculated from the following equation (Murphy et al., 1960): estimated percent retail cuts = 52.56 - 4.95 x single fat thickness (inches) - 1.06 x estimated kidney fat (percent) + 0.682 x rib-eye area (square inches) - 0.008 x carcass weight (pounds). The above factors are part of this yield grading mechanism, and therefore using carcass cutability in a prediction equation from this study as shown by Busch (1968) represents a part-whole relationship. The prediction of carcass cutability from data in the four experiments was a check on the relative accuracy of the previously developed equation. Data in this study were not corrected for any factors. The R^2 and R values changed only slightly for carcass cutability prediction from this study when comparing them with similar corrected data from Busch (1968).

Heritability estimates of quality traits within the ranges of this study would be of little value to the producer. No one trait or set of traits was consistently correlated with a beef quality trait. Busch (1968) calculated the heritability estimates of the carcass quality traits from steers used in this study and other steers from previous years within the same project. The following table illustrates the range of heritability estimates for the carcass quality traits. An estimate of 0.00 for shear tenderness was of particular interest as shown.

Heritability Estimates for Carcass Quality Traits

Trait	Heritability estimate
Carcass grade	0.34
Marbling	0.31
Lean color	0.19
Lean firmness	0.29
Tenderness	0.00

The present beef quality grading system could be the best available, but it must be continually upgraded. The grading system did not function well in the relatively narrow limits under which it was tested here and was not able to differentiate very accurately the limited amount of variation in quality traits which this study encompassed. Schafer (1968) supported the grading service over a wider range of carcass quality and maturity groups, but the application of the present grading system to the ranges of this study are extremely important to the present beef industry. A large percentage of the present market steers is included within the ranges of this study, and the grading system should function within narrow ranges as well as over wider maturity and quality levels.

The real value difference in dollars between the carcasses of this study was in yield of boneless retail cuts and not quality grade levels. If the steers of this study were similar to those marketed by today's feeders, emphasis should be changed to other measures of quality or lower the relative economic value of beef quality.

This study illustrates a greater need for the discovery of highly correlated live and carcass traits with beef palatability measures as summarized in table 22. Single variables in this study had low simple correlation coefficients with quality traits and variables combined were unable to predict quality accurately or repeatedly. It should be pointed out that low repeatability between experiments in this study was indicative of even lower repeatability in the beef population, since the data used in experiments 2 and 3 were portions of the data used in experiment 1.

TABLE 22. SIMPLE CORRELATIONS OF PREDICTED TRAITS FROM THE FOUR DIFFERENT GROUPS OF CATTLE ANALYZED IN THIS STUDY

	Shear tenderness	Marbling score	Carcass cutability	Live market grade	Muscle fiber diameter	Taste panel tenderness	Taste panel flavor	Taste panel juiciness
				Carcass Quality Grade				
N = 246	-.08	0.90	0.01	0.17	-.06			
N = 578	-.20	0.84	0.25	0.38	--			
				Shear Tenderness				
N = 246		-.08	-.11	0.11	0.12			
N = 578		-.13	0.10	0.13	--			
N = 60		-.19	0.03	-.03	0.01	0.27	-.01	-.04
N = 52		0.09	-.14	-.06	0.11	0.34	0.17	0.18
				Marbling Score				
N = 246			-.07	0.19	0.00			
N = 578			0.04	0.21	--			
N = 60			-.13	-.02	0.14	-.26	-.23	-.16
N = 52			-.51	0.28	0.55	0.20	0.13	0.23
				Carcass Cutability				
N = 246				0.19	-.04			
N = 578				0.30	--			
N = 60				-.33	0.03	0.08	0.01	-.09
N = 52				-.26	-.40	-.41	-.08	-.46

TABLE 22 CONTINUED

	Shear tenderness	Marbling score	Carcass cutability	Live market grade	Muscle fiber diameter	Taste panel tenderness	Taste panel flavor	Taste panel juiciness
				Live Market Grade				
N = 246					-.04			
N = 578					--			
N = 60					-.22			
N = 52					0.06			
				Taste Panel Tenderness				
N = 60							0.81	0.79
N = 52							0.77	0.72
				Taste Panel Flavor				
N = 60								0.87
N = 52								0.72

SUMMARY

Data from 578 time-constant and 52 weight-constant steers were analyzed in this study. Time-constant steers were marketed when ranch groups reached an average weight of 1000 pounds and weight-constant steers were marketed when each animal reached one of four specific weights. All cattle were handled similarly at Brookings in a commercial type feedlot prior to being slaughtered at a plant in Huron. Data were collected at the slaughter plant and wholesale cuts or whole carcasses were returned to the South Dakota State University meats laboratory for further analysis. Prior to being slaughtered the animals were subjectively evaluated by members of the animal science staff for the estimates of live animal traits.

Simple correlation coefficients, means and standard deviations were obtained by a computer program. Multiple regression prediction equations were also obtained by a stepwise method. The rankings of variables in prediction equations were determined by the relative size of the reduction of sum of squares accounted for by a particular trait.

Data were not adjusted for any specific reason, but each trait was included as an X variable in multiple regression analysis whenever possible. Generally speaking, almost all multiple regression equations accounted for only a small portion of the total variation in a predicted beef quality trait when a part-whole relationship did not exist. More variation in carcass cutability, a quantity trait, was accounted for by the multiple regression stepwise method under all data conditions than was accounted for in the quality traits.

Live animal traits were poor predictors of beef quality. The ability to predict carcass cutability was higher than the ability to predict quality using live traits. Taste panel tenderness, flavor, and juiciness were not highly related to the live animal traits. Final market grade did not highly reflect the carcass quality grade as a predictor of beef palatability.

Fiber diameter, muscle fiber length, and muscle fiber waviness were analyzed on three experiments but were found to be poor predictors of carcass quality. Chemical traits; percent moisture, percent fat, and percent protein of the Longissimus dorsi muscle; were not good indicators of beef palatability.

Prediction of beef palatability from live animal and carcass traits was the main purpose of this study. Many of the traits were used in the study because they are presently part of beef quality evaluation. Much of the variation in palatability or quality traits could not be related to any trait or group of traits.

The U.S.D.A. grade division between low choice and high good within live and carcass beef is associated with a significant reduction in price per hundred in the present marketing system. The present grading system did not account for a large portion of the variation in beef quality within the choice to good range of this study. Since a considerable number of steers are marketed within the age, weight, and quality limits of this study, the beef industry should consider reevaluation of the grading system and/or pricing structure of live and carcass beef.

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APPENDIX

TABLE 1. SIMPLE CORRELATION COEFFICIENTS FOR THE ENTIRE SAMPLE (N = 578)

Trait no.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	-.41	0.14	0.28	-.47	-.47	0.21	0.14	0.26	0.28	0.11	-.27	0.18	-.25	0.20	0.06	-.13	0.18	0.07	-.03	-.18	0.06	0.24	0.17
2		-.04	0.42	-.07	-.02	0.35	0.23	0.28	-.14	0.09	0.13	0.25	-.34	0.07	0.23	0.31	-.09	0.26	-.03	-.18	0.43	0.19	0.29
3			0.30	-.12	-.13	0.37	0.42	0.50	0.01	0.33	-.25	0.10	-.13	0.27	0.25	0.08	0.34	0.39	-.09	-.08	0.12	0.69	0.73
4				-.60	-.61	0.68	0.43	0.61	0.22	0.19	-.18	0.58	-.60	0.22	0.40	0.14	0.20	0.38	0.02	-.50	0.61	0.51	0.46
5					0.92	-.34	-.25	-.29	-.22	-.08	0.02	-.64	0.62	0.04	-.31	-.08	-.18	-.19	-.09	0.51	-.45	-.09	-.11
6						-.36	-.24	-.34	-.26	-.04	0.03	-.70	0.65	0.14	-.35	-.06	-.17	-.18	-.13	0.59	-.49	-.06	0.08
7							0.51	0.62	0.03	0.27	-.14	0.45	-.42	0.30	0.39	0.27	0.24	0.48	0.02	-.41	0.41	0.47	0.45
8								0.42	-.12	0.86	-.05	0.27	-.33	0.25	0.37	0.50	0.46	0.96	-.16	0.04	0.10	0.35	0.35
9									0.13	0.21	-.32	0.30	-.42	0.38	0.37	0.08	0.21	0.38	-.06	-.36	0.39	0.59	0.61
10										-.13	-.22	0.10	-.12	0.00	-.02	-.19	-.05	-.20	0.06	-.21	0.24	0.09	0.06
11											-.01	0.04	-.01	0.26	0.14	0.40	0.39	0.84	-.19	0.30	-.13	0.26	0.23
12												0.06	0.11	-.23	0.01	0.16	-.07	-.02	0.06	0.07	-.05	-.35	-.33
13													-.44	-.41	0.39	0.14	0.14	0.25	0.11	-.59	0.52	0.00	0.06
14														-.08	-.38	-.24	-.16	-.29	-.05	0.49	-.52	-.07	-.17
15															0.05	0.01	0.21	0.24	-.12	0.14	-.03	0.45	0.39
16																0.22	0.16	0.36	0.02	-.36	0.33	0.20	0.25
17																	0.16	0.52	-.14	0.03	0.02	0.04	0.08
18																		0.39	-.09	0.09	-.01	0.17	0.15
19																			-.16	0.07	0.06	0.32	0.32
20																				-.17	0.44	-.07	-.07
21																					-.55	-.10	-.16
22																						0.21	0.27
23																							0.95

1. Initial age
2. Days on feed
3. Rate of gain
4. Dressing percent
5. Final conformation
6. Final condition
7. Carcass conformation
8. Carcass grade
9. Live market grade
10. Tenderness
11. Marbling score
12. Live percent cutability
13. Carcass cutability
14. Loin eye area
15. Fat thickness
16. Carcass maturity
17. Lean firmness
18. Lean color
19. Carcass quality grade
20. Percent moisture
21. Percent fat
22. Percent protein
23. Chilled carcass weight
24. Live weight

r >.08; significance at P<.05 (d.f. = 577).
r >.11; significance at P<.01 (d.f. = 577).

TABLE 2. SIMPLE CORRELATION COEFFICIENTS FOR THE ENTIRE SAMPLE (N = 246)

Trait no.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	-.62	0.16	-.21	-.31	-.39	0.01	0.13	0.16	0.07	0.10	-.26	-.22	0.08	0.12	0.08	-.07	-.02	0.14	0.24	0.26	-.14	-.33	0.00	-.24	-.02	0.18	0.11
2		-.37	0.30	0.34	0.54	-.16	-.35	-.10	-.01	-.23	0.17	-.10	-.15	0.00	-.47	0.05	-.18	-.36	-.06	-.27	0.17	0.47	0.20	0.14	-.12	-.02	0.08
3			-.07	0.13	0.12	0.18	0.44	0.42	0.02	0.38	-.43	-.22	0.32	0.25	0.35	0.01	0.32	0.43	0.28	-.10	0.21	-.26	-.14	0.14	0.10	0.63	0.65
4				0.20	0.37	0.26	0.04	0.04	0.17	0.08	-.09	-.11	0.32	0.24	-.15	-.06	-.03	0.04	0.09	-.17	0.14	0.13	0.00	0.13	0.10	0.40	0.22
5					0.79	0.19	0.00	0.30	-.09	0.02	-.20	-.13	0.02	0.18	0.03	0.01	0.06	-.01	-.45	-.26	0.17	0.14	0.00	0.17	-.02	0.19	0.25
6						0.16	-.04	0.32	0.05	-.04	-.43	-.30	0.07	0.35	-.15	-.02	-.02	-.09	-.30	-.29	0.21	0.23	0.04	0.18	-.06	0.37	0.42
7							0.28	0.35	0.28	0.35	0.12	0.21	-.24	-.04	0.18	0.09	0.16	0.27	-.10	0.12	-.06	-.12	-.08	-.02	0.09	0.26	0.14
8								0.18	-.09	0.88	-.09	0.89	-.22	0.01	0.52	0.36	0.52	0.99	0.09	-.26	0.47	-.41	-.06	0.06	-.03	0.26	0.18
9									0.11	0.19	-.57	-.41	0.27	0.48	-.05	-.11	0.13	0.17	0.00	-.02	0.06	-.08	-.04	0.07	0.06	0.50	0.47
10										-.08	-.18	-.11	-.17	-.13	-.20	-.02	-.18	-.08	0.09	0.15	-.20	0.17	0.12	-.01	0.11	0.18	0.15
11											-.23	-.07	0.21	0.14	0.32	0.35	0.43	0.90	0.09	-.28	0.49	-.38	0.00	0.02	-.04	0.26	0.20
12												0.52	-.19	-.58	0.03	0.02	-.09	-.22	0.04	0.04	-.13	0.15	0.00	-.01	0.04	-.60	-.54
13													0.27	-.77	0.23	-.12	0.08	0.01	-.11	0.02	-.14	-.01	-.04	0.08	0.22	-.44	-.44
14														0.11	0.10	-.22	0.16	0.26	0.19	-.05	0.06	-.10	-.02	0.16	0.28	0.45	0.34
15															-.08	-.07	0.02	0.09	-.01	-.05	0.14	-.06	-.02	0.07	-.05	0.46	0.38
16																0.18	0.51	0.52	-.04	-.04	0.13	-.35	-.23	0.04	0.10	0.02	0.00
17																	0.10	0.36	-.02	-.21	0.33	-.11	-.02	-.09	-.25	-.03	0.00
18																		0.52	0.05	-.15	0.25	-.29	-.06	0.07	0.08	0.12	0.11
19																			0.09	-.26	0.47	-.41	-.06	0.06	-.03	0.25	0.18
20																				0.09	0.03	-.04	-.02	0.01	0.02	0.50	0.50
21																					-.64	-.13	-.04	-.12	-.03	-.07	-.09
22																						-.23	0.04	0.02	-.02	0.19	0.19
23																							0.01	0.27	-.10	-.09	-.02
24																								-.21	-.05	-.04	-.04
25																									0.17	0.12	0.11
26																										0.07	0.01
27																											0.95

1. Initial age
2. Days on feed
3. Rate of gain
4. Dressing percent
5. Final conformation
6. Final condition
7. Carcass conformation
8. Carcass grade
9. Live market grade
10. Tenderness
11. Marbling score
12. Live percent cutability
13. Carcass cutability
14. Loin eye area
15. Fat thickness
16. Carcass maturity
17. Lean firmness
18. Lean color
19. Carcass quality grade
20. Estimated live maturity
21. Percent moisture
22. Percent fat
23. Percent protein
24. Muscle fiber diameter
25. Muscle waviness
26. Muscle fiber length
27. Chilled carcass weight
28. Live weight

r >.13; significance at P <.05 (d.f. = 245).
r >.17; significance at P <.01 (d.f. = 245).

TABLE 3. SIMPLE CORRELATION COEFFICIENTS FOR THE ENTIRE SAMPLE (N = 60)

Trait No.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1	0.00	0.00	0.26	-.08	0.15	0.08	0.00	0.06	0.10	0.05	-.11	0.23	0.20	-.20	-.12	-.17	0.31	-.02	-.09	0.01	0.03	-.03	0.02	0.04	0.01	-.03	0.40	0.36
2		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3			0.06	0.30	0.39	-.06	0.23	0.45	0.19	0.14	-.20	0.19	0.11	0.20	0.01	0.05	0.31	-.06	-.20	-.18	-.47	0.42	0.43	-.03	0.32	0.17	0.57	0.69
4				0.07	0.20	0.12	0.09	0.09	0.13	0.17	-.10	0.34	0.10	-.26	-.06	-.16	0.26	-.01	-.03	-.13	-.23	0.12	0.26	-.13	0.11	0.24	0.55	0.34
5					0.77	0.32	0.09	0.56	-.06	0.20	-.28	0.13	0.37	-.12	0.10	0.16	-.44	-.26	-.23	-.23	-.14	0.14	-.04	0.14	0.15	0.14	0.26	0.27
6						0.34	0.18	0.64	0.09	0.20	-.45	0.18	0.50	-.13	0.10	0.04	-.19	-.22	-.31	-.25	-.20	0.18	-.02	0.02	0.22	0.12	0.53	0.50
7							0.01	0.41	-.08	0.04	-.10	0.15	0.20	0.01	0.01	0.18	-.26	0.09	0.13	0.20	0.19	-.20	0.07	0.04	-.05	-.01	0.08	-.01
8								0.02	-.10	0.84	-.10	0.29	0.13	0.43	0.52	0.32	0.00	-.29	-.25	-.22	-.59	0.61	-.08	0.06	0.19	-.20	0.23	0.15
9									-.03	-.02	-.34	0.19	0.48	0.15	-.16	0.13	-.09	-.01	0.01	0.08	-.16	0.12	0.04	-.22	0.29	0.24	0.46	0.46
10										-.19	0.03	0.05	-.12	-.32	-.09	-.29	0.32	0.27	-.01	-.04	0.27	-.31	0.18	0.01	-.07	0.07	0.13	0.20
11											-.13	0.22	0.12	0.29	0.43	0.25	-.05	-.26	-.23	-.16	-.47	0.51	-.09	0.14	0.09	-.16	0.23	0.13
12												[illegible]	[illegible]	0.00	-.23	0.11	-.03	0.09	0.01	-.09	0.13	-.02	-.07	0.03	-.09	0.31	-.45	-.41
13													[illegible]	0.06	0.00	0.19	0.09	0.04	-.06	-.11	-.29	0.33	-.16	0.08	-.09	0.18	0.31	0.22
14														0.11	0.12	0.10	-.10	-.04	-.01	0.12	-.06	0.04	-.07	0.00	0.14	-.19	0.38	0.30
15															0.16	0.53	0.12	-.04	0.04	0.12	-.35	0.35	-.09	-.16	0.29	0.03	0.02	-.01
16																-.01	-.14	-.31	-.15	-.14	-.34	0.37	-.11	0.02	-.18	-.26	0.03	-.02
17																	-.09	-.02	0.00	0.03	-.25	0.26	0.01	0.11	0.12	0.11	-.04	-.05
18																		0.22	0.05	0.08	-.23	0.15	0.09	-.04	0.12	0.10	0.55	0.59
19																			0.91	0.79	0.24	-.19	-.14	-.08	-.22	0.12	0.01	0.07
20																				0.97	0.19	-.13	-.11	-.04	-.28	0.00	-.11	-.10
21																					0.19	-.12	-.11	-.02	-.21	-.05	-.07	-.06
22																						-.93	0.10	0.08	-.21	-.04	-.43	-.38
23																							-.38	-.03	0.07	0.05	0.35	0.31
24																								-.07	0.29	-.08	0.12	0.11
25																									[illegible]	-.15	-.05	[illegible]
26																										0.37	0.12	[illegible]
27																											0.10	0.06
28																												0.94

1. Initial age
2. Days on feed
3. Rate of gain
4. Dressing percent
5. Final conformation
6. Final condition
7. Carcass conformation
8. Carcass grade
9. Live market grade
10. Tenderness
11. Marbling score
12. Carcass cutability
13. Loin eye area
14. Fat thickness
15. Carcass maturity
16. Lean firmness
17. Lean color
18. Estimated live maturity
19. Taste panel tenderness
20. Taste panel flavor
21. Taste panel juiciness
22. Percent moisture
23. Percent fat
24. Percent protein
25. Muscle fiber diameter
26. Muscle waviness
27. Muscle fiber length
28. Chilled carcass weight
29. Final weight

$r > .25$; significance at $P < .05$ (d.f. = 59).
$r > .33$; significance at $P < .01$ (d.f. = 59).

TABLE 4. SIMPLE CORRELATION COEFFICIENTS FOR THE ENTIRE SAMPLE (N = 52)

Trait no.	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	-.20	0.08	-.12	-.10	-.01	-.17	-.16	-.41	0.06	-.13	-.37	-.35	0.09	-.02
2		-.39	0.69	0.54	0.81	0.58	0.74	0.47	-.03	0.76	-.51	0.53	0.55	-.08
3			-.26	-.03	-.15	-.08	-.19	-.20	-.02	-.24	0.18	-.08	-.23	0.13
4				0.44	0.61	0.62	0.56	0.32	-.26	0.50	-.37	0.57	0.48	-.29
5					0.83	0.55	0.49	0.52	-.04	0.44	-.40	0.25	0.39	-.16
6						0.58	0.61	0.49	-.03	0.61	-.58	0.33	0.60	-.20
7							0.59	0.32	-.17	0.55	-.31	0.47	0.31	-.17
8								0.24	0.01	0.87	-.46	0.51	0.46	0.09
9									-.06	0.28	-.26	0.27	0.42	-.17
10										0.09	-.14	-.11	0.18	-.11
11											-.51	0.46	0.42	-.03
12												0.13	-.72	0.05
13													0.00	-.10
14														-.12

Trait no.	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1	-.15	-.18	0.08	0.13	0.10	0.18	-.05	0.09	-.20	0.18	0.17	-.12	0.01	0.04
2	0.32	-.13	0.07	0.16	-.06	0.14	-.55	0.54	-.18	0.63	-.29	0.04	0.84	0.79
3	-.15	0.08	0.11	0.07	0.06	-.05	0.28	-.19	-.04	-.31	0.04	-.14	-.09	-.02
4	0.06	-.18	0.10	0.08	0.08	0.17	-.40	0.43	-.20	0.52	-.27	-.09	0.75	0.60
5	0.24	-.12	0.20	0.23	0.02	0.07	-.38	0.41	-.08	0.26	-.20	0.00	0.53	0.49
6	0.23	-.19	-.08	0.32	0.10	0.12	-.49	0.52	-.18	0.47	-.28	0.03	0.79	0.76
7	0.29	-.02	-.22	0.16	0.08	0.22	-.33	0.29	-.06	0.42	-.24	-.19	0.55	0.45
8	0.48	0.12	-.01	0.23	0.11	0.25	-.69	0.69	-.22	0.50	-.33	-.02	0.64	0.60
9	0.31	-.06	-.26	0.21	0.05	0.06	-.16	0.10	0.11	0.06	-.08	0.13	0.36	0.33
10	0.10	-.30	0.09	0.34	0.17	0.18	0.04	-.05	0.09	0.11	0.24	0.47	-.11	-.06
11	0.51	-.02	0.04	0.20	0.13	0.23	-.68	0.65	-.19	0.55	-.26	-.05	0.67	0.64
12	-.32	0.06	-.06	-.41	-.08	-.46	0.45	-.41	0.18	-.40	-.09	-.15	-.60	-.60
13	-.03	-.10	0.02	-.12	-.10	-.12	-.26	0.27	-.07	0.25	-.38	-.17	0.56	0.51
14	0.30	-.14	0.08	0.40	0.15	0.27	-.36	0.39	-.13	0.34	0.03	0.20	0.56	0.54
15	0.26	0.70	-.07	0.02	0.07	-.06	-.09	0.04	0.20	-.14	-.04	0.23	-.15	-.08
16		0.32	-.09	0.38	0.28	0.28	-.51	0.33	0.21	0.12	0.08	0.19	0.15	0.13
17			-.18	-.01	0.02	0.02	-.14	0.04	0.27	-.25	-.14	0.22	-.21	-.20
18				0.01	-.01	0.01	-.02	0.07	-.21	0.16	0.06	-.08	0.18	0.19
19					0.77	0.72	-.11	0.02	0.14	0.11	-.02	0.31	0.42	0.15
20						0.72	-.06	-.03	0.13	0.10	-.12	0.26	0.03	0.00
21							-.18	0.07	0.10	0.15	-.01	0.14	0.16	0.10
22								-.91	0.15	-.46	0.27	0.06	-.49	0.47
23									-.44	0.46	-.25	-.11	0.54	0.51
24										-.24	0.13	0.31	-.30	-.30
25											-.23	-.04	0.50	0.44
26												0.31	-.23	-.21
27													-.10	-.10
28														0.98

1. Initial age
2. Days on feed
3. Rate of gain
4. Dressing percent
5. Final conformation
6. Final condition
7. Carcass conformation
8. Carcass grade
9. Live market grade
10. Tenderness
11. Marbling score
12. Carcass cutability
13. Loin eye area
14. Fat thickness
15. Carcass maturity
16. Lean firmness
17. Lean color
18. Estimated live maturity
19. Taste panel tenderness
20. Taste panel flavor
21. Taste panel juiciness
22. Percent moisture
23. Percent fat
24. Percent protein
25. Muscle fiber diameter
26. Muscle waviness
27. Muscle fiber length
28. Chilled carcass weight
29. Final weight

r >.27; significance at P <.05 (d.f. = 51).
r >.35; significance at P <.01 (d.f. = 51).