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The Effects of Sex and Hormonal Implant on Carcass Characteristics and Palatability

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THE EFFECTS OF SEX AND HORMONAL IMPLANT ON CARCASS CHARACTERISTICS AND PALATABILITY

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for 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.

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INTRODUCTION

Consumer demand for beef has undergone a number of dramatic changes during recent years. Consumers are expressing a preference for reasonably priced beef cuts with a high proportion of lean in relation to fat. Increasing demand for ground beef and steaks has prompted the meat industry to look at the use of a variety of production methods. The hotel, retail and industrial trades utilize large amounts of ground beef and restructured steaks. Future production may be geared toward making ground beef from chuck, foreshank, brisket, short plate, flank and round, with the desire to sell the rib and short loin as steaks in order to lower the break-even price of the ground beef.

Consumers will ultimately determine the type of beef produced in the future. Increasing interest in uncastrated males is related to the declining demand for animal fat, the increased emphasis on more efficient red meat production and the needs of a changing world population. Although beef from bullocks is not being marketed on a large scale in the United States today, present trends indicate that "choice" bullock beef may be economically feasible in the future. Carcasses and wholesale cuts which meet the quality standards desired are of greatest value.

The value of wholesale cuts (e.g., ribs) as predictors of total beef carcass merit is essential in developing a more desirable consumer product. Comparative relationships between wholesale cuts and total beef carcass composition provide a means of examining different management practices. Research workers have long been interested in percentages of fat, lean, bone and an accurate method of determining these factors. Many workers (Bailey et al., 1966; Brannang, 1969; Champagne et al., 1969; Klosterman et al., 1954; Robertson et al., 1967, 1970; Wickens and Ball, 1967) have compared the development of entire males with castrates and have shown that young bulls have faster growth rates, superior efficiency of food utilization and a greater yield of lean with a higher proportion of salable meat.

Castration and hormonal injections are some of the management practices available to increase beef production. Hormones are well known among biochemists, physiologists and nutritionists, playing a major role in both rate of growth and efficiency of feed utilization. Along with the management practice of castrating meat-producing animals, hormones may also play a part in the quality of meat produced by an animal. The relationship of castration and hormonal injections to the efficiency of meat production and the quality of meat produced have not been critically investigated.

This study was undertaken to provide evidence on the comparative carcass characteristics of animals from similar genetic and production environments by the use of rib sections obtained from the carcasses. Some effects of castration and hormonal injections on the quality and palatability of rib steaks were observed.

REVIEW OF LITERATURE

Effects of Sex on Carcass Characteristics and Palatability

Several reports have shown that young bullocks are leaner than steers (Field et al., 1964; Hedrick, 1968, 1972).

Palatability studies involving beef from bull and steer carcasses have produced conflicting results. Adams and Arthaud (1963) and Aitken et al. (1963) reported that steaks from steer carcasses were significantly (P<.01) more tender than those from bull carcasses. Field et al. (1966) reported no significant difference in tenderness of beef produced by bulls and steers that were 300 to 399 days of age. Koger et al. (1960), Hedrick et al. (1969) and Champagne et al. (1969) observed no significant difference in tenderness, juiciness or flavor ratings between steaks from bull and steer carcasses.

Reagan et al. (1971) in a comparison between two sources of steers and bulls found differences in palatability traits between groups. Steaks from steer carcasses possessed significantly (P<.01) higher flavor and overall satisfaction scores in both groups and higher (P<.05) tenderness scores than those from bull carcasses in one group. However, bull carcasses from the second group were older. Shear force values were significantly (P<.05) higher for steaks from bulls from group one but did not differ in group two. Bulls produced steaks which had lower (P<.05) percentages of cooking loss than those from steers. However, differences were not significant in group two. No significant differences in juiciness were observed in either group.

In an article by Field et al. (1966) comparing the effects of sex on palatability, no significant differences were found between bulls or steers and heifers 300 to 399 days old. In Field's article, steers and heifers 400 to 499 days old had slightly higher palatability ratings than bulls which were similar with respect to age and marbling. Sensory tenderness and shear scores indicated that bulls 500 to 599 and 600 to 699 days old were tougher ($P<.01$) than steers and heifers of comparable ages. Sensory flavor and juiciness scores for roasts from steers and heifers were also more ($P<.01$) desirable than from bulls 600 to 699 days of age. Simple correlation coefficients indicated that sensory quality factors in all roasts were closely interrelated. Correlations between shear and sensory tenderness were -.65 and -.77 for bulls and for steers and heifers, respectively. Least squares estimates on the influence of age and marbling on shear and sensory tenderness showed that bulls under 400 days old were more ($P<.01$) tender than older bulls when marbling was held constant. Age of steers and heifers did not affect any palatability characteristics when marbling was held constant. When age was held constant, higher marbling scores in bulls were more directly related to higher sensory ratings than were higher marbling scores in steers and heifers.

In studies of beef quality, Jones et al. (1964) determined that steer meat was more tender and that it also had slightly higher scores in juiciness and flavor when comparisons were made with 10 pairs of bull and steer twins. Significant differences in tenderness were found in the longissimus, biceps femoris and semi-tendinosus muscles. The differences in quality were most marked in the region of the 7th-8th rib. Shear values directly supported all taste panel assessments of tenderness. The bull meat also contained less fat than the steer meat as measured by ether extract determination.

Cahill (1964) and King et al. (1965) reported bull carcasses yield the greatest area of longissimus muscle per unit of weight. The yield of trimmed boneless cuts indicated that bulls have approximately 6% more meat than steers and 10% more meat than heifer carcasses. The yield was influenced by the degree of finish. The trimmed boneless beef-to-bone ratio was greatest in bulls and usually was intermediate in heifers and lowest in steers. Percent total fat trim was significantly associated with cutability (-.85). Cahill (1964) indicated that the edible portion was higher for steers (69.0%) than heifers (67.7%) when compared on a muscle-fat ratio. Steers yielded 54.8% and heifers yielded 51.0% lean in the carcass, although heifers had proportionately heavier hindquarters than steers. Most of these results were nonsignificant when fat was held constant.

In a study by Albaugh et al. (1976) using the longissimus muscle, there were no differences in total cooking losses attributed among steers, intact bulls and short scrotum bulls.

Robertson and Lowman (1978) of Edinburgh with a consumer acceptance trial showed that, in relation to steaks normally purchased, 61.0% of local customers judged bull steaks as average or above in eating quality compared with a similar 91% rating for steer steaks. In a similar study at Virginia Polytechnic Institute, Lamm and Kelly

(1979) with 36 bulls and 39 heifers showed overall acceptability of roasts was very high for all groups of cattle, but there was a trend for a slight preference for meat from heifers over bulls.

A stratified random sample representing all socioeconomic classes in the Boise metropolitan area was selected by Araji et al. (1977) to evaluate steaks from bulls vs steers with respect to such beef quality characteristics as tenderness, flavor, leanness, juiciness and color. The results indicated that consumer evaluations of steaks from bulls and steers showed that tenderness was the principal beef quality characteristic controlling consumer preferences for beef. Jacobs et al. (1977) compared consumer responses from a retail survey involving three retail outlets. The responses indicated that consumers preferred the tenderness of steer cuts as compared to bull cuts. However, over 85% of the consumers indicated that retail cuts from bulls were "as good as" or "better than" beef they normally purchased. Retail cuts from bull rounds received the lowest ratings from consumers for tenderness. In-store questionnaires revealed that over 65% of the consumers interviewed were able to detect differences in tenderness. Over 44% of these consumers felt that "leanness" was most important in visual selection of retail beef (when color, leanness and marbling were considered) and over 47% felt that marbling was the least important factor.

Shear scores and taste panel scores reported by Brown et al. (1962) and Wipf et al. (1964) on bulls and steers of similar age support the conclusion that there was a tendency for the bull meat to exhibit higher shear forces and lower sensory scores in the groups 400 to 499 days of age.

Mechanical objective measurement and specialized taste panel evaluations conducted by Klosterman et al. (1954), Wierbicki et al. (1955), Adams and Arthaud (1963), Aitken et al. (1963) and Bailey et al. (1964) on cattle estimated to be 400 to 499 days of age showed scores for bull meat ranged from slightly tougher to significantly tougher than scores for meat from steers. Field et al. (1964) compared consumer acceptance of retail cuts from steers and bulls averaging 480 days of age. Consumers gave bull rib steaks significantly lower taste and tenderness ratings but rated chuck roasts from bulls more desirable because of less intermuscular fat. Sumwalt et al. (1964) also found consumer acceptance of loin steaks from steers superior to loin steaks from bulls.

Steers had higher marbling scores than bulls in all previously mentioned studies where carcasses from animals approximately 400 to 499 days of age were used. In the study by Field et al. (1966) when roasts from steers and heifers with marbling scores similar to roasts from bulls were chosen, the differences were not significant. Nevertheless, differences in palatability ratings for this age group are similar to those reported by other workers who have shown cuts from bull carcasses to be slightly less palatable than those from steers at 400 to 499 days of age.

Bulls 500 to 599 and 600 to 699 days old were significantly tougher than steers and heifers of comparable age. Flavor and juiciness ratings for steer and heifer roasts were significantly ($P<.01$) higher than for bulls in the older age group. Marbling scores for both these groups were significantly higher in steers and heifers than in bulls.

Significantly ($P<.01$) higher palatability ratings favoring the steers and heifers were obtained when all steer and heifer carcasses were compared with the bull carcasses (Field et al., 1966). Age of steers and heifers was positively correlated with tenderness, flavor and juiciness and negatively correlated with Warner-Bratzler shear values, indicating that older steers and heifers were more palatable than younger steers and heifers. Bulls were less tender as age increased.

Adams et al. (1977) showed correlations between USDA quality grades and taste panel ratings for tenderness, flavor and juiciness to be low or not significant in both overall and pooled analyses. When a group of cattle was fed to the US Choice grade end point and some carcasses fail to achieve the grade because of inadequate marbling, their meat was often very similar in palatability to that from carcasses that grade Choice. Carcasses from cattle produced under systems of controlled management and nutrition are normally variable in marbling, but the meat may be similar in palatability. Among cattle fed differently and produced under varying management systems, marbling may be a more reliable indicator of palatability. A part of the relationship of marbling score to palatability in the general population of cattle coming to market may be the extent to which marbling is a reflection of previous management and feeding. Warner-Bratzler shear force was favorably associated by Adams et al. (1977) with USDA quality grade.

Rhodes (1969) has demonstrated that meat from young bulls when compared with meat from conventionally reared steers can be considerably paler. Darkness in bull meat has also been attributed to difficulties in animal handling during transport and slaughter, resulting in dark cutting carcasses.

Effects of Breed of Dam on Carcass Characteristics and Palatability

Allen (1974) in his work at the US Meat Animal Research Center, Clay Center, Nebraska, compared 2,264 calves of various breed sires and found Charolais-, Simmental- and Limousin-sired steers had the best mean yield grade, greatest *longissimus* muscle areas and least external finish. Hereford, Angus and their reciprocal crosses had more external fat, poorer yield grades and smaller *longissimus* muscle areas. Limousin-sired steers yielded the most retail product and the least fat trim followed closely by Charolais- and Simmental-sired groups. Simmental-sired steers also yielded the greatest proportion of bone (13.3%).

Adams et al. (1977) found similar results in an experiment involving 78 steers produced by Hereford dams and sired by Hereford, Angus, Lincoln Red, Brown Swiss, Simmental, Limousin, Maine Anjou or Charolais bulls. Carcasses from steers sired by bulls of the British breeds (Hereford, Angus and Lincoln Red) were fatter (greater fat thickness; higher fat trim; higher marbling score; more chemical fat in the rib section; lower yield of boneless chuck, rib, loin and round) than carcasses from steers sired by the French breeds (Limousin, Maine Anjou and Charolais). Carcasses from crossbred steers sired by bulls of the French breeds had higher bone trim percentages, more protein in the rib section, lower fat thickness measurements, less chemical and trimmable fat, higher yields of trimmed boneless cuts and lower quality grades than carcasses from steers sired by bulls of the British breeds. Simmental-sired steers tended to be similar to those sired by bulls of the French breeds. Taste panel members rated the cooked steaks from all breed groups in the acceptable range for palatability and found no significant differences in tenderness or flavor among breed groups. Differences were observed among breed groups in juiciness and overall satisfaction ratings.

Koch et al. (1976) reported that Charolais, Simmental, Limousin, Maine Anjou and Brown Swiss crossbreds had less fat thickness than Angus x Hereford or straightbred Herefords. Brown Swiss crossbreds, although not significantly different from Angus or Charolais crossbreds, exhibited the highest percentage of kidney, pelvic and heart fat. Simmental and Limousin crossbreds had larger ($P<.05$) longissimus muscle areas than Angus crossbreds or straightbred Herefords.

Daily gains and quantitative and qualitative carcass characteristics of 18 Hereford bullocks and steers and 27 Charolais x Hereford reciprocal crossbred bullocks and steers were evaluated by Landon et al. (1978). In this experiment, bullocks quality graded lower than steers because of less marbling. Percentages of total retail cuts were greater for bullocks than for steers. No differences in tenderness, as measured by the Warner-Bratzler shear, were noted among the sex groups.

Judge et al. (1965) compared five breed groups, including beef type, dairy type and dual-purpose type cattle, slaughtered at the same live weight and reported that few pronounced differences in palatability were present among the five breed groups. Crockett et al. (1959) compared beef from steers of Angus, Brahman-Hereford, Charolais-Brahman and Santa Gertrudis and found no differences among breed groups in tenderness. Powell et al. (1961) compared beef from Hereford and Angus steers and observed no differences in tenderness as measured by the Warner-Bratzler shear. Butler et al. (1962) compared beef from Hereford and Angus steers and found no significant differences in tenderness when measured by the Warner-Bratzler shear. Damon et al. (1960) reported no differences in tenderness between beef from Hereford, Angus and Charolais cattle, but steaks from Brahman crosses were less tender. DeRouen et al. (1961) reported that, among Angus, Brahman-Angus, Africander-Angus and Sindhi cross cattle, beef from Brahmans was least tender. Huffman et al. (1962) compared beef from Angus, Hereford, Brahman, Angus x Hereford x Brahman and Angus x Brahman and found that beef from Angus cattle was most tender and that from Brahman cattle was least tender. Kellaway (1973) compared beef from Holstein and Brahman-Holstein cattle and reported that Brahman-Holstein beef was inferior in tenderness.

Important, significant (P<.01) heterotic effects were found by Gregory et al. (1966) for carcass weight, longissimus muscle area, dressing percentage and actual cutability when both crossbred and purebred steers were slaughtered at the same age. However, the lack of hybrid vigor on traits associated with carcass composition after the data were adjusted for weight indicated that heterosis effects on carcass composition were a result of their growth rate. Heterosis increased slaughter weight of the crossbreds at the same slaughter age. Thus, on a weight constant basis, there is little heterosis effect on carcass traits.

Gaines et al. (1967) also studied Hereford, Angus and Shorthorn cattle and observed a heterosis effect in carcass weight of 3.1% in steers and 4.3% in heifers and a significant ($P<.05$) longissimus muscle area advantage for the crossbred over the straightbred when the data were adjusted to a constant age. No significant differences were found in fat thickness, marbling score, conformation score or carcass quality grade.

Carroll and Rollins (1965) found no significant differences for the previously mentioned carcass traits between purebreds and crossbreds, although the trend of the carcass measurements indicated that the purebreds were higher in carcass quality grade and had greater fat thickness. Lasley et al. (1971) found heterotic effects were negligible for carcass quality as determined by carcass conformation, marbling score, Warner-Bratzler shear value and carcass quality grade.

Results from LeVan et al. (1979) suggest that neither breed nor slaughter weight have marked effects on relative distribution of retail lean, fat or bone throughout the animal's body. Berg and Butterfield

(1976) noted no major differences in lean distribution among breed types using the "standard muscle groups" classification. They also indicated that neither slaughter weight nor breed affect the percentage distribution of most of the individual retail cuts. This research not only supported previous conclusions (Berg and Mukhoty, 1970; Truscott et al., 1976; Koch and Dikeman, 1977) with regard to the absence of breed effects on retail lean distribution but also established that increases within breed in slaughter weight do not alter retail lean distribution.

Olson et al. (1978) in their work with 497 crossbred steers and 35 crossbred heifers found maternal heterosis effects on carcass traits of steers and heifers at either a constant age or constant weight end point were generally nonsignificant.

LeVan et al. (1979), Judge et al. (1965), Price and Berg (1975) and Truscott et al. (1975) have concluded that Friesian and dual-purpose breeds have a higher bone percentage than English breeds. LeVan et al. (1979), Truscott et al. (1976) and Koch and Dikeman (1977) stated that British breeds had higher fat trim percentages than Continental breeds.

Cartwright et al. (1958) reported data from 18 Hereford and 20 Brahman x Hereford steers fed for 140 days. Measurements of separable lean from the 9-10-11 rib and estimated lean in the carcass were closely parallel.

Effect of Hormonal Implant on Carcass Characteristics and Palatability

In a study by Forrest (1975), a total of 72 Holstein-Friesian males from 11 sire groups were reared from birth on a concentrate ration. At 136 kg, one-half of the calves were castrated (Burdizzo) and, at 340 kg, one-half of the bulls and steers were implanted with hormones (200 mg progesterone plus 20 mg estradiol-17-β-benzoate). Following slaughter at 475 kg, the 9th to 11th rib section was removed from the left side of the carcasses and frozen. Later, the four treatment and 11 sire groups were compared by taste panel evaluation of these rib roasts. No significant differences in quality factors (tenderness, juiciness and flavor) due to preslaughter hormone treatment were evident in rib roasts from either bulls or steers. Hormone treatment significantly decreased (P<.05) fat deposition in steers and tended to increase fat levels in bulls. Rib roasts from bulls were significantly less desirable than roasts from steers in both treatment groups for all quality factors. However, significant sire effects for all taste panel evaluations were noted.

Numerous workers (Turton, 1962; Field et al., 1964; Nichols et al., 1964; Bailey et al., 1966) have reported that bulls exhibited significantly (P<.05) greater average daily gains and were signifcantly more efficient feed converters.

Cahill (1964), Warner et al. (1965), Hedrick et al. (1969) and Nygaard et al. (1971) have reported that bull carcasses yielded a significantly greater percentage of total retail cuts than steers. However, palatability studies involving carcasses from intact males and castrates have produced conflicting results. Glimp et al. (1971) reported that, although some differences were detected in tenderness between castrate and noncastrate groups, trained taste panelists were unable to detect significant sex treatment differences in flavor, juiciness or overall acceptability of cooked steaks. Warner et al. (1965) also reported that Warner-Bratzler shear values and sensory panel evaluation of loin steaks indicated no significant differences in tenderness of beef from bulls, steers and heifers. Other researchers (Adams and Arthaud, 1963; Field et al., 1964; King and Carpenter, 1966) have reported that meat from intact males ranged from slightly and nonsignificantly less tender to significantly less tender than comparable meat from steers.

The use of diethylstilbestrol on bulls improved the efficiency of meat production according to Wierbicki et al. (1955). According to their 3-year study, bull carcass quality grades and consumer quality of bull meat approached that for steers.

Diethylstilbestrol (DES) has been utilized orally and as an implant to promote growth. Increased daily gains of bulls associated with DES implants have been reported by Klosterman et al. (1955), Bailey et al. (1966), Hunsley et al. (1967) and Martin and Stob (1978). Garrigus et al. (1969) reported that DES implants improved daily gain of bulls during the first 84 days on feed but did not improve total performance over a 168-day feeding period.

In a study by Carroll et al. (1975), 32 steers implanted with 36 mg of DES were compared with 32 untreated bulls as to growth rate and carcass characteristics. Of these animals, 17 paternal half-sib bull-steer pairs were used to compare eating quality. Average age at slaughter was approximately 14 months. Bulls produced more carcass weight per day of age than steers. Bull carcasses had less fat content, less marbling, larger longissimus muscle areas, darker meat, higher conformation grades and lower quality grades. Raw muscle samples from steers had more bound moisture, while samples from bulls tended to have more free moisture. However, total moisture differences were nonsignificant. Total cooking losses were comparable in rib roasts from bulls and steers but higher in top round roasts from bulls. Cooked muscle samples from bulls and steers were comparable in shear value.

In an experiment by Martin et al. (1979), 153 head of Angus bulls were tested for the effects of DES at four protein supplementation levels. Feeding DES produced more rapid gains and more efficient dry matter conversion, especially during the first part of the feeding period.

Synovex-S, an ear implant formulation that contains 200 mg of progesterone and 20 mg of 17-β-estradiol benzoate per dose, is an approved hormonal growth promotant in feedlot steers (Rumsey and Beaudry, 1979). Growth responses with Synovex-S have been equal to or greater than those with diethylstilbestrol (Dinius et al., 1978; Rumsey, 1978; Kahl et al., 1978).

According to Thomas (1979), a 1969 summary of 18 college experiments showed that Synovex implants increased daily gains of cattle by 12 to 14% and improved feed efficiency by 8 to 10%. When using the two Synovex implants, Synovex-S and Synovex-H, similar results were obtained as with cattle implanted with DES. Synovex-S contains 200 mg progesterone and 20 mg estradiol benzoate. Synovex-H contains 200 mg testesterone propionate and 20 mg estradiol benzoate. Recent tests have shown that implanting Synovex twice during the fattening period gave a greater response than using Synovex in combination with any other hormonal implant.

Schake et al. (1979) using 16,240 crossbred steers found no significant difference between DES implants and those reimplanted with either DES or Synovex in regard to fee-d efficiency, daily feed consumed or final weight. However, no controls were used in this study and, therefore, gains over nonimplants could not be computed.

Harris et al. (1979) in a study using 96 Hereford steers noted no significant differences in carcass weight, dressing percentage or the remainder of the carcass traits except marbling score ($P<.01$) for steers treated with 20 mg estradiol benzoate and 200 mg progesterone. They did note Zeranol-implanted steers gained less during the first 87 days, yielded carcasses with less ($P<.10$) external fat, more ($P<.10$) kidney fat and higher ($P<.01$) marbling scores. Data from this study were across three dietary energy levels which Harris et al. (1979) noted as being nonsignificant to implant type.

Thomas (1979) reported that Ralgro (Zeranol) is a growth-promoting implant given FDA clearance in 1970. Twelve years elapsed between the time the product was discovered, thoroughly investigated and approved. This time lapse is typical of products approved for use today. In a 1970 summary, improvement in rate of gain by fattening steers and heifers was about 8%. For growing steers, the increase was about 15% for gain and for growing heifers was about 9%. Ralgro implants in suckling calves have resulted in 4 to 10% increases in both steers and heifers. This increase means a weaning weight gain of 7 to 10 kg or more.

Perry et al. (1970) in six experiments studying the effects of implantation of 36 mg resorcyclic acid lactone (RAL) noted increased daily gains of beef cattle under a variety of conditions of management.

Growing and fattening steers demonstrated significant (P<.01) gain responses to implanted RAL which were comparable to those obtained from implanted DES. However, the implantation of the two together was no more effective than either alone. Implanted RAL was effective in stimulating the rate of gain of both steers and heifers. Furthermore, its use stimulates rate of gain under both growing conditions (.50 kg per day) and fattening conditions (1.00 kg per day). The greatest response from RAL implants occurred in the early stages of the feedlot period, suggesting such implants may be depleted in from 84 to 112 days.

Sharp and Dyer (1970) reported that Zeranol increased percent body water and protein and decreased percent body fat after a time constant finishing period. However, Perry et al. (1970) observed no significant effects of Zeranol on carcass grades of steers. Wilson et al. (1972a,b) did not observe significant reductions in percent body water or protein or significant changes in carcass fat content. The former study also indicated that there was no significant interaction effects between Zeranol and sex type on growth rate or body composition.

Monensin (Rumensin) has been used primarily to increase feed efficiency and is the biologically active compound produced by Streptococcus cinnamonensis (Haney and Hoehn, 1967) that inhibits the growth of gram-positive organisms and alters the type of fatty acids produced. Various studies have shown that monensin improves feed efficiency (Boling et al., 1977; Mosely et al., 1977; Perry et al., 1976), decreases feed intake (Mies and Sherrod, 1977; Potter et al., 1976; Utley et al., 1976) and alters the molar percentages of ruminal VFA (Potter et al., 1974; Richardson et al., 1976; Beede and Farlin, 1977).

Utley et al. (1976) in a study conducted to compare the response of heifers fed or not fed monensin (Rumensin) when not implanted, implanted with Zeranol (Ralgro) or implanted with testosterone-estradiol (Synovex-H) determined that no synergistic effect (P>.05) between additive and implant compounds and no additive x implant interactions (P>.05) were detected during the feeding trials.

Pendlum et al. (1978) in a study using 96 Angus x Hereford steers found no significant differences in carcass weight, fat thickness, kidney fat, marbling, yield grade or quality grade when feeding monensin. However, they showed that longissimus muscle area was significantly (P<.05) smaller when feeding higher monensin levels. These values were not significant when adjusted to a 100-kg carcass weight.

9-10-11 Rib Component

In any large group of animals, an inexpensive experimental method which allows an opportunity to study carcass measurements would be desirable, especially one which would accurately estimate total carcass fat, lean and bone. A constant and accurate indicator of these factors would assist in the production of a more desirable economic product.

Hankins and Howe (1946) determined separable components (muscle, fat and bone) of the 9-10-11 rib sections were highly ($P<.001$) related to corresponding tissue components of the total carcass.

Kidwell et al. (1959) concluded that there appeared to be no relation between slaughter score (score assigned by certain live measures) and rate or economy of gain, but there was a fairly high relation between slaughter grade (assigned by USDA grader) and carcass score (similar to conformation score), dressing percent and percent bone, muscle and fat in the 9-10-11 rib. A low but significant relation existed between slaughter grade and percent of wholesale cuts.

Hopper (1964) reported phenotypic correlations calculated from data of 92 cattle. The wholesale rib, edible portion of the wholesale rib, the 9-10-11 rib and the edible portions of the 9-10-11 rib were studied as indicators of physical composition. The edible portions of the wholesale rib and the composition of the 9-10-11 rib were found to be highly correlated with physical composition of the carcass and edible portion of the carcass. The correlations between the composition of the 9-10-11 rib with percent fat and edible portion of the wholesale cuts were .85 and .97, respectively.

Cartwright et al. (1958) reported data from 18 Hereford and 20 Brahman x Hereford steers fed for 140 days. Measurements of separable lean from the 9-10-11 rib and estimated lean in the carcass were closely parallel. A positive correlation, accounting for 75% of the variation in slaughter score, was found between feeder score and slaughter grade. Slaughter grade was also correlated with separable fat in the 9-10-11 rib (.59) and fatness over the rib eye (.49) and negatively correlated with separable bone in the 9-10-11 rib (-.54). However, the correlation between separable lean in the carcass and slaughter grade was positive but very small.

Price and Berg (1976) used data collected over 11 years from single side, total anatomical dissection of 256 beef carcasses. They were from bulls, steers and heifers of a wide variety of breeding, maturity types and live weights. Initial results indicated that the relationship between predictor muscles and total side muscle was such that indicator muscles can be used to give a meaningful estimate of total side muscle in a wide range of carcass types.

Cole et al. (1959) conducted an experiment to study the relationship of rib eye size and separable lean of various beef cuts to total separable lean of the carcasses. The study involved 50 steers, 9 heifers and 9 cows of British, Brahman and large and small dairy breeding. Statistical analysis of the lean, fat and bone separation data from one side of each carcass resulted in a correlation coefficient of .45 between rib eye area and total separable carcass lean. Correlation coefficients of .96, .81, .85, .94, .82 and .76 were obtained between separable lean and the lean from the round, sirloin, short loin, rib, chuck and 9-10-11 rib cut, respectively. They concluded that separable lean from these cuts, especially round and rib, was a more accurate predictor of total carcass lean than rib eye area.

Cole et al. (1962) collected data from 132 straightbred and crossbred steers and undertook a study to determine the relationship of kilograms of separable lean in steer carcasses with carcass length, carcass weight, fat thickness and area of the longissimus muscle at the 5th rib, 12th rib and last lumbar vertebra. Predicted values obtained with the developed equations were comparable in accuracy to those obtained with the Hankins and Howe (1946) equations.

Trowbridge and Moulton reached the conclusion, as reported by Lush (1926), that the composition of the "wholesale rib cut rather adequately represented the carcass." This work by Trowbridge and Moulton involved fat as determined by chemical means. Lush also reported that the fat content of the entire live steer could be estimated from dressing percentage by the use of the following equation: percentage of fat in entire live animal = 1.782 x dressing percentage - 86.40. The coefficient of correlation was .84 ± .04. For estimating the fat content of the live animal from the percentage of caul fat, he offered the following equation: percentage of fat in entire live animal = 14.55 x percentage of caul fat based on live weight + 5.19. In this instance, the correlation coefficient was .89 ± .03. The most reliable indicator of fatness of the entire animal found by Lush was the percentage of fat in the edible portion of the wholesale rib cut. The estimating equation was as follows: percentage of fat in live animal = .603 x percentage of fat in the rib flesh + 3.92. The relationship was represented by the correlation coefficient of .987 ± .003.

Interest in bull feeding in recent years prompted Nelms et al. (1970) to develop equations for predicting retail cuts from bulls. Data gathered from 196 bull carcasses indicated that equations predicting weight of retail cuts had higher coefficients (of determination) than those predicting percent retail cuts. They concluded that the equations developed for steers and heifers predicted weight of retail cuts in bull carcasses almost as accurately as those for steers.

Workers in the Bureau of Animal Industry, United States Department of Agriculture (1935), found that the percentage of bone in the 9-10-11 rib cut provided a basis for estimating the bone content of the dressed beef carcass. The correlation coefficient was .83 ± .02, and the estimating equation was as follows: percentage of bone in dressed carcass = .612 x percentage of bone in 9-10-11 rib cut + 4.296.

Murphey et al. (1960) developed a regression equation from reviews of other work useful in estimating the yields of retail cuts from beef carcasses. Results were from several years of study on 450 beef carcasses and over 300 live cattle. The most useful and accurate prediction equation was percent of boneless, trimmed retail cuts from the round, loin, rib and chuck = 51.34 - 5.784 (fat thickness over the rib eye in inches) - .0093 (carcass weight, lb) - .462 (percent kidney, pelvic and heart fat) + .74 (area of rib eye in square inches). In cases of unusual fat deposition patterns, improved predictability resulted from a subjective adjustment of fat thickness over the rib eye. The prediction equation developed by Murphey _et al_. (1960) was the basis of the USDA yield grade and accurately predicts ($R^2 = .85$) the percent of boneless, trimmed retail cuts from the round, loin, rib and chuck.

Field (1971) in his review showed that sex would definitely play a part in estimating proportion of retail and wholesale cuts from different parts of the carcass. However, he did not conclude that there was a need for using different equations for estimating composition of bulls.

Chatfield (1926) stated that the protein content of the edible portion of a fresh, mature beef side was a curvilinear function of the fat content and that the ash content, as a linear function of the fat content, can be estimated for sides or wholesale cuts with fair accuracy. This worker also reported that the bone content of the entire side or of certain standard wholesale cuts can be estimated roughly from the fat content, but that there is too much variation in bone content to permit much accuracy in such an estimation. Also, for any wholesale cut there was a close relation between the content of fat measured by ether extract and visible or separable fat.

In a study by Adams _et al_. (1977), the 10-11-12 rib sections were used. Steers sired by bulls of the British breeds had slightly higher percentages of fat trim on the rib than they had on the carcass. The reverse was also true for all other breeds. Composition determined by density revealed that fat content of the rib section was consistently higher (about 10%) in every breed group than fat content of the carcass, but comparative rank of breed groups was the same and rib density and carcass density were highly correlated (r = .86, overall; r = .71, pooled).

Fat thickness was the most important variable in Adam's (1977) equations for predicting edible portion in which boneless steak and roast percentage was the cutability end point (Murphey et al., 1960; Abraham et al., 1968; Martin et al., 1970; Epley et al., 1970; Crouse et al., 1974).

Results reported by Iwanaga and Cobb (1963) seem to conflict with these studies. Utilizing 40 steers with an average slaughter weight of 475 kg, low and nonsignificant relationships were found between yield of trimmed retail cuts and average daily gain on test (r = .20), carcass grade (r = -.14), rib eye area (r = -.02), marbling score (r = -.20) and fat thickness over the rib eye at the 12th rib (r = -.22). Yield of total retail product was significantly correlated with ether extract of the longissimus muscle (r = -.36), yield grade (r = -.33) and carcass weight (r = -.39).

Thackston et al. (1967) analyzed carcasses from 66 steers, 37 bulls and 22 heifers to compare three methods used in predicting percentage of closely trimmed retail cuts. Simple correlation coefficients between USDA method, Wisconsin method and the Tennesse method of predicting percentage of closely trimmed retail cuts were .69, .78 and

.61, respectively. The Wisconsin method uses untrimmed wholesale round weight, side weight and rib eye area to determine the pounds of trimmed retail cuts in the round, loin, rib and chuck. The Tennessee equation uses fat thickness and hot carcass weight to determine pounds of separable muscle. Sex did not significantly influence the accuracy of the USDA system.

EXPERIMENTAL PROCEDURE

Ninety-eight Charolais cross cattle were used to evaluate the effect of sex, implant and breed of dam on carcass characteristics and palatability. These animals were obtained from the Hereford x Angus and Simmental x Angus dams from the South Dakota State University cow herd at Cottonwood and Fort Meade. This cow herd was purchased and maintained using the South Dakota Performance Records Program. All animals were sired by the Charolais bull Bamark, owned by American Breeders Service, Beloit, Wisconsin.

The experimental animals consisted of 24 bulls, 22 steers and 52 heifers. All animals were raised under South Dakota conditions and given implants of Ralgro twice in the preweaning period. Immediately post-weaning, all animals were divided by sex and breed, whenever possible, into eight equal groups. One-half of the animals in each pen were randomly selected and implanted with Synovex according to the required sex treatment on the label.

All the pens were essentially identical, concrete outside lots with fence-line concrete bunks and cable fences. All animals were fed identical diets consisting of 75% anhydrous ammonia-treated corn silage, 25% whole shelled corn and a 38% protein supplement (low urea; .45 kg per head per day). This commercial supplement contained 440 mg Rumensin per kilogram. Cattle were fed 73 days on this diet and reimplanted with Synovex on February 14, 1980. On that date, all cattle were changed to a 75% shelled corn and 25% anhydrous ammonia-treated corn silage diet with a continuation of the 38% low urea commercial supplement.

Because of a limitation of the commercial packing company used to slaughter the cattle, two pens of cattle were slaughtered weekly. This divided the cattle into four slaughter groups. As nearly as possible, heifers were slaughtered in groups one and two and one pen of steers and one pen of bulls were slaughtered in groups three and four.

A shrunk weight was obtained on groups one and two on May 14, 1980, and on groups three and four on May 28, 1980. Group one was transported to slaughter on May 15 and group three on May 29. Group two was transported to slaughter on May 22 and group four on June 5. Because of the 7-day interim between weighing and slaughter of the second and fourth groups, weights were adjusted using average daily gain for each animal times 7 days plus shrunk weight. This value was used for computing dressing percent and live weight.

Data were obtained at the commercial packing company after a 24-hour chill. A USDA grader employed at the packing plant provided marbling scores, kidney, heart and pelvic fat percentages, maturity scores and final quality grades for the right side of each carcass. Fat thickness and rib eye area measurements were collected from the right side of each carcass.

The right wholesale rib from each carcass was transported to the South Dakota State University Meat Laboratory. Wholesale ribs were then split according to procedures of Hankins and Howe (1946) with the exception that ribs were cut at 22.9 cm from the chine bone on the 12th rib end and 17.8 cm on the 6th rib end. After facing the remaining 12th rib component, a 2.5-cm steak was cut from the 12th rib end for

Warner-Bratzler shear and a second steak was cut 1.7 cm wide for taste panel evaluation. After removing the 9-10-11 rib sample from the wholesale rib, each 9-10-11 rib sample was weighed to the nearest .02 kg and physically separated into soft tissues, separable lean, subcutaneous fat, separable bone, separable fat and longissimus muscle. Each separable component was reweighed to the nearest .02 kilogram. Soft tissue and separable lean were then ground individually and a sample of each component was randomly removed for proximate analysis. The first steak from the 11th rib end of the longissimus muscle was removed for proximate analysis.

Carcass Data Collected

Carcass Maturity. The main indicator of carcass maturity was the degree of ossification of cartilage along the dorsal processor of the thoracic vertebrae. However, the width and shape of the ribs, color and texture of the lean and degree of ossification of the pelvic bone were also factors considered. According to the official USDA grader employed by the meat packing company, the carcasses ranged from A- to B+ (table 1).

Marbling. Marbling level was established by the USDA grader upon observation of the amount and distribution of intramuscular fat within the cut surface of the longissimus muscle between the 12th and 13th ribs. Each degree of marbling (table 1) was rated from practically devoid (+1) to abundant (+27).

TABLE 1. CARCASS, PALATABILITY AND QUALITY CHARACTERISTIC CODES

Maturity	Score
A -	6
A	5
A +	4
B -	3
B	2
B +	1

Quality	Grade
Good -	4
Good	5
Good +	6
Choice -	7
Choice	8
Choice +	9
Prime -	10

Marbling	Score
Slight -	7
Slight	8
Slight +	9
Small -	10
Small	11
Small +	12
Modest -	13
Modest	14
Modest +	15

Doneness	Score
Very Rare	1
Rare	2
Medium Rare	3
Medium	4
Well Done	5
Very Well Done	6

Juiciness	Score
Extremely juicy	8
Very juicy	7
Moderately juicy	6
Slightly juicy	5
Slightly dry	4
Moderately dry	3
Very dry	2
Extremely dry	1

Tenderness	Score
Extremely tender	8
Very tender	7
Moderately tender	6
Slightly tender	5
Slightly tough	4
Moderately tough	3
Very tough	2
Extremely tough	1

Flavor Desirability	
Extremely desirable	8
Very desirable	7
Moderately desirable	6
Slightly desirable	5
Slightly undesirable	4
Moderately undesirable	3
Very undesirable	2
Extremely undesirable	1

Overall Desirability	
Extremely desirable	8
Very desirable	7
Moderately desirable	6
Slightly desirable	5
Slightly undesirable	4
Moderately undesirable	3
Very undesirable	2
Extremely undesirable	1

USDA Carcass Grade. Marbling and maturity evaluation were the factors involved in determining the carcass quality grade as established by the USDA grader in accordance with the United States Standards for Grades of Carcass Beef (USDA, 1965). The bull carcasses were graded using the steer and heifer standards.

Warm Carcass Weight. Weight of the carcass immediately postmortem was recorded from the packer's tag and used to determine dressing percentage and yield grade.

Rib Eye Area. The longissimus muscle between the 12th and 13th ribs of the right side was traced on acetate tracing paper. The longissimus muscle area was then determined using a compensating polar planimeter and recorded to the nearest .02 square centimeter.

Fat Thickness at the 12th Rib. A single fat thickness measurement was made three-fourths of the distance from the medial to the lateral end of the exposed longissimus muscle at the 12th rib on the right side. The fat measurement was occasionally adjusted to reflect unusual external fat deposition patterns.

Percent Internal Fat. The USDA grader estimated the pelvic, kidney and heart fat in each carcass as a percentage of carcass weight.

USDA Yield Grade. The USDA yield grade was determined by using the warm carcass weight, rib eye area, fat thickness and estimated percentage of internal fat in the following yield grade formula: yield grade = 2.50 + (2.50 x adjusted fat thickness, inches) + (.20 x kidney, pelvic and heart fat, percent) + (.0039 x warm carcass weight, pounds) - (.32 x area of rib eye, square inches).

Warner-Bratzler Shear. The 12th rib samples were placed in freezer storage for no longer than 2 months. From the freezer, all samples were placed in a 4 C cooler overnight to thaw. The next morning six samples at a time were removed from the cooler and weighed to the nearest gram. They were then cooked on a Faberware open hearth broiler to an internal temperature of 71 C. The internal temperature was monitored by copper Constantan thermocouple wires. Steaks were then reweighed and percent cooking loss calculated for each steak using initial weights and weights obtained after cooking. Core samples 2.54 cm in diameter were removed from the steak. Duplicate core samples were sheared twice in the standard Warner-Bratzler shear machine for an objective determination of tenderness.

Proximate Analysis. Samples of the 9-10-11 rib component were frozen in liquid nitrogen and powdered in a Waring blender. Percentages of moisture and fat were determined on duplicate samples of soft tissue, separable lean and longissimus muscle by oven drying and ether extract, respectively (AOAC, 1970).

Sensory Evaluation. The steak which was removed from the 12th rib area was cooked on Faberware open hearth broilers to an internal temperature of 71 C. The internal temperature was monitored by copper Constantan thermocouple wires. The percentage cooking loss was calculated for each steak using initial weights and weights obtained after cooking. Steak characteristics were recorded and a degree of doneness score (6 = well done, 1 = rare, table 1) was assigned to each cooked steak using photographic standards. The steaks were cut into 1.2 cm cubes and evaluated by a 10-member trained sensory panel for juiciness (8 = extremely juicy; 1 = extremely dry), tenderness (8 = extremely tender; 1 = extremely tough), texture desirability, flavor desirability and overall palatability (8 = like extremely; 1 = dislike extremely).

Statistical Analysis. Data were analyzed by analysis of variance (Steel and Torrie, 1960). Mean values were obtained by least squares analysis. Correlation coefficients are shown in appendix table 1.

RESULTS AND DISCUSSION

Sums of squares for carcass characteristics are presented in table 2. Main effects show significance in many of the sex and dam categories. Much of this significance might be explained by differences in carcass weight. Since the entire group of cattle was very lean, fat thickness showed little variability. Marbling scores and quality grades were significantly ($P<.01$) affected by sex.

The combination of the variables sex and implant exhibited a high degree of significance ($P<.001$) toward dressing percent. However, neither sex nor implant showed significance by itself for dressing percent.

The correlation coefficient between live weight and sex was $r = -.62$, which showed that bulls had the heaviest live weights and heifers had the lightest live weights. Since the correlation coefficient between carcass weight and rib eye area was $r = .68$, it was difficult to quantitatively determine sex and carcass weight effects other than as a percent. However, mean values obtained by least squares analysis implied bulls produced more total weight and increased rib eye areas. Therefore, Americans may eventually eat more bull meat if populations and the need for animal proteins increase, provided bull meat is more economical to produce.

Mean values obtained by least squares analysis for carcass traits by sex are presented in table 3. The difference in live weight and carcass weight was significantly ($P<.001$) influenced by sex. This may

TABLE 2. SUMS OF SQUARES FOR CARCASS CHARACTERISTICS

Trait	Main effects			First order interactions			Second order interactions	
	Sex	Dam	Implant	Sex x dam	Sex x implant	Implant x dam	Sex x dam x implant	Error
Live weight	41489.55***	11933.62**	399.18	3283.25	31.42	4508.08	1083.58	1194.23
Carcass weight	21147.69***	7093.50***	865.58	879.86	615.10	2064.15	661.01	590.72
Dressing percent	10.63	7.53	10.68	2.16	23.29***	.41	.67	3.64
Rib eye area	610.18***	757.57**	98.67	.32	216.81*	208.82	88.68	67.02
Fat thickness	.09	.03	.03	.04	.05	.01	.23	.06
Kidney, pelvic and heart fat	4.79***	.39	2.11*	1.00	.54	.19	.24	.34
Maturity	.34	1.08*	.91*	.68*	.08	.01	.02	.20
Marbling	27.27**	5.17	18.77	13.50	11.12	7.88	9.17	5.15
Quality grade	8.94**	.013	3.75*	4.08*	1.68	.81	3.05	1.29
Yield grade	.60	.90*	.13	.03	.77*	.02	1.01*	.22
Days of age	1521.16***	1203.15**	358.86	41.67	87.94	.09	103.23	104.96

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

TABLE 3. MEAN VALUES OBTAINED BY LEAST SQUARES ANALYSIS FOR CARCASS CHARACTERISTICS BY SEX

Trait	Sex classification		
	Bulls	Steers	Heifers
Live weight, kg***	578.17[X]	560.88[X]	512.07[Y]
Carcass weight, kg***	371.56[X]	355.44[X]	323.27[Y]
Dressing percent	64.25	63.37	63.12
Rib eye area, cm^2***	97.10[X]	91.21[XY]	88.44[Y]
Fat thickness, cm	.56	.58	.65
Kidney, pelvic and heart fat, %***	2.42[X]	2.75[XY]	3.16[Y]
Maturity[a]	4.81	4.98	5.02
Marbling score[b]**	9.56[X]	11.78[Y]	10.90[XY]
Quality grade[c]**	6.20[X]	7.45[Y]	7.00[XY]
Yield grade[d]	1.80	2.04	2.07
Days of age***	441.14[X]	441.48[X]	429.88[Y]

** P<.01.
*** P<.001.
[a] A- = 6, B+ = 1.
[b] Practically devoid = 1, small = 10, abundant + = 27.
[c] Standard - = 1, Choice - = 7, Prime + = 12.
[d] United States Standards for Grades of Carcass Beef (USDA, 1965).
[X,Y] Means with similar superscript letters do not differ significantly from each other (P<.01).

also account for differences in rib eye area Marbling score and quality grade were significantly (P<.01) influenced by sex. Bulls exhibited lower marbling scores and quality grades than heifers and steers. These data agree with those found by Cahill (1964) and King (1965) in work done to determine muscle-to-fat ratio. Percent kidney, pelvic and heart fat showed a correlation of r = .45 with sex.

The fact that bulls had more desirable yield grades than the other sexes may account for some of the difference in quality grade. The correlation coefficient between yield grade and quality grade was r = .33. If the bulls had been fed for a longer period of time, they may have been capable of reaching higher quality grades.

Means obtained by least squares analysis for carcass characteristics by breed of dam are found in table 4. These means showed that Simmental-Angus crossbreds had significantly (P<.001) heavier carcasses with larger rib eye areas (P<.01) than Hereford-Angus crossbreds. Hereford-Angus crossbreds were significantly (P<.01) older and had significantly less desirable (P<.05) yield grades. Magnification of days of age and maturity scores may have affected yield and quality grades. In this regard, it can be noted that there was a tendency toward heavier carcasses and larger rib eye areas shown by Simmental-Angus crossbreds even after considering these effects.

TABLE 4. MEAN VALUES OBTAINED BY LEAST SQUARES ANALYSIS FOR CARCASS CHARACTERISTICS BY BREED OF DAM

	Breed of dam	
Trait	Hereford x Angus	Simmental x Angus
Live weight, kg**	538.04	562.70
Carcass weight, kg***	340.58	359.60
Dressing percent	63.27	63.89
Rib eye area, cm^2**	89.14	95.36
Fat thickness, cm	.62	.58
Kidney, pelvic and heart fat, %	2.85	2.70
Maturity[a]*	4.82	5.05
Marbling score[b]	10.49	11.01
Quality grade[c]	6.90	6.87
Yield grade[d]*	2.08	1.86
Days of age**	441.42	433.59

* P<.05.
** P<.01.
*** P<.001.
[a] A- = 6, B+ = 1.
[b] Practically devoid = 1, small = 10, abundant + = 27.
[c] Standard - = 1, Choice - = 7, Prime + = 12.
[d] United States Standards for Grades of Carcass Beef (USDA, 1965).

These data, showing heavier carcasses with larger rib eye areas, agree with work by Allen (1974) and Adams (1977) but disagree with work by Olson et al. (1978). These data also showed similarities with work by Carroll and Rollins (1965), showing a trend toward increased fat thickness and higher quality grade in British breed crosses.

Means obtained by least squares analysis for hormonal implants among carcass characteristics are found in table 5. These data show carcasses from implanted animals to be significantly (P<.05) higher in quality grade. However, there were no significant implant effects on rib eye area or fat thickness. Percent kidney, pelvic and heart fat was significantly (P<.05) larger in the control group.

These data would indicate that, in general, hormonal treatments do not affect carcass composition to any large extent when adjustments were made for maturity. Other work showing no observable differences was reported by Forrest (1975) and Harris (1979). However, studies by Cahill (1964) and Warner et al. (1965) showed hormonal treatments affected carcass composition.

Table 6 shows the sums of squares for the 9-10-11 separable rib component. The combination of sex and implant showed significance for all the fat and muscle percentages, while implant by itself did not show significance for any trait. Main effects were significant for sex and dam in almost all characteristics. Sex x dam x implant was significant (P<.05) for percent total fat and muscle and highly significant for intermuscular fat (P<.01). However, sex x dam or implant x dam did not show a significant effect.

TABLE 5. MEAN VALUES OBTAINED BY LEAST SQUARES ANALYSIS FOR CARCASS CHARACTERISTICS BY HORMONAL IMPLANT

	Hormonal implant	
Trait	Control	Implant
Live weight, kg	548.12	552.63
Carcass weight, kg	346.77	353.41
Dressing percent	63.21	63.95
Rib eye area, cm^2	91.13	93.37
Fat thickness, cm	.58	.62
Kidney, pelvic and heart fat, %*	2.94	2.61
Maturity[a]*	5.04	4.83
Marbling score[b]	11.24	10.26
Quality grade[c]*	7.10	6.66
Yield grade[d]	2.01	1.93
Days of age	439.64	435.36

* P<.05.
[a] A- = 6, B+ = 1.
[b] Practically devoid = 1, small = 10, abundant + = 27.
[c] Standard - = 1, Choice - = 7, Prime + = 12.
[d] United States Standards for Grades of Carcass Beef (USDA, 1965).

Correlation coefficients between percent subcutaneous fat and fat thickness and between percent muscle and rib eye area were r = .50 and r = .61, respectively. This agrees with work by Hankins and Howe (1946) and Price and Berg (1976).

In table 7, means obtained by least squares analysis can be found for separable components of the 9-10-11 rib by sex. Main effects were significant (P<.05) or highly significant (P<.01) for most component traits. The only exception was muscle-to-bone ratio. Bull carcasses contained a higher percent muscle and less fat than other sex classifications, but they did not differ greatly in muscle-to-bone ratio. This agrees with work by Hankins and Howe (1946), Price and Berg (1976) and

TABLE 6. SUMS OF SQUARES FOR 9-10-11 SEPARABLE RIB COMPONENT CHARACTERISTICS

	Main effects			First order interactions			Second order interactions	
Trait	Sex	Dam	Implant	Sex x dam	Sex x implant	Implant x dam	Sex x dam x implant	Error
Bone, %	6.14*	7.66*	1.76	.19	.08	1.60	1.60	1.34
Fat, %	190.07***	211.54***	.11	8.14	56.78**	4.18	43.83*	9.82
Subcutaneous, %	34.08***	11.63*	.67	4.80	7.71*	4.06	4.91	2.10
Intramuscular, %	1.33**	.02	.02	.15	.02	.14	.53	.20
Intermuscular, %	44.13***	110.82***	.00	3.78	37.26***	.09	29.60**	4.57
Muscle, %	129.87***	138.67***	2.73	6.09	60.13***	10.94	29.19*	7.79
Muscle:bone	.08	.02	.20	.01	.40	.41	.02	.16

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

TABLE 7. MEAN VALUES OBTAINED BY LEAST SQUARES ANALYSIS FOR SEPARABLE COMPONENTS OF 9-10-11 RIB BY SEX

Trait	Sex classification		
	Bulls	Steers	Heifers
Bone, %*	13.80^{x}	13.18^{xy}	12.93^{y}
Fat, %***	30.19^{X}	34.74^{Y}	34.84^{Y}
Subcutaneous, %***	6.38^{X}	7.87^{Y}	8.42^{Y}
Intermuscular, %***	21.62^{X}	24.40^{Y}	23.41^{Y}
Intramuscular, %**	1.39^{X}	1.48^{XY}	1.76^{Y}
Lean, %***	56.01^{X}	52.09^{Y}	52.22^{Y}
Lean:bone	4.08	3.97	4.06

* P<.05.
** P<.01.
*** P<.001.
x,y Means with similar superscript letters do not differ significantly from each other (small letters = P<.05; capital letters = P<.01).

the 9-10-11 rib separation may be an acceptable process in the future for experimental animals. Physical separation of this component may quite adequately represent the entire carcass and might, therefore, be a more practical indicator of carcass characteristics.

Breed of dam and separable components are compared by means obtained by least squares analysis in table 8. Rib components from Simmental x Angus had significantly (P<.05) more bone and also showed a higher significance (P<.001) for percent lean. Cattle from Simmental x Angus dams had a greater percent lean than those from Hereford x Angus dams. A higher degree of significance (P<.001) was found in least squares means for percent total fat in the Hereford x Angus cattle. Rib sections from Hereford-Angus crossbreds contained

TABLE 8. MEAN VALUES OBTAINED BY LEAST SQUARES ANALYSIS FOR SEPARABLE COMPONENTS OF 9-10-11 RIB BY BREED OF DAM

	Breed of dam	
Trait	Hereford x Angus	Simmental x Angus
Bone, %*	12.99	13.61
Fat, %***	34.90	31.64
Subcutaneous, %*	7.94	7.18
Intermuscular, %***	24.33	21.96
Intramuscular, %	1.56	1.53
Lean, %***	52.11	54.77
Lean:bone	4.02	4.05

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

2.37% more intermuscular fat. This may explain some of the reason for their increased total percent fat in the rib component.

Percent intermuscular fat had a correlation of r = -.38 to dam, whereas lean to dam had a correlation of r = .35. This might indicate that Simmental x Angus animals have less intermuscular fat and therefore a smaller total fat percentage. Although bone percentage was larger in Simmental x Angus cattle, muscle-to-bone ratio stayed approximately equal. This agreed with work by Berg and Butterfield (1976) which was supported by Berg and Mukhoty (1970), Truscott et al. (1976) and Koch and Dikeman (1977).

Means obtained by least squares analysis for separable components by hormonal implant are presented in table 9. The implant had no significant effect on 9-10-11 rib components as a main effect. The

TABLE 9. MEAN VALUES OBTAINED BY LEAST SQUARES ANALYSIS FOR SEPARABLE COMPONENTS OF 9-10-11 RIB BY HORMONAL IMPLANT[a]

Trait	Hormonal implant	
	Control	Implant
Bone, %	13.15	13.45
Fat, %	33.22	33.29
Subcutaneous, %	7.47	7.65
Intermuscular, %	23.14	23.15
Intramuscular, %	1.56	1.53
Lean, %	53.63	53.25
Lean:bone	4.09	3.99

[a] No significant effects shown by statistical analysis.

lack of significant effects showed that hormones have little, if any, main effects on the 9-10-11 rib sections. This work disagreed with work by Forrest (1975). However, Forrest did note significant sire and sex effects. This would indicate that further studies should be done to determine the effect of hormonal implants on percentages of fat, muscle and bone within a particular sex group.

Sums of squares for sensory and palatability characteristics are found in table 10. Main effects were significant (P<.05) for breed of dam for tenderness and connective tissue amount. A significance of .001 was found for sex x implant interaction, while no significant main effects for either alone were noted. Significant figures of .05 were also found for sex x implant in the traits of juiciness, connective tissue amount and overall desirability. Shear values were significant

TABLE 10. SUMS OF SQUARES FOR SENSORY AND PALATABILITY CHARACTERISTICS

Trait	Main effects			First order interactions			Second order interactions	
	Sex	Dam	Implant	Sex x dam	Sex x implant	Implant x dam	Sex x dam x implant	Error
Juiciness	.18	.50	.36	.59	2.45*	2.23	1.65	.64
Tenderness	1.17	4.60*	.00	.10	9.76***	.26	.81	.82
Connective tissue amount	1.10	2.63*	.14	.11	2.79*	1.06	.16	.40
Flavor desirability	.79	.17	.17	.12	.33	.03	.69	.37
Overall desirability	1.05	.59	.02	.09	1.92*	.15	1.16	.57
Cooking loss, %	27.39	1.24	10.68	11.94	16.31	61.45	10.09	22.19
Degree of doneness	.22	1.02	.12	.33	.13	.00	.00	.29
Shear	14.83	34.61	16.85	2.37*	17.37	2.81*	13.96**	8.87

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

(P<.05) for sex x dam and implant x dam and were highly significant (P<.01) for sex x dam x implant.

These data would indicate that sex and implant together have a greater effect on palatability and sensory characteristics than either sex or implant alone. This agreed with the data of Wierbicki (1955) and Carroll (1975).

Means obtained by least squares analysis for sensory and palatability characteristics by sex are found in table 11. No significance was found with regard to sex classifications. Although not significant, there was a trend for the steaks from bulls to require a higher shear force. However, taste panel data in general showed a trend in the opposite direction.

TABLE 11. MEAN VALUES OBTAINED BY LEAST SQUARES ANALYSIS FOR SENSORY AND PALATABILITY CHARACTERISTICS BY SEX[a]

Trait	Sex classification		
	Bulls	Steers	Heifers
Juiciness[b]	5.37	5.21	5.24
Tenderness[c]	5.32	5.79	5.48
Connective tissue amount[d]	4.83	5.23	5.16
Flavor desirability[e]	5.33	5.69	5.59
Overall desirability[e]	5.13	5.49	5.47
Cooking loss, %	28.30	30.32	29.91
Degree of doneness[f]	3.64	3.72	3.81
Shear, kg	4.73	3.98	4.31

[a] No significant effects shown by statistical analysis.

[b] Extremely dry = 1, slightly juicy = 5, extremely juicy = 8.

[c] Extremely tough = 1, slightly tender = 5, extremely tender = 8.

[d] Abundant = 1, slight = 5, none = 8.

[e] Extremely undesirable = 1, slightly desirable = 5, extremely desirable = 8.

[f] Very rare = 1, medium = 4, very well done = 6.

Field et al. (1966) used several ages of cattle and among cattle of similar ages found steers and heifers had slightly higher palatability ratings than bulls. Data for shear scores in the present study were also in agreement with Field's data. Studies by Kroger et al. (1960), Hedrick et al. (1969) and Champagne et al. (1969) were also in agreement with Field when age was taken into consideration. The data were also in general agreement with those of Reagan et al. (1971), including the fact that no significant differences in juiciness were observed.

Table 12 lists means obtained by least squares analysis for sensory and palatability characteristics by breed of dam. Hereford-Angus crossbreds showed significantly ($P<.05$) more tenderness and less connective tissue amounts than Simmental-Angus crossbreds. However, no significance was noted in overall desirability. In general, steaks from Simmental x Angus cattle did require more shear force. Taste panel data were in agreement with shear force values for tenderness, which agreed with work by Adams et al. (1977).

The increased flavor, juiciness and overall desirability scores of carcasses from Hereford-Angus crossbreds were supported by the significance shown in tenderness and connective tissue amounts. The general trend in palatability and sensory characteristics showed a preference toward Hereford-Angus crossbred carcasses.

In table 13 are mean values obtained by least squares analysis for sensory and palatability characteristics by hormonal implant. The main effects of implant showed no significant differences in table 10.

TABLE 12. MEAN VALUES OBTAINED BY LEAST SQUARES ANALYSIS FOR SENSORY AND PALATABILITY CHARACTERISTICS BY BREED OF DAM

Trait	Breed of dam	
	Hereford x Angus	Simmental x Angus
Juiciness[a]	5.35	5.20
Tenderness[b]*	5.77	5.29
Connective tissue amount[c]*	5.26	4.89
Flavor desirability[d]	5.58	5.49
Overall desirability[d]	5.45	5.28
Cooking loss, %	29.39	29.64
Degree of doneness[e]	3.61	3.84
Shear, kg	4.04	4.64

* $P<.05$.
[a] Extremely dry = 1, slightly juicy = 5, extremely juicy = 8.
[b] Extremely tough = 1, slightly tender = 5, extremely tender = 8.
[c] Abundant = 1, slight = 5, none = 8.
[d] Extremely undesirable = 1, slightly desirable = 5, extremely desirable = 8.
[e] Very rare = 1, medium = 4, very well done = 6.

TABLE 13. MEAN VALUES OBTAINED BY LEAST SQUARES ANALYSIS FOR SENSORY AND PALATABILITY CHARACTERISTICS BY HORMONAL IMPLANT[a]

Trait	Hormonal implant	
	Control	Implant
Juiciness[b]	5.20	5.34
Tenderness[c]	5.53	5.53
Connective tissue amount[d]	5.12	5.03
Flavor desirability[e]	5.58	5.49
Overall desirability[e]	5.38	5.35
Cooking loss, %	29.88	29.14
Degree of doneness[f]	3.69	3.76
Shear, kg	4.13	4.55

[a] No significant effects shown by statistical analysis.
[b] Extremely dry = 1, slightly juicy = 5, extremely juicy = 8.
[c] Extremely tough = 1, slightly tender = 5, extremely tender = 8.
[d] Abundant = 1, slight = 5, none = 8.
[e] Extremely undesirable = 1, slightly desirable = 5, extremely desirable = 8.
[f] Very rare = 1, medium = 4, very well done = 6.

Hormonal implants seemed to show minimal effects in all areas, with the exception that steaks from implanted cattle required slightly more shear force.

The relationship evident between data of tables 13 and 9 indicate that there were, in general, few main effects caused by hormonal implants. Correlation coefficients for hormonal implant by percent lean and percent fat were $r = .06$ and $r = .09$, respectively. When compared to overall desirability, implant had a correlation coefficient of $r = .14$. These data agreed in general with those of Forrest (1975), Glimp et al. (1971) and Warner et al. (1965).

Table 14 contains the means obtained by least squares analysis for rib components from the interaction of sex and implant. Total fat percent showed that bulls produced significantly ($P<.001$) more fat when implanted, whereas in heifers total fat percent decreased when they were implanted. Bulls showed significantly higher percentages ($P<.001$) of lean when not implanted, whereas control heifers showed a decrease in percent lean. This inverse relationship held true in that the effects on subcutaneous fat were significant ($P<.05$) and those for intermuscular fat were highly significant ($P<.001$). This agreed with work by Forrest (1975) who showed that hormonal treatment significantly ($P<.05$) decreased fat deposition in steers and tended to increase fat levels in bulls.

In general, this showed that Synovex implants may have the opposite effect on bulls as they do on heifers and steers. This effect showed bulls to have an increase in fatness and a decrease in lean.

TABLE 14. MEAN VALUES OBTAINED BY LEAST SQUARES ANALYSIS FOR RIB COMPONENT BY SEX AND IMPLANT

	Bulls		Steers		Heifers	
	Control	Implant	Control	Implant	Control	Implant
Bone, %	13.58^{xy}	14.02^{x}	13.08^{xy}	13.27^{xy}	12.80^{y}	13.07^{xy}
Fat, %**	28.72^{X}	31.65^{XY}	34.92^{YZ}	34.56^{YZ}	36.02^{YZ}	33.67^{YZ}
Subcutaneous, %*	5.68^{X}	7.08^{y}	8.39^{Y}	7.36^{y}	8.33^{Y}	8.52^{Y}
Intermuscular, %***	20.83^{X}	22.41^{XY}	24.03^{Y}	24.77^{Y}	24.56^{Y}	22.25^{XY}
Intramuscular, %	1.42^{xy}	1.35^{x}	1.50^{xy}	1.46^{xy}	1.75^{xy}	1.77^{y}
Lean, %***	57.69^{X}	54.33^{XY}	52.00^{Y}	52.17^{Y}	51.19^{Y}	53.26^{Y}
Lean:bone	4.26	3.91	3.99	3.95	4.02	4.11

* P<.05.
** P<.01.
*** P<.001.
^{x,y,z} Means with similar superscript letters do not differ significantly from each other (small letters = P<.05; capital letters = P<.01).

The tendency to deposit intermuscular fat was significantly (P<.001) more prominent in bulls.

Table 15 contains means obtained by least squares analysis for sensory and palatability characteristics by sex and implant. A significance of .001 was found in the tenderness factor, in that implanted bulls were more tender than their control counterparts, while heifers and steers showed the reverse effect when implanted. Juiciness also followed this trend, since bulls implanted and steer and heifer controls were significantly (P<.05) more juicy. This also held true for connective tissue amounts, with implanted bulls and both steer and heifer controls having significantly (P<.05) less connective tissue and more desirable overall taste panel ratings. In general, flavor, cooking loss percentage and shear values also followed this trend.

When data from table 15 are combined with information from table 14, many of the factors that were not significant become significant first order interactions. Implants may help provide different alternatives for meat consumers in the future. By implanting, bulls may more closely resemble steer and heifer quality, palatability and sensory characteristics, or they may be left unimplanted and thereby show an increased total lean production.

TABLE 15. MEAN VALUES OBTAINED BY LEAST SQUARES ANALYSIS FOR SENSORY AND PALATABILITY CHARACTERISTICS BY SEX AND HORMONAL TREATMENT

	Bulls		Steers		Heifers	
	Control	Implant	Control	Implant	Control	Implant
Tenderness***	4.71^{X}	5.93^{Y}	5.92^{Y}	5.66^{y}	5.97^{Y}	5.00^{XY}
Juiciness*	5.00	5.74	5.24	5.19	5.37	5.10
Connective tissue amount*	4.55^{x}	5.11^{xy}	5.34^{y}	5.12^{xy}	5.46^{y}	4.85^{xy}
Flavor desirability	5.26	5.40	5.77	5.60	5.71	5.16
Overall desirability*	4.87^{X}	5.40^{XY}	5.58^{Y}	5.39^{XY}	5.69^{Y}	5.25^{XY}
Cooking loss, %	29.40	27.20	30.63	30.01	29.61	30.22
Degree of doneness	3.62	3.66	3.61	3.84	3.83	3.79
Shear, kg	4.86	4.59	3.73	4.22	3.79	4.83

* $P<.05$.

*** $P<.001$.

[x,y] Means with similar superscript letters do not differ significantly from each other (small letters = $P<.05$; capital letters = $P<.01$).

SUMMARY

Carcass characteristics of yearling bulls, steers and heifers from the same Charolais sire were studied. The carcasses used in this study were from either Hereford-Angus or Simmental-Angus dams. All animals were originally from the experimental cow herd at Fort Meade and Cottonwood and were obtained after a feedlot performance trial at Beresford. One-half of each sex and dam group had been implanted with Synovex.

The experiment was designed to study the carcass measurements, sensory (and palatability) characteristics and 9-10-11 rib components of the carcasses. The primary objective was to study differences in breed of dam, sex and implant.

When cattle reached a predetermined slaughter weight, they were slaughtered at a commercial packing company and the following data were obtained: live weight, fat thickness, rib eye area, carcass weight, kidney, pelvic and heart fat, maturity score, marbling score, USDA quality grade and USDA yield grade.

The right wholesale rib of each carcass was transported to the South Dakota State University Meat Laboratory for sectioning into a standard 9-10-11 rib component. Physical separation and biochemical testing was done on these rib components to determine percent fat, muscle and bone. Steaks from each carcass component were then analyzed by taste panel evaluation, proximate analysis and tenderness determination with the Warner-Bratzler shear press.

Mean values obtained by least squares analysis indicated that the carcasses of Simmental-Angus crossbreds were larger with a greater percent bone than those of Hereford-Angus crosses. Simmental-Angus cattle also showed significantly (P<.001) greater percent lean and decreased percent total and intermuscular fat (P<.001). However, Hereford-Angus crossbreds showed significantly (P<.05) greater tenderness and significantly (P<.05) less connective tissue.

Mean values obtained by least squares analysis indicated sex and dam main effects were significant (P<.01) in nearly all carcass and 9-10-11 rib component traits, with the notable exception being fat thickness. Bulls tended to show an increase in percent lean and a decrease in percent fat over steer and heifer counterparts. Main effects for implants were generally not significant except when studied as an interaction among sex groups.

Mean values obtained by least squares analysis for sex by implant were used to determine effects of sex-implant interaction. Sex by implant interactions were significant (P<.05) for many of the sensory and 9-10-11 rib component traits. Yield grade and rib eye area had a significant effect (P<.05) for sex by implant. Dressing percent also showed significance (P<.001) for sex by implant. The effects of implants in bulls were characterized by larger percentages of fat, smaller percentages of lean and higher taste panel ratings over control bull counterparts. The opposite characteristics were found when steers and heifers were implanted. Implanted steers and heifers had smaller percentages of fat, larger percentages of lean and lower taste panel ratings than their control counterparts.

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TABLE 1. SIMPLE CORRELAT

Trait no.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	-.01	.00	-.63	.18	-.37	.45	-.62	.18	.15	.19	-.42	-.07	.04	.14	.15	.1
2		-.02	.04	-.01	.19	-.30	.13	-.21	-.27	-.22	-.17	-.02	-.14	-.16	-.14	-.1
3			.21	-.12	.31	-.02	.24	.18	.11	.05	-.26	-.08	-.22	-.20	-.09	-.1
4				.01	.61	-.32	.94	-.04	.13	.09	.27	.01	.03	-.06	-.01	-.1
5					-.27	.21	-.07	-.06	.20	.24	-.07	-.15	-.01	.07	.09	.0
6						-.21	.68	.07	-.08	-.13	-.04	-.03	-.15	-.17	-.17	-.2
7							-.32	.08	.14	.26	-.23	-.03	.18	.28	.18	.2
8								-.06	.10	.06	.26	.03	-.04	-.12	-.02	-.1
9									.14	.10	-.19	-.10	-.05	.03	.00	-.0
10										.92	.13	.27	.27	.22	.24	.2
11											.11	.22	.27	.23	.21	.2
12												-.00	.09	-.06	.12	.1
13													.42	.27	.30	.4
14														.76	.36	.6
15															.26	.5
16																.7
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1. Sex.
2. Implant.
3. Dam.
4. Live weight.
5. Fat thickness
6. Rib eye area.
7. Percent kidney, pelvic and heart fat.
8. Carcass weight.
9. Maturity.
10. Marbling score.
11. Quality grade.
12. Days of age.
13. Panel juiciness.
14. Panel tenderness.
15. Panel connective tissue amount.
16. Panel flavor.

TION COEFFICIENTS

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
9	.13	.14	-.10	.20	-.22	-.29	.47	.35	.23	-.04	.43	-.65	-.40	-.46	-.01
4	-.02	.03	.19	-.19	.29	.14	.06	-.04	-.14	.01	-.09	.08	.06	.05	-.07
5	.01	.16	.16	-.22	.18	.24	-.25	-.05	-.38	-.19	-.37	.33	.35	.35	.04
9	-.23	-.05	.04	-.13	.17	.11	-.22	-.19	-.15	.34	-.25	.72	.25	.27	.08
3	-.05	-.09	.02	.71	-.22	-.37	.50	.06	.46	.45	.53	-.26	-.49	-.50	-.01
7	-.11	.06	.05	-.74	.41	-.01	-.35	-.06	-.53	-.03	-.53	.78	.61	.55	.46
3	.04	.11	-.11	.39	-.11	-.35	.27	.15	.36	.08	.39	-.43	-.33	-.39	.09
8	-.22	-.0[illegible]	.06	-.20	.49	.10	-.22	-.14	-.20	.33	-.28	.76	.23	.30	.12
3	-.01	.14	.04	-.11	-.08	-.05	.08	.13	-.09	.01	-.02	.05	.04	.03	.08
4	-.18	-.05	-.27	.25	-.03	-.39	.23	.41	.38	.49	.42	-.03	-.35	-.42	.12
3	-.16	.00	-.26	.33	-.06	-.42	.25	.32	.45	.49	.47	-.15	-.40	-.48	.10
3	.11	-.13	-.10	.09	.05	.02	-.13	-.14	.16	.21	.03	.17	-.04	-.03	-.05
9	-.53	-.35	-.11	-.03	.05	-.05	-.07	.18	.07	.05	.05	-.01	-.04	-.05	.01
3	-.30	-.13	-.60	.16	-.18	.00	.02	.14	.28	.17	.23	-.18	-.27	-.26	-.20
0	-.17	-.09	-.52	.20	-.18	.01	.06	.06	.29	.07	.24	-.29	-.28	-.25	-.22
9	.02	-.16	-.11	.23	-.05	-.24	.22	.25	.22	.19	.28	-.19	-.24	-.25	.05
	-.14	-.18	-.32	.23	-.05	-.19	.14	.25	.29	.10	.30	-.32	-.28	-.30	-.02
		.20	.15	-.03	-.03	.02	.05	-.15	-.07	-.18	-.03	-.15	.03	.02	.00
			.06	-.10	-.07	.04	.03	-.01	-.05	-.03	-.03	-.00	.01	-.01	-.03
				-.03	.08	.05	.05	-.16	-.21	-.16	-.16	.08	.17	.16	.08
					-.25	-.19	.50	.04	.69	.43	.69	-.55	-.72	-.67	-.35
						.00	-.05	.06	-.19	.09	-.16	.33	.18	.18	.13
							-.44	-.33	-.46	-.54	-.56	.11	.31	.49	-.71
								.20	.51	.56	.80	-.54	-.77	-.79	-.14
									.10	.23	.30	-.18	-.23	-.30	.16
										.69	.90	-.57	-.88	-.88	-.22
											.73	.01	-.65	-.70	.03
												-.66	-.96	-.98	-.18
													.72	.69	.42
														.96	.44
															.24

17. Panel overall.
18. Cooking loss.
19. Degree of doneness.
20. Warner-Bratzler shear.
21. Yield grade.
22. Dressing percent.
23. Percent bone.
24. Percent subcutaneous fat.
25. Percent intramuscular fat.
26. Percent intermuscular fat.
27. Total fat weight.
28. Percent total fat.
29. Weight total muscle.
30. Percent total muscle.
31. Muscle to fat ratio.
32. Muscle to bone ratio.