AN INVESTIGATION OF CARCASS CUTABILITY
AMONG CATTLE OF SEVERAL
BREED TYPES

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DEDICATION

This dissertation as well as my life is dedicated to the glory of my Lord and Savior, Jesus Christ. May these works, as well as my future life works serve him well.

Additionally, it is with great joy and heart felt love I dedicate this dissertation to my parents, Nathan and Ann Hale. I can say with certainty that their steadfast love, encouragement, advice, and financial aid was instrumental in allowing me to accomplish my educational goals. Words can not express my true feelings for these two wonderful people.

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TABLE OF CONTENTS

LIST OF TABLES

Table Page

Table Page

CHAPTER I

INTRODUCTION

During the last 20 years the use of crossbreeding of beef cattle has increased. Most crossbreeding has involved the incorporation of large Continental European cattle breeding. However, there has also been an increased influx of Dairy breeds into beef cattle crossbreeding systems. The use of crossbreeding in beef cattle management systems resulted from the necessity of cattlemen to maximize production efficiency. Crossbreeding improves efficiency through increased hybrid vigor, particularly in traits related to cow productivity. Additionally, cross breeding permits one to combine outstanding characteristics of one breed with those of another breed. Although, there has been considerable research effort investigating the effects of crossbreeding on cow productivity, research identifying specific breed combinations that optimize carcass composition has been limited.

With the influx of new breeds and increased crossbreeding in today's beef industry, researchers have questioned whether the current USDA beef yield grading system is becoming outdated. The current system of yield grading was developed when beef cattle had smaller frame size and were primarily of British breeding. Thus, there is some belief that the current beef marketing structure may under-value the larger framed Exotic and Exotic X British crossbred steers.

Therefore, this study had three objectives:

1) To compare carcass composition, wholesale cut distribution, and Warner-Bratzler shear force means, adjusted to a Small marbling score slaughter endpoint, among the carcasses of three-breed cross calves. Means were adjusted to Small, because, for "A" Maturity cattle, a marbling score of Small is equivalent to a carcass quality grade of Low Choice. A carcass quality grade of Low Choice is considered to be the desirable economic endpoint in the beef cattle feeding industry. Therefore, breed type comparisons made at this endpoint should be directly applicable to current industry concerns.

2) To examine the effectiveness of the USDA beef yield grading system in predicting carcass cutability, among several cattle breed types. Furthermore, to examine the individual contributions of 12th rib fat thickness, hot carcass weight, rib-eye area and kidney, heart and pelvic fat in predicting carcass cutability among cattle of diverse biological types.

3) To develop regression equations that implement live animal traits to predict carcass leanness (USDA Yield Grade). These equations must be able to account for the variation in breed type, diet and management systems encountered in today's beef cattle industry.

CHAPTER II

REVIEW OF LITERATURE

Beef Carcass Composition

Carcass composition refers to the proportion of carcass weight in the form of muscle, fat, and bone. These major carcass tissues have been reported to grow and develop at relatively different rates postnatally. Therefore, during normal cattle growth, from conception to maturity, individual form and composition are continually changing because of differential growth of their constituent parts (Hammond 1933).

Tissue Growth

Fowler (1968) defined growth from two aspects: 1) the increase of body mass per unit time and 2) the changes in body form resulting from differential growth of component parts. Berg and Butterfield (1968) found that carcass weight increases from birth to maturity following a sigmoid curve with the point of inflection approximating the stage of increased fat deposition, sometime near puberty. Therefore, the stage of development at slaughter potentially has a great influence on carcass composition. Berg and Butterfield (1966) stated that the quantitative developmental requirements for the ideal steer carcass were best met when the proportion of muscle is at a maximum, bone is at a minimum and fat is at an optimum; with the optimum fat level determined by local consumer preferences.

Of the three major carcass tissues, bone is considered early developing; fat, late developing; and muscle, intermediate (Butterfield, 1965; Berg and Butterfield, 1966 and 1968; Berg et al., 1978a; Berg and Walters, 1983). Bone was referred to as early developing because bone represents a higher proportion of the carcass at birth than at later stages of growth. The converse has been reported for fat, and it is therefore considered a late developing tissue.

Postnatal muscle, fat and bone development was discussed by Berg and Butterfield (1968). They observed that muscle percentage first increased and then, as the fattening phase began, muscle percentage decreased. From birth to maturity, fat percentage continuously increased while bone percentage decreased.

Patterns of Relative Muscle Growth

Butterfield and Berg (1966) presented a system for classifying muscles according to their relative growth impetus. This system was based on growth coefficients calculated from the allometric equation, $Y=aX^b$ or when converted to the logarithmic function, $\log_{10} Y=\log_{10}a + b \log_{10}X$. In these equations, Y is the weight of the individual muscle or muscle group; X is the total muscle weight; a is the intercept, and b is the growth coefficient measuring the change in Y relative to X. In their study, 92 steers were divided into five age groups (i.e. 0-84 days, 85-365 days, 1-2 years, and 2 or more years). A b coefficient was calculated for each muscle, for total muscle growth in each growth phase and for total muscle growth in the total period. In the total period, eight muscles were found to grow at a faster rate than total muscle and were classified as high impetus muscles. Twenty-five muscles grew at a lower rate than total muscle, and were classified as low impetus muscles. Furthermore, nine muscles exhibited a biphasic growth and were classed as high-average; two other muscles were classed as average-high; and finally twelve muscles were found to have a low-average growth impetus. The change in diphasic patterns generally occurred between the first and second age groups (3 months of age).

Berg and Butterfield (1968) estimated that while 41% of the total musculature showed growth patterns different from the average in the 0-84 day group, no more than 9% of the total muscle differed significantly from the average in the next three age groups. They found that the major differential muscle growth occurred soon after birth, so only minor differences in muscle weight distribution would be expected across the normal range in slaughter weights.

Berg et al. (1978b) studied growth patterns of muscle in carcass wholesale cuts relative to total muscle. Their growth coefficients indicated that the growth impetus tends to increase centripetally from distal to proximal limbs, caudocephalically on the whole carcass, and dorsoventrally on the trunk.

Patterns of Relative Fat Growth

Carcass composition at a particular weight is profoundly affected by the development and distribution of fat within the various depots (Charles and Johnson, 1976; Koch and Dikeman, 1977; Koch et al., 1983; Berg and Walters 1983).

Kempster (1981) defined the fat depots as follows:

1) Subcutaneous fat (SCF) = the peripheral layer of fat to the level of the connective tissue covering the most peripheral muscle layer;

2) Intermuscular fat (IMF) = the fat lying between the muscles, together with thin connective tissue, small blood vessels and small quantities of muscle that are physically difficult to separate.

3) Kidney knob and channel fat (KKCF) = the perinephric and retroperitoneal fat;

4) Total fat (TF) = the sum of the three above depots.

In cattle, from birth to the normal slaughter age, fat depots grow differentially with subcutaneous fat (SCF) having a higher relative growth rate than intermuscular fat

(IMF). Kidney knob and channel fat (KKCF) tend to grow at the same relative rate as total fat (Kempster, 1981). Kempster (1980) also reported SCF was a faster growing depot (b=1.2) than IMF (b=.87).

Kempster et al. (1976) and Berg et al. (1978c) examined the growth impetus of fat within several carcass "joints", from cattle slaughtered at various age groups. Growth impetus for fat was lowest in the distal limbs and in the proximal hind limb, as well as in the neck and rump. Fattening was found to increase inward from the neck and rump to the mid-back region. Flank and brisket fat was found to have a high growth impetus, while fat in the proximal fore-limb developed at the same rate as total fat. Berg and Butterfield (1976) suggested that fat partitioning and distribution might be related to local pressures that develop with growth. Thus, at birth, the body cavity fat and the IMF depots find little resistance but, as they fill, increasing resistance is encountered, causing more of the surplus energy to be stored under the skin as subcutaneous fat. With respect to SCF and IMF distribution, they hypothesized that the muscles and body shape create variable pressures and that the hindquarter IMF is more resistant to increase than that in the forequarter resulting in a shift forward of IMF as fattening progresses. SCF expands beneath the skin in the less resistant areas, gradually resulting in the overall smooth appearance of very fat animals (Kauffman et al, 1970).

The relative pattern of fat distribution within depots and partitioning among depots in cattle appears to be dependent on breed, sex and plane of feeding (Callow, 1960; Berg and Butterfield, 1966; Kempster et al., 1976 a or b; Berg and Butterfield, 1976). Berg and Walters (1983) reviewed experimental results for fat partitioning and fat distribution. Comparing the two, they cited that fat partitioning among depots showed more genetic variation than fat distribution and reported that substantial differences in fat partitioning have occurred in the evolution of domestic breeds. Fat distribution, on the other hand, follows a more closely defined pattern such that, at equal total depot weights, breed differences in fat distribution within depots are small.

Genetic and Environmental Variation in Fat Partitioning

Both genetic and environmental effects that lead toward earlier fattening result in an increased proportion of subcutaneous fat relative to intermuscular fat, while delayed fattening has an opposite effect. Since depots develop at different rates, differences observed between animals in fat partitioning will depend on their age, body weight and degree of maturity (Berg and Walters, 1983).

Berg and Walters (1983) cited two important reasons for understanding fat partitioning differences:

1) Subcutaneous fat can be trimmed more easily than intermuscular fat and therefore is preferable in carcasses containing fat in excess of consumer requirements.

2) The accuracy of carcass composition prediction equations that employ fat thickness measures, depends on the constancy of fat partitioning and distribution among different cattle types. Numerous factors may contribute to differences in fat partitioning or distribution, including breed, feeding regimen, and climate. These factors may lead to biases in predicting composition unless separate prediction equations are used for different situations.

Nutrition

Callow (1960) studied the effect of four levels of nutrition (Moderate-moderate, Moderate-high, High-moderate, and High-high) on cattle fattening and found those fed at a high plane of nutrition during the last half of the study had the highest percentage fat. Berg (1968) suggested that a high plane of nutrition caused the onset of fattening to occur earlier relative to muscle and bone weight. Earlier, Guenther et al. (1965) reported that a low plane of nutrition retarded fat development.

Cattle fed for faster gains have been found to deposit a higher proportion (carcass weight basis) of internal and subcutaneous fat than steers grown more slowly (Murray et al., 1974). Kempster et al. (1976) found that, at equal total fat weight, cattle from cereal feeding systems deposited a higher proportion of their fat subcutaneously than cattle from grass/cereal feeding systems.

Fortin et al. (1980) studied the effects of energy intake on the distribution of fat. Variation in carcass composition, caused by varying the energy intake levels were thought to occur because of different times of the rapid fattening phase onset and because of differential rates of fattening.

Breed

Cattle breed differences in fat partitioning have been reported to exist for many years. The earliest recorded reference being that of Lawes & Gilbert (1859).

Hammond (1933) found partitioning of fat in the major depots followed the developmental sequence of perinephric, intermuscular, subcutaneous, and intramuscular, respectively. However, more recently, researchers have found that while subcutaneous fat is considered late developing, the growth of the other depots is highly dependent on breed (Berg and Butterfield, 1968; Johnson 1972 as cited in Charles and Johnson, 1976; Kempster et al., 1976; Kempster, 1981; Fortin et al., 1981; and Berg and Walters, 1983).

Several researchers have indicated that cattle with dairy breeding tend to deposit a higher proportion of their total fat as internal fat (kidney, heart, and pelvic fat) than do British beef cattle (Callow, 1960; Charles and

Johnson, 1976; Kempster et al. 1976 a or b; and Kempster, 1981). This presumably occurred because of differences in selection pressures used between these two cattle types.

In a review of the literature, Berg and Walters (1983) found that breeds selected for earlier and heavier fattening (e.g., the Hereford or Angus) usually have higher SCF to IMF ratios than the dairy breeds and the large European continental breeds. Contrary to the general findings, Kempster et al. (1976 a or b) reported the rates of deposition of subcutaneous and intermuscular fat were similar for Angus and Holstein when examined at at a common weight of total fat.

Differences in fat partitioning, at a constant fat thickness and fat percentage were reported by Charles and Johnson (1976). At a constant fat thickness, Herefords had a higher percentage of subcutaneous fat and a lower proportion of total and internal fat than Angus, Friesian, and Charolais-cross steers. At a constant fat percentage, Friesian steers had a higher percent of intermuscular fat than Hereford or Angus steers.

Kempster et al. (1976 a or b) examined the distribution of total fat (TF) between subcutaneous (SF), intermuscular (IF), kidney knob and channel (KKCF) and cod fat depots using data from 643 steer carcasses of 15 breed-type x feeding system groups. The breed-type groups, which were from cereal or grass/cereal feeding systems, included

Ayrshire, Simmental x Ayrshire, British, Friesian and Friesian crosses with Angus, Hereford, Limousin, Charolais, South Devon and Simmental. The growth of each depot relative to TF was examined using the allometric equation ($Y=aX^b$). Small, but significantly different growth coefficients were found between breed groups for SCF and IMF, while the coefficients of KKCF differed widely among breed groups. The growth coefficient for SCF was greater than that for IMF in every group. At a constant TF weight, carcasses from Ayrshire and Ayrshire crosses tended to have proportionally less SCF and more IMF and KKCF than carcasses of Friesian and beef x Friesian breeding. Koch and Dikeman (1977) examined fat distribution patterns among steers obtained from mating Hereford and Angus cows to Hereford, Angus, Jersey, South Devon, Limousin, Charolais and Simmental sires. Breed group differences were primarily in kidney and pelvic fat and external fat covering the round, loin, rib, and chuck. Hereford, Angus and Hereford-Angus crosses reportedly had distinctly less of their total fat in kidney and pelvic fat depot and more in the subcutaneous fat depot than other breed groups.

Nutrition By Breed Interactions

Nutrition by Breed interaction effects on fattening, during the feedlot phase were reported by Fortin et al. (1981). The deposition of fat and its partitioning among the subcutaneous, intermuscular, internal and intramuscular depots was studied on Holstein and Angus steers, fed at two levels of energy: ad libitum and 65 to 70% of ad libitum. For the high energy intake steers, subcutaneous fat was deposited at a faster rate than intermuscular fat. Among the low energy intake cattle, this difference disappeared. For both energy intake groups, intermuscular fat was observed to be the largest depot, followed by subcutaneous, internal and intramuscular fat. Among Holsteins the level of energy intake generally did not affect ($P>.05$) the rate of fat deposition in the individual depots, whereas among Angus, the rates of fat deposition in the subcutaneous and intermuscular depots were generally lower ($P<.05$) for cattle in the low energy intake group than for cattle in the high energy intake group. Among the high energy intake steers, the rates of deposition for subcutaneous, intermuscular and intramuscular fat relative to total fat did not differ ($P>.05$) between breeds; however, the rate of deposition for internal fat was faster ($P<.05$) for Holstein than for Angus steers.

Indices of Carcass Composition

Since Hammond (1933), researchers have attempted to find accurate, repeatable, and easily obtainable carcass measurements that predict carcass composition. There are two factors responsible for the variation found in carcass composition: the first and most important is the proportion of fat deposited in the subcutaneous, intermuscular, body cavity, and possibly intramuscular depots; and the second is the carcasses muscle to bone ratio (Kauffman et al., 1975). As already discussed, these two factors can be highly dependent on genetic and environmental factors (e.g. breed, age, sex, feeding system, and days on feed). Measurements used to predict carcass composition must therefore account for the variation in cattle types encountered in today's U.S. beef industry (Crouse et al., 1975 and Abraham et al., 1980).

Relationship Between Fat Measurements and Composition

Fat is the most variable carcass tissue, both in amount and distribution (Berg and Butterfield, 1976; Kempster, 1981; Koch et al. 1983; and Berg and Walters, 1983). As the percentage of fat increases, there is almost a proportionate decrease in lean content (Hedrick, 1983). Therefore, a measurement of carcass fatness is normally found to have the highest simple correlation coefficient with carcass cutability (Table I).

Numerous subcutaneous fat measures have been investigated (Allen, 1966). Fat thickness measured at the 12 rib, over the longissimus muscle three-fourths of the distance from the medial to the lateral edges is the most common measure used to estimate carcass fatness.

Using this measurement mandates the assumption that twelfth rib fat thickness is highly related to the

TABLE I

SIMPLE CORRELATION COEFFICIENTS BETWEEN CARCASS CUTABILITY AND CARCASS TRAITS

Author	Carcass Trait	r
Murphey et al. (1960)	12th Rib Fat Thickness(FT)	-.85**
	% Kidney Fat(KF)	-.63**
Brungardt & Bray (1963)	FT	-.71**
	Longissimus Muscle Area(LMA)	.45**
	Hot Carcass Weight(CW)	-.23**
Hedrick et al. (1965)	FT	-.50**
	LMA	.41**
Abraham et al. (1968)	FT	-.66**
	LMA	.18
	KF	-.58**
	CW	-.50**
Cross et al. (1973)	FT	-.73**
	LMA	.30**
	%Kidney, Heart, and Pelvic Fat(KHPF)	-.59**
	CW	-.47**
Crouse et al. (1975)	FT	-.76**
	LMA	.47**
	% Kidney and Pelvic Fat(KPF)	-.37**
	CW	-.07
Abraham et al. (1980)	FT	-.79**
	LMA	.02
	KPF	-.57**
	CW	-.37**
	Marbling Score	-.60**

** P<.01

proportion of fat in the entire subcutaneous fat depot, as well as in the intermuscular and intramuscular fat depots. Few researchers have investigated the relationship between 12th rib fat thickness and the proportion of fat in the various depots. Kauffman et al. (1976) reported a .67 correlation between a subjectively measured seam-fat score and 12th rib fat thickness and percent carcass seam-fat.

Kempster et al. (1976 a or b) studied relationships between fat within whole depots (Table II). Subcutaneous fat had a medium to high (.723, $P<.01$) and low (.308, $P<.05$) correlation with intermuscular fat and kidney and pelvic fat, respectively. Another consistent finding in this study was that as fattening progressed, subcutaneous fat made an increasing contribution to total fat relative to intermuscular fat. Moreover, cattle from cereal systems of feeding deposited a higher proportion of their total fat subcutaneously than cattle from grass/cereal systems. This may indicate that the proportion of subcutaneous fat is more highly related to the other depots during early growth, but as the individual becomes fatter these relationships may become less dependable.

TABLE II

SIMPLE CORRELATION COEFFICIENTS AMONG THE FAT DEPOTS AND TOTAL FAT PERCENTAGES IN THE SIDE (Kempster et al., 1976a)

Fat Depot	SCF	KPF	Cod fat	Total fat
Intermuscular fat(IMF)	0.723	0.527	0.629	0.938
Subcutaneous fat(SCF)		0.308	0.651	0.855
Kidney and Pelvic Fat(KPF)			0.445	0.683
Cod fat				0.728
Total fat				

$p<.05$

Relationship Between Longissimus Muscle Area (LMA) and Composition

The most often used indicator of carcass muscling is the longissimus muscle area. The growth gradient theory described by Hammond (1933) and later by Berg and Butterfield (1976) states that the loin is a late maturing region, thus suggesting that muscle development could be estimated best by measuring the cross sectional area of the longissimus muscle (LMA) at the 12th rib since this would be the last area to reach full development. As can be seen in Table I the correlation coefficient between LMA and carcass cutability is quite variable among studies.

Crouse et al. (1975), studying several biological types of steers, calculated simple correlation coefficients overall sire breed groups, as well as within sire breed groups. The correlation between cutability and LMA was much larger (.47) over all sire breed groups than it was within breed groups (.18). This indicates that LMA may be useful in prediction equations by partially identifying variation in cutability associated with breed group differences.

Relationship Between Carcass Weight and Composition

The relationship between carcass weight and carcass composition appears to be quite variable and highly dependent on the homogeneity of the group being analyzed (i.e. breed, type, and nutritional background) (Kauffman et al., 1975).

Murphey et al. (1960) found weight to have a significant effect on the yield of percent "retail cuts"; however, the cattle used in this study were primarily of British type. Allen et al. (1968) demonstrated that the weight range studied could have an effect on the strength of the relationship between these two factors. They studied steer carcasses of two weight groups (227 to 250 kg and 318 to 340 kg) that had similar mean fat thicknesses of 1.9 cm. Simple correlation coefficients for the light group, heavy group, and both groups pooled were -.37, -.09, and -.11, respectively. Crouse et al. (1975) studied 1,121 crossbred steers obtained from the mating of Angus and Hereford dams to Angus, Hereford, Simmental, Charolais, Limousin, South Devon, and Jersey bulls. They found a low, nonsignificant simple correlation coefficient between carcass weight and carcass cutability (percent closely trimmed, boneless round, loin, rib, and chuck) (Table I). Koch et al. (1976), reported on the same cattle, but compared breed types at a constant slaughter weight endpoint. At equal weights, carcass cutability was not significantly different among Hereford, Angus, and their reciprocal crosses or between the Charolais and Limousin sired steers. However, carcass cutability was significantly different among the Charolais and Limousin sired groups and the British sired group. It appears logical that a steer from a large frame size breed could have a higher cutability at a heavier weight than a steer from a smaller frame breed at a lighter weight. Therefore, in variable groups of cattle, care should be exercised when using carcass weight as a predictor of carcass composition.

Relationship Between Conformation and Cutability

The USDA Grading Standards published in 1956 reported that beef carcasses with the most desirable conformation should have a greater than average proportion of preferred cuts. However, Cole et al. (1962) were unable to show any significant advantage to the traditional British Breeds over the "longer legged longer bodied" Zebu type cattle. In fact the Zebu cattle had a higher percent separable lean and bone and a lower proportion separable fat than British steers. Martin et al. (1966) studied compositional differences among groups of carcasses representing USDA Choice conformation and USDA standard conformation. He reported that Choice conformation carcasses had .93% ($P<.05$) more meat in the thick cuts, .82% ($P<.05$) less thin cut meat, 2.6% ($P<.05$) more carcass fat, and 2.72% ($P<.05$) less total carcass bone than Standard conformation carcasses. Similarly, Kempster and Harrington (1980) reported that breeds with higher conformation scores had higher muscle to bone ratios.

Carcass Composition Prediction Equations

Numerous equations have been proposed to estimate beef carcass composition (Hankins and Howe, 1946; Murphy et al., 1960; Cole et al., 1962; Brungardt and Bray, 1963; Allen, 1966; Abraham et al., 1968; Powell and Huffman, 1973; Crouse et al., 1975; and Abraham et al., 1980). The most widely used equations in today's beef industry are the Murphey equation (Murphey et al., 1960) and the USDA beef carcass "cutability" equation. Both equations are used to predict the percent of carcass weight in closely trimmed, boneless retail cuts from the round, loin, rib, and chuck (carcass cutability).

Both equations were developed using the same data source. Murphey et al. (1960) developed these equations selecting variables from the following recorded measurements: (1) length of body, (2) length of hind leg, (3) circumference of round, (4) depth of body, (5) length and width of the rib eye muscle between the twelfth and 13th ribs, (6) cross sectional area of 12th rib longissimus muscle (LMA), (7) three thicknesses of fat over the twelfth rib longissimus muscle, (8) percent of carcass weight in the form of kidney, heart, and pelvic fat (KHPF), and (9) single 12th rib fat thickness (FT). Carcasses studied were first divided into standard wholesale cuts which were then defatted and otherwise trimmed to reflect a rather close "retail-style trim." Surface fat was trimmed to within 1/2 inch on the thick cuts and to within 1/4 inch on the thinner cuts such as the brisket. The cuts were either partially or completely boned.

The Murphey equation reported is as follows (Murphey et al., 1960):

The percent of cold carcass weight in closely trimmed, boneless retail cuts from the round, loin, rib, and chuck = 56.65 - 4.95 (12th rib fat thickness opposite the longissimus muscle, in.) - 1.06 (percent kidney, heart, and pelvic fat) - .008 (warm carcass weight, lbs.) + .682 (longissimus muscle area, sq. in.).

Note that the regression coefficient for kidney heart and pelvic fat was 1.06, indicating that each one percent change in KHPF affected the yield of retail cuts from the round, loin, rib, and chuck slightly over one percent. Murphey et al. (1960) speculated that the percent KHPF might be interrelated to some other factors that also affect yields of cuts, possibly intermuscular fat.

It was thought that meat packers might misrepresent carcass cutability by totally removing KHPF. To avoid this, its partial regression coefficient was set at .462 and the remainder of the equation was then derived (Murphey, 1984 personnel communication). This equation was referred to as the USDA cutability equation and is reported as follows (USDA, 1965):

Percent boneless, closely trimmed retail cuts from round, loin, rib, and chuck = 51.34 - 5.784 (single fat thickness over the longissimus muscle, in.) - .462 (percent kidney, heart and pelvic fat) - .740 (area of rib eye, sq. in.) - .0093 (warm carcass wt., lbs.).

The USDA yield grading system was based on the USDA cutability equation, with a numerical yield grade USDA 1 analogous to a high carcass cutability and a USDA 5 to a low carcass cutability.

Ramsey et al. (1962) were the first to evaluate the effectiveness of the yield grading system (USDA cutability equation) in predicting carcass cutability. They studied 133 steers that were of Angus, Hereford, Brahman, Brahman X British, Santa Gertrudis, Jersey, or Holstein breeding. Simple correlation coefficients between yield grade and separable muscle and separable fat, ignoring breed, were -0.75 and .73 ($P<.01$), respectively.

Brackelsberg et al. (1967) found coefficients of determination between actual carcass cutability and carcass cutability estimated from the Murphey and USDA equations to be .62 and .58, respectively. Cross et al. (1973) studying eighty-two carcasses from Angus, Hereford, Charolais, or Brahman-British steers reported that each of the equations accounted for approximately 70% of the variation in carcass cutability.

Boyd (1976) reported a simple correlation coefficient of .47 ($P<.01$) between the USDA's estimated carcass cutability and the actual cutability of carcasses from steers produced from mating Hereford and Angus dams to Hereford, Angus, Simmental, Brown Swiss, and Jersey sires. Regardless of the breed of sire, the USDA equation was found to underestimate actual cutability in these studies. The difference between actual cutability and the USDA equation's estimate was smallest for the Jersey sired steer carcasses and largest with the Simmental sired steer carcasses.

Crouse et al. (1975) evaluated the USDA cutability equation using steer carcasses produced from mating Angus and Hereford dams to Limousin, Charolais, Simmental, South Devon, Hereford, Angus, and Jersey sires. The simple correlations between actual cutability and the USDA equation estimated cutability on a within sire group basis were .82 for Hereford and Angus, .78 for Charolais, Limousin, and Simmental, and .73 for Jersey. The USDA equation consistently underestimated actual cutability regardless of sire group, however the Simmental, Limousin, and Charolais sired steer carcasses were underestimated by 4% and the Jersey sired steer carcasses by 1.7%.

Abraham et al. (1980) selected 280 beef carcasses that varied widely in weight, fatness and muscling for the purpose of evaluating the USDA cutability equation. They reported a high (.90, P<.01) correlation coefficient between actual and estimated carcass cutability, however the USDA cutability equation on the average, underestimated the actual cutability by 3.41%.

Comparisons of Carcass Composition Breed Means Adjusted to a Constant Marbling Score of Small

Carcass composition, among many newly introduced breeds, as well as among breeds that have been used previously for milk production, has not been adequately evaluated under the feeding and management conditions traditionally associated with beef production in the United States (Koch et al., 1976).

Several studies have compared compositional and quality characteristics of steer carcasses from several biologically different cattle breed-types. Reported means were adjusted to a common marbling score of Small which in young cattle is equivalent to a carcass quality grade of low Choice. Boyd (1976) studied steers and their carcasses obtained from mating Hereford (H) and Angus (A) cows to Hereford, Angus, Jersey (J), Brown Swiss (BSw), and Simmental (S) sires. Koch et al. (1976) collected data from the carcasses of calves born to Hereford and Angus cows and sired by either Hereford, Angus, Jersey, Limousin (L), Charolais (C) or Simmental bulls. Carcasses of steers obtained from matings of Hereford, Angus, Brown Swiss, and Gelbvieh (G) sires to Hereford and Angus dams were later studied by Koch et al. (1979) and Koch et al. (1982) analyzed steer carcasses obtained from mating Hereford and Angus cows to Hereford or Angus, and Brahman (Br) sires.

With the exception of Boyd (1976) breed group comparisons were discerned at several slaughter endpoints and in all studies, comparisons were made at either 5% fat in the longissimus muscle (equivalent to a typical Small degree of marbling) or at a Small degree of marbling slaughter endpoint (Table III). Breed group differences in relative proportions of retail product, fat trim and bone were largest when compared at a constant carcass weight and smallest when compared at a constant marbling score of Small (Koch et al., 1976; Koch et al., 1979). Steers sired by Brown Swiss and large European Continental breed bulls had a lower percent fat trim ($P<.05$) and a higher percent retail product ($P<.05$) than Hereford, Angus, and Jersey sired steers, within a study, when means were adjusted to a constant marbling score of Small.

Summary

Most research had indicated that carcass compositional traits differ because of breed, feeding regimen, age, and environment.

It has been reported that fat partitioning among depots may be affected by nutrition and breed. British type cattle tend to deposit less fat internally and more fat subcutaneously than Dairy type cattle. Cattle placed on a high plane of nutrition begin their fattening phase

TABLE III

CARCASS TRAITS LEAST SQUARES MEANS ADJUSTED TO 5% FAT IN THE LONGISSIMUS MUSCLE

Source	Trait	Breed Group Least Squares Means				
Boyd (1976)						
	Type	HAx	Jx	BSwx	Sx	
	Final weight, kg	469.3	414.7	495.3	502.6	
	Hot carcass weight, kg	286.3	249.5	306.9	310.1	
	Longissimus area, cm^2	77.6	70.5	81.5	83.6	
	Fat thickness, mm	29.0	24.8	26.0	25.8	
	Yield grade	4.5	4.2	4.3	4.2	
	Actual cutability, %	49.0	49.5	50.5	51.0	
	Fat trim, %	26.3	25.1	23.3	22.7	
	Bone, %	11.4	12.3	12.1	12.1	
	Kidney and Pelvic Fat, %	3.9	5.7	4.3	3.9	
Koch et al. (1976)						
	Type	HAx	Jx	Lx	Cx	Sx
	Hot carcass weight, kg	264.8	249.3	319.4	319.3	317.0
	Longissimus area, cm^2	69.7	67.4	83.6	83.7	79.6
	Fat thickness, mm	13.8	9.9	13.0	10.3	10.8
	Yield grade	3.1	3.1	2.9	2.6	2.7
	Retail product, %	67.1	66.9	69.6	70.9	69.7
	Fat trim, %	20.3	20.3	18.5	16.2	17.2
	Bone, %	12.6	12.9	11.9	12.9	13.1
	Kidney and pelvic fat,%	3.2	5.3	4.4	3.8	4.0

H-Hereford, A-Angus, S-Simmental, C-Charolais, L-Limousin, G-Gelbvieh, Br-Brahman, BSw-Brown Swiss, J-Jersey, and x-Cross.

TABLE III (CONTINUED)

Source	Trait	Breed Group Least Squares Means		
Koch et al. (1979)				
	Type	HAx	BSwx	GX
	Final weight, kg	456.4	524.0	565.3
	Carcass weight, kg	284.9	328.5	351.6
	Longissimus area, cm^2	66.3	76.0	79.8
	Fat thickness, mm	16.7	12.0	12.9
	Yield grade	3.1	3.5	3.4
	Retail product, %	66.8	68.3	67.8
	Fat trim, %	21.3	18.9	20.3
	Bone, %	11.8	12.7	11.9
	Kidney and Pelvic fat, %	4.3	4.6	5.3
Koch et al. (1982)				
	Type	HAx	Brx	
	Final weight, kg	456.1	529.6	
	Carcass weight, kg	288.5	347.9	
	Longissimus area, cm^2	68.6	73.2	
	Fat thickness, mm	15.1	17.7	
	Yield grade	3.7	4.3	
	Retail product, %	66.8	64.8	
	Fat trim, %	21.0	23.5	
	Bone, %	12.2	11.7	
	Kidney and pelvic fat, %	3.9	5.0	

H-Hereford, A-Angus, S-Simmental, C-Charolais, L-Limousin, G-Gelbvieh, Br-Brahman, BSw-Brown Swiss, J-Jersey, and x-Cross.

earlier than cattle grown on a medium or low nutritional plane.

It has also been found that breeds of diverse biological types differ in percent carcass lean and fat when examined at a common weight, age, or marbling score. Percent carcass bone appear to be similar among breeds regardless of the common slaughter endpoint considered. In addition, the untrimmed wholesale cut weight as a proportion of carcass weight appears to be similar across breed types.

Several researchers have attempted to quantify carcass composition using carcass measurements. Fat thickness, taken at the twelfth rib interface, has been the most commonly used measure of carcass fatness in the industry. Reported correlations between twelfth rib fat thickness and carcass cutability have ranged between .85 and .50. Recently, researchers have questioned whether this trait can account for variation in fat deposition within the intermuscular depots. Numerous investigators have reasoned that percent kidney, heart and pelvic fat may account for more variation in carcass fatness than its own weight would indicate. Correlations between carcass cutability and hot carcass weight and longissimus muscle area have been quite variable. The magnitude of the association appears to be related to the degree of homogeneity of cattle type within the study. Carcass conformation appears to be positively related to muscle to bone ratio, however carcasses with higher conformation score have not been found to have any significant advantage in carcass cutability.

The use of these traits in cutability prediction equations have shown mixed results. Studies done in the 1960's, examining British type cattle reported high coefficients of determination between actual carcass cutability and cutability predicted using 12th rib fat thickness, hot carcass weight, longissimus muscle area, and kidney, heart and pelvic fat as independent variables. However, Crouse et al. (1975) examining these equations on more diverse biological cattle types, reported somewhat lower coefficients of determination.

It appears that additional studies are needed, to adequately quantify breed differences in carcass composition, as well as to determine if carcass cutability prediction equations developed in the 1960's are still applicable to the types of cattle produced in the 1980's.

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CHAPTER III

THE PREDICTIVE ABILITY OF THE MURPHEY, USDA AND PROPOSED USDA BEEF CARCASS CUTABILITY REGRESSION EQUATIONS

Summary

The predictive abilities of the Murphey and the USDA cutability regression equations were examined using carcass information from 176 three-breed cross calves produced by Hereford X Angus (HA), Angus X Hereford, Simmental X Hereford (SH), Simmental X Angus (SA), Brown Swiss X Hereford (BSH), Brown Swiss X Angus (BSA), Jersey X Hereford (JH), and Jersey X Angus (JA) cows mated to Charolais and Limousin bulls. Additionally, a cutability prediction equation recently proposed by the USDA was evaluated. On an overall breed type and within breed type basis, the Murphy and the USDA cutability regression equations accounted for similar amounts of variation in actual carcass cutability (@43%). The proposed cutability regression equation had the lowest coefficient of determination with actual cutability on an overall basis as well as on a within breed types basis. The greatest amount of variation identified in actual measured cutability was among the steers out of AH and HA dams, while the lowest R^2

was found among steers out of JH and JA cows. Therefore, it appeared that each of the three studied prediction equations has its best fit with cattle that most closely resembled the type used in the original studies (British). Several one, two, three, four and five variable cutability prediction equations were derived. The regression equation with the smallest lack of fit error variance and the highest R^2, included 12th rib fat thickness, longissimus muscle area, hot carcass weight, marbling score and kidney, heart, and pelvic fat. The second best equation contained the same independent variables as found in the Murphey and the USDA cutability prediction equations. An equation including only 12th rib fat thickness, hot carcass weight, and longissimus muscle area as independent variables, as in the Proposed equation, appears to increase lack of fit of the equation considerably. Equation variables may not be capable of discerning breed type differences in fat partitioning. Carcasses from JA and JH dams had a significantly higher percent kidney, heart, and pelvic fat (total fat weight basis) than any other breed types. Carcasses from steers of BSH and BSA cows tended to have less fat deposited intermuscularly and more fat subcutaneously than the other breed types and significantly more internal fat than carcasses from steers out of AH and HA cows.

Introduction

Regression equations are often used to predict the cutability (percent of closely trimmed, boneless retail cuts from the round, loin, rib, and chuck) of beef carcasses. If such regression equations are implemented in U.S. Beef marketing programs they must be able to account for the variation in breed, age and feedlot history encountered in today's beef industry.

Numerous regression equations for estimating percentage of carcass cutability have been developed (Cole et al., 1962; Brungardt and Bray, 1983; Allen 1966; Abraham et al., 1968; Cross et al., 1973; Crouse et al., 1975; and Abraham et al., 1980). Regression equations developed in the 1960's used a sample of the total cattle population and accordingly, will perform best for cattle closely resembling the type of cattle in that sample. Therefore, caution should be taken when using these equations on dissimilar cattle types.

In 1965, USDA adopted an equation that predicted the percent closely trimmed, boneless retail cuts from the round, loin, rib, and chuck (cutability). This equation closely corresponds to the current USDA yield grading system. This equation (USDA equation) was developed and reported by Murphey et al. (1960). Murphey and associates also derived another commonly used regression equation (Murphey equation) that estimates cutability. Both cutability regression equations utilize 12th rib fat thickness, hot carcass weight, longissimus muscle area, and kidney, heart and pelvic fat. Both were developed from work done prior to 1960, on carcasses of unknown history. It can be speculated that the studied carcasses were from small framed cattle that were primarily Angus, Hereford, and Shorthorn. Obviously there have been several changes in beef cattle types since then, primarily due to the influx of new breeds and to the intensified use of crossbreeding.

USDA has recently proposed a new system for beef yield grading (Federal Register, USDA, 7CRS parts 53 and 54, 1984). The regression equation that corresponds to the proposed yield grade change was developed in 1974 and reported by Abraham et al. (1980). This regression equation (Proposed equation) uses only three regression variables 12th rib fat thickness, longissimus muscle area, and hot carcass weight. The regression equation's accuracy in predicting carcass cutability has not been examined using an independent data source.

Two primary objectives of this study were:

1) To examine the effectiveness of the USDA, Murphey, and the USDA Proposed cutability regression equations for several cattle breed types.

2) To examine the individual contributions of 12th rib fat thickness, hot carcass weight, rib eye area and

percent kidney, heart and pelvic fat (as a percent of carcass weight) in predicting carcass cutability.

Materials and Methods

Data Source

Data were collected from calves born in the years 1976 through 1979 as part of an experiment, in progress at the Oklahoma Agricultural Experiment Station, involving efforts to evaluate the lifetime productivity of various two-breed cows when mated to sires of a third breed. The crossbred dams involved in this study were produced in 1973, 1974, and 1975 by mating Angus, Hereford, Simmental, Brown Swiss, and Jersey bulls to Angus and Hereford cows.

Three-breed cross calves were produced by mating purebred Brahman, Charolais, and Limousin bulls to Hereford X Angus, Angus X Hereford, Simmental X Angus, Simmental X Hereford, Brown Swiss X Angus, Brown Swiss X Hereford, Jersey X Angus, and Jersey X Hereford two-breed cross cows. This study involved carcasses from 176 steers. The carcasses from these three-breed cross steers were separated into four breed type groups (Exotic X British, Exotic X SimmentalXBritish, Exotic X Brown SwissXBritish and Exotic X JerseyXBritish). A description of the breed type grouping procedure is presented in Table IV. Charolais sires produced 114 steers from 1976 to 1979 and Limousin bulls produced 62 steer offspring from 1978 to

TABLE IV

BREED TYPE GROUPING OF THREE-BREED CROSS CALVES

Breed Type	Abbreviation	Sire	Dam
Exotic X British	E X B	Charolais Limousin	A X H "
Exotic X SimmentalXBritish	E X SXB	Charolais Limousin	A X S or H X S "
Exotic X JerseyXBritish	E X JXB	Charolais Limousin	A X J or H X J "
Exotic X Brown SwissXBritish	E X BSXB	Charolais Limousin	A X BS or H X BS "

A, Angus; H, Hereford; S, Simmental; J, Jersey; BS, Brown Swiss; and X, cross

1979. Four Charolais bulls were used for the 1976 calf crop, while three of the original Charolais sires, plus six new Charolais bulls produced the 1977 calf crop. For the 1978 and 1979 calf crops, a different set of eight Limousin sires were used each year. Moreover, during the 1978 and 1979 calf crops, eight Charolais sires were also used each year; however, some were used during both breeding seasons. Limousin sires were selected by the North American Limousin Foundation. All but two of the Charolais sires were purchased from Oklahoma breeders and selected on the basis of growth performance. The remaining two Charolais sires were purchased from out-of-state.

Management from Birth to Slaughter

Calves were born and reared to weaning at the Lake Carl Blackwell Research Range, west of Stillwater. Thirty-five calves produced in 1978 were reared under dry-lot conditions until weaning. The remaining calves were reared by their dams to approximately 205 days on native and bermuda grass pastures. Bull calves were dehorned and castrated prior to one month of age.

Weaned calves were trucked to the Southwestern Livestock and Forage Research Station, El Reno, Oklahoma, and placed in their feedlot the following day. Steer calves of a specific three-breed cross were fed together in a pen assigned at random. Cattle were fed a finishing ration ad libitum (Table V). All cattle received Synovex-S

TABLE V

FINISHING RATION

Ingredient		Percent in Ration
Corn (IFN 4-02-931)		78
Alfalfa (IFN 1-00-063)		8
Cottonseed Hulls (IFN 1-01-599)		4
Molasses (IFN 1-01-599)		5
Supplement		5
[a]Soybean meal (IFN 5-04-604)	67.6%	
Urea	12.0	
Calcium Carbonate	10.0	
Salt plus Aurofac, Vitamin A, and Trace minerals	8.0	
Total		100

[a] The percent feedstuffs in the Supplement.

implants upon entering the feedlot. In 1979, half of the calves, in each pen, were reimplanted after approximately 120 days on feed. Cattle were weighed approximately every 30 days until the first steers were removed for slaughter. In the time period in which the cattle were being slaughtered, steers were weighed and examined for degree of finish at two-week intervals.

Steers were sent to slaughter when they were appraised as having attained an estimated low Choice (USDA, 1975) carcass quality grade. Visual appraisal of finish, average daily gain from the last weigh period, and carcass quality grade of previously slaughtered cattle were used by persons experienced in evaluating live slaughter cattle to determine when cattle reached the desired low Choice carcass quality grade. Prior to slaughter a final shrunk weight was obtained.

The cattle were transported to a commercial slaughter plant in Oklahoma City, Oklahoma from 1976 to 1977 and to one in Sand Springs, Oklahoma during 1978 and 1979.

Carcass Data Collection. Carcass data were obtained after a minimum of 48 hours of chilling. Carcasses were evaluated, by OSU Meat Scientists, for conformation, maturity, marbling score, percent kidney, heart, and pelvic fat, and quality grade according to specifications outlined by USDA (1975). Table VI presents the numerical system for

TABLE VI

NUMERICAL VALUES TO THE VARIOUS LEVELS OF CARCASS QUALITY GRADE AND MARBLING SCORE

Carcass Quality Grade	Marbling Score
Prime+[a] = 15	Abundant = 10
Prime = 14	Moderately Abundant = 9
Prime- = 13	Slightly Abundant = 8
Choice+ = 12	Moderate = 7
Choice = 11	Modest = 6
Choice- = 10	Small = 5
Good+ = 9	Slight = 4
Good- = 8	Traces = 3

[a] +,high; no symbol, average; and -, low;

describing marbling score and carcass quality grade. A tracing of the longissimus muscle and subcutaneous fat covering at the 12th rib was taken for measurement of the cross-sectional area of the longissimus muscle and to estimate single and average fat thickness. Single fat thickness was determined by measuring the distance from the longissimus muscle perpendicular to the fat covering at a point 3/4 of the distance of the longissimus muscle, from the vertebral end. Average fat thickness was the average of the fat thicknesses measured at the points 1/4, 1/2 and 3/4 of the distance of the longissimus muscle. These points were determined by bisecting the longest axis of the longissimus muscle with a line and then by dividing this line into four equal segments. A line was drawn perpendicular to the bisecting line at each of the segments. The points at which the lines crossed the longissimus muscle were the locations at which the fat measurements were taken.

Cutability (the percent of carcass weight as boneless, closely trimmed retail cuts from the round, loin, rib, and chuck) was estimated by Murphey's equation (Murphey et al., 1960) {cutability = 56.65 - 1.95 (12th rib fat thickness opposite the longissimus muscle, cm) - 1.06 (% kidney, heart, and pelvic fat) - .0176 (hot carcass weight, kg) + .1057 (longissimus area, cm^2)}, by the USDA equation (USDA, 1965) {cutability = 51.34 - 2.277 (single fat thickness at 12th, cm) - 0.462 (% kidney, heart and pelvic fat) + 0.1147 (longissimus area, cm^2) - 0.0205 (hot carcass weight minus kg of kidney, heart and pelvic fat, kg)}, and by the Proposed equation (Abraham et al., 1980) (cutability = 54.56 - 2.80 (single fat thickness, cm) - 0.0117 (hot carcass weight minus kg of kidney, heart and pelvic fat, kg) + .089 (longissimus area, cm^2).

The right side of each carcass was transported to the Oklahoma State University Meat Laboratory where they were stored at 2°C prior to performing more extensive carcass evaluation, including the determination of each carcass's actual cutability by the following procedure.

Cutting Procedure

The right side was first divided into standard wholesale cuts and an untrimmed weight of each wholesale cut recorded. The "thick cuts" including the round, loin, rib, and chuck, were trimmed to 8 mm external fat (determined by probing) and then individually weighed. Carefully controlled lean, fat and bone dissection procedures were then conducted on the loins, ribs, rounds and chucks. Individual weights of the separable lean, fat and bone were recorded for each wholesale cut. The "thin cuts", including the brisket, plate, flank, and shank were separated into lean, fat and bone. Individual weights of separable lean, fat and bone were recorded for each of the "thin cuts". Lean trim from each wholesale cut was adjusted to contain 25-30% fat. The following is a detailed explanation of the cutting procedure.

Forequarter

1) The rib and plate were removed from the chuck between the 5th and 6th ribs, by a straight line cut perpendicular to the dorsal side of the forequarter.

2) The plate was removed from the rib at a point 62% of the distance from the ventral edge of the 13th thoracic vertebral spinal canal to the sternal end of the 12th rib. A straight cut bisecting all rib bones was made parallel to the spinal canal. The plate was boned and the lean and fat separated.

3) The rib was trimmed to a 8 mm average external fat thickness. The longissimus muscle, cap muscle and external cover were removed leaving a 5.08 cm tail on the cut. Two, 5.08 cm steaks were removed, wrapped and frozen for further W-B Shear determination. The lean trim from the rib was adjusted to contain 25-30% fat.

4) The brisket and shank were removed from the chuck at a point 6.35 cm above the elbow and perpendicular to the 5th rib. A saw cut was made across the 5 ribs and the distal portion of the humerus bone. The shank was separated from the brisket at the "natural seam". The shank was boned and trimmed; while the brisket was trimmed of external fat to an average of 8 mm, boned and the "deckle" removed.

5) The untrimmed square cut chuck was trimmed to an external fat thickness 8 mm as determined by probe. The chuck was then boned as follows:

a) The outside chuck (clod) was removed by first cutting along the medial-dorsal portion of the humerus to the scapula-humerus joint. Then a cut was made along the ventral side of the scapula pine and to the cartilagenous end of the scapula. The muscle systems, inferior to the scapula spine and dorsal to the natural fat seam of the blade and arm face of the chuck were removed. The clod was trimmed of lean less than 5.08 cm thick. (b) The scapula, humerus, rib, and neck bones were removed (taking care to remove as muscle and fat free as possible), cleaned and weighed. (c) The inside chuck muscle system was removed by a cut parallel to the dorsal side of the chuck and even with the ventral edge of a fat pocket that was dorsal to the serratus ventralis muscle (located at the blade end). The anterior end of the inside chuck was removed at the point of the scapula-humerus articulation (the cut should bisect the Prescapular lymph node). (d) The lean trim from the chuck was adjusted to 25-30% fat.

Hindquarter

1) The flank was dropped from the outside edge of round to facilitate removal of kidney knob and pelvic fat. These fats were removed leaving no more than 1 cm of fat in

the tail of porterhouse steak section.

2) Removal of the flank was completed by cutting in a straight line from the outer edge of the round to a place at the 13th rib that corresponded to the point on the 12th rib marking the separation of rib and plate (62% of distance from edge of spinal canal on the thoracic vertebra to junction of rib end and beginning of the costal cartilage).

3) Round and loin separation occurred at a line determined by a point at the 4 1/2 sacral vertebrae and another point which marks the end of the head of the femur.

4) The round was boned by first removing the aitchbone; followed by the excision of the quadriceps, semimembranosus, biceps femoris, semitendinosus, adductor and gracillis muscles, by following natural seams around the respective muscles systems; next, the patella, shank, and femur were removed, taking care to remove as free of muscle as possible; and finally, muscle lean less than 5.1 cm thick were cut and put into lean trim and all muscles and muscle systems were trimmed of fats in excess of 8 mm.

5) The full loin was separated into sirloin and short-loin by cutting perpendicular to the lumbar vertebrae immediately in front of the forward edge of the ilium. The short-loin was trimmed of all fats in excess of 8 mm; while the sirloin was boned by first removing the butt end of psoas major and minor and then removing the ilium, last lumbar vertebra and 5 1/2 sacral vertebrae. The "Top sirloin butt" was trimmed of fats in excess of 8 mm.

Untrimmed wholesale cut, trimmed wholesale cut, and wholesale cut lean, fat and bone weights were recorded to the nearest one-tenth of a kilogram.

Calculating Actual Cutability

Actual carcass cutability was determined using the described cutting procedure and the following formula (Murphey, personal communication):

Cutability = (Weight in kg of the closely trimmed, boneless round, loin, rib, and chuck) multiplied by 100 and divided by (Side weight, kg - Kidney, heart and pelvic weight, kg).

Statistical Analysis

Pearson correlation coefficients were calculated to study the degree of association between actual carcass cutability and 12th rib fat thickness, hot carcass weight, longissimus muscle area, marbling score, and kidney, heart and pelvic fat. Additionally, simple correlation coefficients were derived to study the relationships between measures of carcass fatness (12th rib fat thickness, marbling score, and kidney, heart and pelvic fat) and percent of fat within particular depots on a carcass weight basis (percent total fat, percent fat in the primal cuts region, percent subcutaneous and percent intermuscular fat in the primal cuts region, and percent kidney, heart and pelvic fat). Coefficients were calculated according to the method described by Steel and Torrie (1980).

The predictive abilities of the Murphey, USDA, and Proposed cutability regression equations were examined using least squares regression techniques.

Least squares mean differences between actual cutability values and cutabilities values predicted using the Murphey, USDA, and Proposed equation were calculated by using actual cutability as a covariate in the full and reduced model. The full model included calf sire breed (SB), dam breed (DB), and year (Y) as fixed effects and SB X DB, SB X Y, DB X Y as interactions. Additionally, random nested effects included sire within year and calf sire breed. The reduced model, which included DB and SB was used to calculate least squares means.

New regression equations (OSU equations) were developed using 12th rib fat thickness, hot carcass weight, longissimus muscle area, marbling score, and kidney, heart and pelvic fat as independent variables. The all possible regression technique described by Neter et al. (1983) was used to develop the best one, two, three, four, and five variable models. R^2 and CP were used to discern the best equations as described by MacNeil (1983) and Neter et al. (1983).

Finally, least squares mean breed type fat partitioning differences were studied using the same full and reduced models described above, with the exception that percent total carcass fat trim was used in the model as a covariate, instead of actual cutability. Differences among breed types least square means were tested by Duncan's New Multiple Range Test as described by Steel and Torrie (1980).

Results and Discussion

Data Characterization

Means and standard errors of several common carcass measurements were calculated for each breed type and overall breed types (Table VII). Data ranges in hot carcass weight, longissimus muscle area, and kidney, heart and pelvic fat were similar to those normally encountered in the beef packing industry. However, because a visual live estimate of 12th rib fat thickness was used to determine whether carcasses would have a marbling score of Small, and thus grade U.S. Choice, the range in 12th rib fat thickness was not as large as is commonly found in the beef packing industry. Consequently, the majority of the carcasses were either yield grade 2 or 3, with only a few a having numerical yield grades of 1 and 4.

Correlation Coefficients

The degree of association between the percentage closely trimmed, boneless retail cuts in the round, loin, rib and chuck (actual cutability) and 12th rib fat thickness, hot carcass weight, longissimus muscle area,

TABLE VII

UNADJUSTED MEANS AND STANDARD ERRORS OVERALL AND AMONG CATTLE TYPES OF CARCASS TRAITS

Breed Types[a]	n	Fat[b],cm	LMA[b],cm^2	KHP[b],%	HCWT[b],kg	Y.G.[b]	Cutability[b],%
OVERALL	176	1.13	86.35	3.29	334.3	2.6	51.28
E X B	28	1.24 (.08)	83.90 (1.70)	3.14 (.13)	321.1 (5.37)	2.7 (.7)	51.01 (.54)
E X SXB	49	1.11 (.06)	91.16 (1.28)	3.10 (.10)	349.8 (4.07)	2.4 (.8)	52.22 (.40)
E X JXB	53	1.07 (.06)	81.94 (1.24)	3.10 (.10)	312.0 (3.91)	2.6 (.7)	50.64 (.39)
E X BSXB	46	1.16) (.06)	87.81 (1.28)	3.38 (.10)	351.6 (4.19)	2.7 (.7)	51.21 (.42)

a- Br, Brahman; B, British; BS, Brown Swiss; E, Exotic; J, Jersey; S, Simmental

b- Fat, 12th rib fat thickness; LMA, longissimus muscle area; HCWT, hot carcass weight; KHP, kidney, heart and pelvic fat; Y.G., Yield Grade; and Cutability, actual cutability;

Numbers in parenthesis are standard errors marbling score, and kidney, heart, and pelvic fat is found in Table VIII. In this study, the highest Pearson correlation coefficient was between actual cutability and 12th rib fat thickness. This agrees with the findings of Murphey et al. (1960), Cross et al. (1973) and Abraham et al. (1980). Longissimus muscle area (LMA) had the next highest correlation coefficient with actual cutability as determined by dissection methods used in this study. Many earlier researchers (Allen, 1966; Abraham et al., 1968; Cross, et al., 1973; and Abraham et al., 1980) reported that both hot carcass weight and kidney, heart and pelvic fat percentage had higher correlation coefficients with cutability than did LMA. However, those studies used a more homogeneous breed type (British), than was the case in this study. Therefore, greater variability in longissimus muscle area among carcasses of Exotic, Jersey, and Brown Swiss breeding may be responsible for this higher correlation coefficient. The mix of Exotic and dairy breeding may also have influenced the low, nonsignificant correlation coefficient between actual cutability and hot carcass weight. Notice that the heavier from Exotic X SimmentalXBritish steers carcasses had a higher mean actual carcass cutability than the lighter carcasses from Exotic X JerseyXBritish steers in this study (Table VII). Kauffman (1975) reported similar findings, when comparing the carcass cutability of Charolais and British cattle.

TABLE VIII

SIMPLE CORRELATION COEFFICIENTS BETWEEN CARCASS MEASUREMENTS AND WITH ACTUAL CARCASS CUTABILITY

Trait	Correlation With Actual Cutability
12th Rib Fat Thickness	-.51***
Hot Carcass Weight	-.12NS
Longissimus muscle area	.42***
Kidney, Heart, and Pelvic Fat	-.39***
Marbling Score	-.27***

*** P<.001

Predictive Ability of the Murphey, USDA and USDA Proposed Equations

Predictive Ability of Current Cutability Equations

On an overall and breed type basis, the Murphey and the USDA cutability regression equations accounted for similar amounts of variation in actual carcass cutability (Table IX). For all breed types, the USDA Proposed cutability regression equation, which was recently recommended by the USDA to replace the current USDA equation, had the lowest coefficient of determination (R^2) with actual cutability.

The greatest variation in actual cutability was identified within the Exotic X British carcasses while the lowest R^2 was with the Exotic X JerseyXBritish carcasses. MacNeil (1983) reported that regression equations perform best when they are applied to samples of the same population from which the equation was developed. From these data, it appears that all three prediction equations have their best fit among cattle that were closest to the type used in the original study (British). As cattle breed type became more diverse than the original populations, less variation was accounted for by these prediction equations (Table IX).

TABLE IX

COEFFICIENTS OF DETERMINATION (R^2) BETWEEN ACTUAL CARCASS CUTABILITY AND PREDICTED CUTABILTY FROM THE MURPHEY, USDA, AND PROPOSED REGRESSION EQUATIONS, OVERALL AND AMONG BREED TYPES

Breed Type	Murphey	USDA	Proposed
	R^2	R^2	R^2
Overall	.45	.43	.37
E X B	.57	.56	.53
E X SXB	.50	.53	.44
E X JXB	.28	.25	.21
E X BSXB	.52	.50	.46

a- Br, Brahman; B, British; BS, Brown Swiss; E, Exotic; J,Jersey; S, Simmental

Predicted Cutability vs Actual Cutability Values

The Murphey and USDA equations consistently underestimated actual cutability, while the Proposed equation overestimated actual cutability (Table X). Overestimation and underestimation of carcass cutability, by these regression equations, may be due to differences between our detailed carcass cutting procedure and the cutting procedure used to develop the USDA and Murphey equations (Murphey et al., 1960) and the cutting procedure implemented in the development of the Proposed equation (Abraham et al., 1980). Although the Proposed equation overestimated cutability from all cattle types, the Proposed equation tended ($P<.1$) to overpredict actual cutability more among Exotic X JerseyXBritish carcasses than with Exotic X British carcasses. Charles and Johnson (1976) and Kempster et al. (1976a) reported that dairy cattle tended to deposit a greater proportion of their total fat internally and less subcutaneously. Possibly, eliminating percent kidney, heart and pelvic fat as an equation variable, as in the Proposed equation, reduces equation accountability of fat partitioning in Dairy type cattle.

Development of an OSU Cutability Equation

In addition to evaluating existing cutability equations, new regression equations were developed using

TABLE X

OVERALL AND BREED TYPE LEAST SQUARES MEANS PERCENT CUTABILITY PREDICTED BY THE MURPHEY, USDA, AND PROPOSED REGRESSION EQUATIONS AND THE DIFFERENCE BETWEEN PREDICTED AND ACTUAL CUTUBILITY VALUES AT AN ADJUSTED ACTUAL CARCASS CUTABILITY

Breed Types[a]	Actual Cutability	Murphey Cut	[b]Difference	USDA Cut	Difference	Proposed Cut	Difference
Overall	51.28	50.09 (.16)	-1.19 (.16)	50.80 (.16)	-.49 (.16)	55.16 (.17)	3.88 (.17)
E X B	51.28	50.13 (.24)	-1.15 (.24)	50.67 (.24)	- .61 (.24)	54.87 (.23)	3.58 (.23)
E X SXB	51.28	50.18 (.19)	-1.10 (.19)	50.77 (.19)	- .51 (.19)	55.12 (.18)	3.83 (.18)
E X JXB	51.28	50.22 (.18)	-1.06 (.18)	51.09 (.18)	- .20 (.18)	55.45 (.17)	4.17 (.17)
E X BSXB	51.28	49.82 (.19)	-1.46 (.19)	50.57 (.19)	- .72 (.19)	55.05 (.18)	3.76 (.18)

a- Br, Brahman; B, British; BS, Brown Swiss; E, Exotic; J, Jersey; S, Simmental

b- Differences were calculated by subtracting the value from the predition equation from the actual cutability value.

Numbers in parenthesis are standard errors

Cut - Cutability

Note: No values were significantly different ($p<.05$)

12th rib fat thickness, longissimus muscle area, hot carcass weight, marbling score and percent kidney, heart, and pelvic fat as independent variables. Marbling score was included because of research cited by Kauffman et al. (1975) and Abraham (1980) in which they observed that marbling score improved the prediction of beef carcass cutability. These equations were developed for the purpose of evaluating each trait's contribution (singularly and in combination with other traits) in predicting carcass composition.

Developed Equations for Overall Breed Types

Several one, two, three, four and five variable regression equations were derived and their respective R^2 and C(P) (Mallow, 1973) are given in Table XII. R^2 is the most often used statistic when choosing the optimal prediction equation; however, the equation with the maximum R^2 is not necessarily the equation with the best fit (MacNeil, 1983). For groups of prediction equations with a constant number of variables, R^2 insures minimized residual variance; however, the inclusion of increased numbers of equation variables will increase R^2, but not necessarily reduce residual variance. Residual variance includes both squared true error and squared lack of fit. Mallow (1973) proposed a selection criterion (C(P)) for prediction equations, that identifies the relative contribution of squared true error and squared lack of fit. C(P) is

TABLE XI

CONTRIBUTIONS OF 12TH RIB FAT THICKNESS, KIDNEY, HEART, AND PELVIC FAT, LONGISSIMUS MUSCLE AREA, HOT CARCASS WEIGHT, AND MARBLING SCORE IN REGRESSION EQUATIONS THAT PREDICTS CARCASS CUTABILITY

Eqaution Variables	R^2	C(P)[a]
<u>One Variable Equations</u>		
Hot Carcass Weight(HCWT)	.01	150.3
Marbling Score(MS)	.07	131.5
Kidney, Heart, and Pelvic fat(KHP)	.15	106.3
Longissimus muscle area(LMA)	.18	97.6
12th Rib Fat Thickness(Fat)	.26	66 6
<u>Two Variable Equations</u>		
Fat HCWT	.26	71.5
Fat MS	.31	55.2
Fat LMA	.34	45.3
Fat KHP	.34	44.5
<u>Three Variable Equations</u>		
Fat HCWT MS	.31	56.6
Fat HCWT KHP	.35	45.5
^Fat LMA HCWT	.40	28.7
Fat LMA KHP	.41	24.4
<u>Four Variable Equations</u>		
Fat LMA HCWT MS	.43	19.8
Fat LMA KHP MS	.45	13.9
^^Fat LMA KHP HCWT	.46	12.2
<u>Five Variable Equations</u>		
Fat LMA KHP HCWT MS	.48	5.1

^ Equation with similar variables to the Proposed equation

^^Equation that contain variables similar to the Murphey and USDA equations

a - Mallows Test (Mallow, 1973)

TABLE XII

PARTIAL REGRESSION COEFFICIENTS AND R^2 FOR EQUATIONS THAT PREDICT ACTUAL CUTABILITY OVERALL BREEDS AND AMONG BREED TYPES

Equation[a]	R^2	Intercept	Fat	LMA	KHP	HCWT
Murphey		52.65	-1.95	.106	-1.06	-.0176
USDA		51.34	-2.28	.115	-.462	-.0205
Proposed		54.56	-2.80	.089		-.0117
OSU Equations						
Overall	.46	53.94	-2.33*	.117*	-.983*	-.0207*
E X B	.71	65.91	-4.27*	.045	-.742	-.0344*
E X SXB	.56	58.02	-1.73*	.131*	-.789	-.0381*
E X JXB	.28	53.04	-2.26*	.091	-1.03*	-.0126
E X BSXB	.54	59.74	-3.14*	.105*	-.778	-.0327*

a - E, Exotic; S, Simmental; BS, Brown Swiss; J, Jersey; B, British
Fat, 12th rib fat thickness; LMA, Longissimus Muscle Area;
KHP, Kidney, Heart and Pelvic Fat; and HCWT, Hot Carcass Weight
* -Indicates independent variables were significant ($p<.05$)

calculated using the following formula:

$C(P) = \{(SSy-SSr)\text{prediction error variance}\}-(n-2p)$

where:

SSY = Corrected total sum of squares

SSr = Sum of squares due to regression

n = Number of observations

p = Number of parameters in the equation

Therefore C(P) evaluates equations for biases, as well as for minimized squared errors. Models with a "close fit" have C(P)'s that approach the number of the independent variables in the equation plus one (P).

The best single variable equation for predicting actual cutability was 12th rib fat thickness. Nevertheless, it only accounted for 26% of the variation in cutability and had a high C(P). The regression equation with C(P) closest to P, as well as the highest R^2, included 12th rib fat thickness, longissimus muscle area, hot carcass weight, marbling score and kidney, heart, and pelvic fat. The second best equation contained the same independent variables as found in the Murphey and USDA equations. Recently, researchers have called for the elimination of the kidney, heart, and pelvic fat (KHP) from cutability prediction equations, such as in the Proposed equation, because of ease and efficiency of its removal on the slaughter floor, as well as because many packing plants trim KHP in order to lower the carcass's numerical yield grade. Using only 12th rib fat thickness, hot carcass weight, and longissimus muscle area as independent variables, such as in the Proposed equation, appears to increase C(P) considerably, indicating a greater total disparity between predicted and observed cutability values.

With the possible exception of the five variable model it appears no equation that uses 12th rib fat thickness, longissimus muscle area, hot carcass weight, and/or percent kidney, heart, and pelvic fat can accurately, and without bias, predict carcass cutability among the cattle in this study.

Equations Developed For Breed Types. Although it is not practical to develop equations for different breed types, separate equations were derived in order to look for possible breed biases encountered when using these types of variables. The partial regression coefficients within the regression equation developed to be used overall breed types were quite similar to those in the Murphey equation. Additionally, this overall equation identified variation in cutability similar to the amount identified by the Murphey and USDA equations (Table XII). The partial regression coefficients for each breed type equation were dissimilar to the coefficients in the Murphey, USDA and Proposed equations. The breed type equations also were considerably different from one another. This may indicate that different breed types have different relationships between actual cutability and the equation independent variables. Additionally, note that the Exotic X JerseyXBritish equation accounted for 28% of the variation in actual cutability among Jersey cross carcasses, while the Exotic X British equation had an R^2 of .71 when used on Exotic X British carcasses. Therefore, possibly implementing an equation that includes these four particular variables has limitations with certain cattle breed types. The use of more biologically diverse cattle in this study compared to earlier studies may thus account for discrepancies in reported R^2's.

Relationship Between Measures of Carcass Fatness and Fat Partitioning. Simple correlation coefficients were calculated between 12th rib fat thickness, marbling score and percent kidney, heart and pelvic fat and internal, intermuscular, and subcutaneous fat (Table XIII). This was done in order to examine the degree of association between measures of carcass fatness and percent fat in the intermuscular, subcutaneous, and internal depots. Fat thickness at the 12th rib had "medium" correlations with percent total carcass fat ($P<.001$), percent fat on a carcass basis in the primal cut region ($P<.001$), and with percent subcutaneous fat covering the primal cuts. Subjectively estimated percent kidney, heart and pelvic fat had only a .64 ($P<.001$) simple correlation coefficient with internal fat. Significant correlations were also found

TABLE XIII

SIMPLE CORRELATION COEFFICIENTS BETWEEN SELECTED FAT DEPOTS AND 12TH RIB FAT THICKNESS, MARBLING SCORE, AND KIDNEY, HEART AND PELVIC FAT

FAT DEPOT[a]	Correlation With 12th Rib Fat Thickness	Kidney, Heart and Pelvic Fat	Marbling Score
%Total Fat	.57***	.39***	.24**
%Primal Cuts Total Fat	.46***	.27***	.18**
%Primal Intermuscular Fat	.06	.006	.07
%Primal Subcutaneous Fat	.65***	.43***	.15+
%Internal Fat	.16*	.64***	.19**

a- Percent calculated on a percent of carcass weight basis.
*** - p<.001; ** - p<.01; * - p<.05; + - p<.10

between KHP and percent total carcass fat (P<.001) and percent subcutaneous fat in the primal cut region. Murphey et al. (1960) speculated that the typically large partial regression coefficient reported for KHP in cutability prediction equations indicated that KHP accounted for more than its own weight, possibly identifying variation in other fat depots. Marbling score does not appear to be highly related to the percent of fat in any of the fat depots. The three measures of carcass fatness all had low, nonsignificant simple correlation coefficients with percent intermuscular fat, on a carcass basis, in the primal cut region. Therefore, using fat thickness, kidney, heart and pelvic fat and/or marbling score as equation variables may not necessarily identify variations in percent fat within the intermuscular depot.

Fat Partitioning Among Breed Types

Possibly, the equation variables mentioned above were not able to account for fat partitioning variation among diverse cattle breed types. Several investigators reported fat partitioning differences among cattle of Exotic, Dairy and British breeding (Kempster et al., 1976; Charles and Johnson, 1976; Kempster, 1981; and Berg and Walters, 1983).

To determine if differences in fat partitioning existed between the breed types in this study, least squares means for the percent of fat in each depot was calculated on a total fat basis, adjusted to a constant average percent total carcass fat (20.97%) (Table XIV). Fat proportion in the respective depots followed trends in fat partitioning, previously reported by Berg and Butterfield (1976) and Kempster (1981). The greatest percentage of total fat was found in the intermuscular fat depot; percent subcutaneous fat was intermediate; and internal fat was the lowest in percent of total fat. Exotic X JerseyXBritish carcasses had a significantly higher percent of internal fat (total fat weight basis) than any other breed type. Additionally, Exotic X British carcasses had a lower ($P<.05$) percent internal fat than Exotic X Brown SwissXBritish carcasses. Carcasses with Brown Swiss Breeding tended to have less fat deposited intermuscularly and more fat subcutaneously than the other breed types ($P<.1$).

Conclusions

It appears that, from these data that, the Murphey and the USDA cutability equations have some breed type biases; therefore, care should be taken when applying these equations to other cattle breed types. Equations particularly overestimated carcasses from cattle that had 25% Jersey breeding compared to other breeds. Not only did these equations demonstrate lack of fit; the Overall OSU equation, that used the same independent variables, failed

TABLE XIV

BREED TYPE COMPARISONS OF FAT PARTITIONING AMONG INTERNAL, SUBCUTANEOUS, AND INTERMUSCULAR DEPOTS AT A CONSTANT PERCENT OF TOTAL CARCASS FAT BASIS

Breed Type	12th Rib Fat Thickness	%Total fat	%Primal fat	%Internal	a%Inter-muscular	a%Subcu-taneous
bE X B	1.19	20.97	53.77	18.93	29.32	24.44
	(.06)		(.80)	(.85)	(1.53)	(.96)
E X SXB	1.18	20.97	52.63	20.71	28.05	24.58
	(.05)		(.61)	(.65)	(1.17)	(.73)
E X JXB	1.05	20.97	52.74	23.75	28.64	24.09
	(.05)		(.58)	(.66)	(1.11)	(.70)
E X BSXB	1.14	20.97	52.12	21.48	26.06	26.07
	(.05)		(.62)	(.62)	(1.19)	(.74)

a - Subcutaneous and Intermuscular Fat in the round, loin, rib and chuck wholesale cuts

b - E, Exotic; B, British; BS, Brown Swiss; J, Jersey;

Note: Percent primal, perinephric, intermuscular, and subcutaneous fat were calulated on a total fat weight basis.

to account for more than 50% of the carcass variation in cutability. Of the three equations evaluated, the Proposed equation had the lowest R^2. The elimination of percent kidney, heart and pelvic fat, as an equation variable, may increase equation bias, particularly by overpredicting cutability of dairy breed type cattle. Possibly, these equation variables are not capable of discerning breed type differences in fat partitioning. Breed types had significantly different amounts of internal fat as a percent of total fat. Study differences exist when cattle only differ by 25% in their breeding (ie. 25% British, 25% Simmental, 25% Brown Swiss, or 25% Jersey). Possibly the differences stated above may be magnified if studied among cattle more diverse in biological type. Additionally, possibly new carcass measurements should be sought, in order to account for breed type fat partitioning differences in subcutaneous, intermuscular, and internal fat depots, such as measurements of fat between the longissimus muscle and spinalis dorsi muscle at the 12th rib interface.

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CHAPTER IV

CARCASS AND WHOLESALE CUT CHARACTERISTICS OF SEVERAL CATTLE TYPES SLAUGHTERED AT A CONSTANT MARBLING SCORE OF SMALL

Summary

Genetic contributions to Warner-Bratzler shear force values, carcass composition, fat partitioning, and wholesale cut distribution were analyzed using 216 three-breed cross steer calves. Calves were produced by mating Hereford X Angus (HA), Angus X Hereford, Simmental X Hereford (SH), Simmental X Angus (SA), Brown Swiss X Hereford (BSH), Brown Swiss X Angus (BSA), Jersey X Hereford (JH), and Jersey X Angus (JA) cows to Brahman, Charolais and Limousin bulls. All comparisons were made using least squares means adjusted to a common marbling score of Small. There were no sire breed differences among Warner-Bratzler shear force means; however calves from AH and HA cows required 1.19 kg less force to shear 2.54 cm cores than in carcasses from calves produced by SA, SH, BSA, and BSH cows. Charolais sired calves had carcasses with 2.18% more retail product and 2.15% less carcass fat than Brahman sired calves. Calves from SA and SH cows had 1.67% less carcass fat and 1.51% more retail product than calves from BSA and BSH cows. There were no differences in fat partitioning among fat depots of Limousin and Charolais sired steer carcasses; however Charolais sired steer carcasses deposited more fat intermuscularly and less fat subcutaneously than carcasses from Brahman sired calves. Calves from the JA and JH cow groups deposited a higher proportion of their fat internally, when compared to calves from the other cow groups. There were few differences in distribution of wholesale cuts (carcass weight basis) among calves from the various crossbred cow groups. Carcasses produced by Limousin sires had 1.1% more retail product in the untrimmed round than carcasses from Charolais sired calves. Carcasses from Charolais sired steers had a higher percent retail product in the hindquarter and within the thin cuts than carcasses from Brahman sires. Calves from SA and SH cows had more retail product in the round, rib, flank, plate and shank than counterparts from BSA and BSH cows. Stated differences were significant (P<.05).

Introduction

In the last 20 years there has been a marked increase in the use of crossbreeding to improve productivity of commercial beef herds in the U.S. In commercial crossbreeding systems many new breeds, as well as breeds used previously for milk production, have been implemented.

The correct selection of breeds is very important when developing a crossbreeding program for the purpose of improving carcass traits. For carcass traits, it has been shown that direct effects have been found to be a much more important consideration than heterosis (Gregory et al. 1966; Lasley et al. 1971).

Cattle breeds have been shown to make genetic contributions to carcass merit through a two-breed crossbreeding program in two manners. Koch et al. (1976) reported that Charolais, Limousin, and Simmental breeding increased retail product yield and lowered percent fat; while Hereford and Angus breeds resulted in carcasses with higher carcass quality grades. Incorporation of Brahman (Peacock et al. 1979) and dairy (Drewry et al., 1979) breeding into two breed-crossbreeding systems have also been shown to be helpful in combining superior carcass characteristics with other important economical and environmental traits, such as milking ability and heat resistance.

Numerous studies have reported the carcass merit of two-breed cross calves (Boyd, 1976; Koch et al., 1976; Koch et al., 1979; and Koch et al. 1982); however, only a few researchers have studied carcasses from three-breed cross steers. It would be expected that a breed's influence in a crossbreeding system is in direct proportion to their contribution of genes into the system. Therefore it is important to determine the potential value of incorporating three breeds into commercial herds.

The primary objective of this study was to compare carcass composition, wholesale cut distribution, and Warner-Bratzler shear force means of three-breed cross steers. In each case means were adjusted to a marbling score slaughter endpoint of Small. For young cattle (A maturity), a marbling score of Small is equivalent to a carcass quality grade of Low Choice (USDA, 1975). Low Choice is the desired economic endpoint in the beef cattle feeding industry; therefore, breed type comparisons made at this endpoint are directly applicable to present day industry concerns.

Materials and Methods

Data Sources. With one exception, a description of the steers used in this study was discussed previously by Hale et al. (1985a). The exception was that Brahman sired calves were studied in addition to Charolais and Limousin sired steers.

In brief, the data used in this study were collected as part of an Oklahoma Agricultural Experiment Station Animal Breeding research project, during the calving seasons of 1976 through 1979. Three-breed cross calves studied were produced by mating purebred Brahman, Charolais and Limousin bulls to Hereford X Angus (HA), Angus X Hereford (AH), Simmental X Angus (SA), Simmental X Hereford (SH), Brown Swiss X Angus (BSA), Brown Swiss X

Hereford (BSH), Jersey X Angus (JA), and Jersey X Hereford (JH) two-breed cross cows. A total of 216 steer calves were studied. Forty steer calves were from Brahman sires, produced during the 1976 and 1977 calf crops; Charolais sires produced 114 progeny from 1976 to 1979; and Limousin bulls produced 62 calves from 1978 to 1979. Three Brahman sires were used for the 1976 calf crop and three different Brahman sires were used for the 1977 season.

Feedlot History. Weaned calves were trucked to the Southwestern Livestock and Forage Research Station, El Reno, Oklahoma, and placed in the feedlot. Calves of a specific three-breed cross were fed together in a pen assigned at random. Steers were sent to slaughter when they were estimated to have a low choice carcass quality grade. Visual appraisal of finish, lack of gain from the last weigh period, and carcass quality grade of previously slaughtered cattle were used to estimate when cattle had reached the desired low choice carcass quality grade.

Carcass Measurements. Carcasses were evaluated 48 hours postmortem for conformation, maturity, marbling score, percent kidney, heart, and pelvic fat, and quality grade according to specifications outlined by USDA (1975). Single fat thickness, average fat thickness, and longissimus muscle cross-sectional area were measured at the 12th rib.

Cutting Procedure. After routine carcass measurements were taken, the right side of each carcass was used to determine carcass composition, as well as wholesale cut distribution. The side was first divided into standard wholesale cuts and the untrimmed weight of each cut was recorded. The thick cuts (round, loin, rib, and chuck) were trimmed to 8 mm external fat (determined by probing) and individually weighed. Then each thick cut's lean, fat, and bone was separated and weighed. The thin cuts (brisket, plate, flank, and shank) were directly separated into lean, fat and bone and weighed. Lean trim from each portion was adjusted to contain 25-30% fat.

Actual cutability in this section was determined using the following formula calculated using side weight minus kidney, heart, and pelvic fat in the denominator:

$$\frac{\text{(Weight in kg of the round, loin, rib, and chuck)}}{\text{(Side weight, kg - kidney, heart and pelvic weight, kg)}}$$

Percentages of subcutaneous and intermuscular fat in the primal cuts region and internal fat were determined on a total fat weight basis.

Warner-Bratzler Shear. The Warner-Bratzler Shear apparatus was used to objectively measure meat tenderness. Two 5.08 cm thick steaks were excised from the loin end of the wholesale rib between. Steaks were first broiled to an internal temperature of 65°C and then chilled overnight in a 2°C cooler. Tenderness was then determined by averaging the shear force values determined from shearing six cores (three 2.54 cm diameter cores taken from each steak). A core was removed from each of three areas of the steak: dorsal, medial, and lateral according to the procedure described by Hedrick et al., (1968).

Statistical Analysis. Crossbred cow group effects were analyzed by least square mixed model procedure (Harvey, 1977; 1982). Four linear contrasts were examined: Contrast 1 (C_1) compared Hereford dam effects and Angus dam effects. Contrast 2 (C_2) compared calves from AH and HA cows with calves from SA, SH, BSA, and BSH cows. Contrast 3 (C_3) examined the difference between steers from AH and HA cows and steers from JA and JH cows. Contrast 4 (C_4) compared carcass traits of calves from SH and SA cows with those of calves from BSA and BSH cows. Marbling was included as a covariate in each crossbred cow group comparison model.

Sire breed effects were tested using a full model that included calf sire breed (SB), dam breed (DB), and year (Y) as fixed effects and SB X DB, SB X Y, DB X Y as interactions. Additionally, random nested effects included sire within year and calf sire breed. The mean square for sires within years and within calf sire breed was used to test for significance of sire breed effects. Marbling score was used in the full model as a covariate. Brahman vs Charolais comparisons and Charolais vs Limousin comparisons were made. Brahman vs Limousin sire breed comparisons were not made because they were not studied simultaneously in any year of the study.

Results and Discussion

Part I: Crossbred Cow Group Comparisons

Crossbred Cow Group Comparisons of Three-Breed Cross Calves Carcass Merit

W-B Shear Values and Carcass Composition

Least square means for Warner-Bratzler Shear values and carcass composition are presented by crossbred cow group in Table XIV. Contrasts between crossbred cow groups for these traits are in Table XIVA.

Loin steaks from steer carcasses produced by Simmental X Hereford (SH), Simmental X Angus (SA), Brown Swiss X Hereford (BSH) and Brown Swiss X Angus (BSA) crossbred cows had greater Warner-Bratzler shear values ($P<.001$) than loin steaks from steers produced by Angus X Hereford (AH) and Hereford X Angus (HA) crossbred cows.

There were no significant contrast differences in percent actual cutability (percent closely trimmed, boneless round, loin, rib and chuck). However, calves from SA and SH cows tended to have a higher percent actual cutability (P<.10) than calves from BSA and BSH cows. Similarly, there were no significant differences in percent carcass bone, among cross bred dam groups.

Differences were encountered in percent retail product and in percent carcass fat. SH and SA cow groups produced steers yielding a higher percentage (P<.01) retail product (percent closely trimmed, boneless retail cuts from the round, loin, rib, chuck, flank, plate, brisket, and shank, with lean trim adjusted to 25% fat) and a lower percent (P<.01) carcass fat than BSA and BSH steers. Steers from Jersey X Angus (JA) and Jersey X Hereford (JH) cow groups, also appeared to have a lower percent retail product and higher percent carcass fat than calves from SA and SH cows. Koch et al. (1976) also reported JA and JH calves had a lower percent retail product, higher percent carcass fat, and similar percent carcass bone when compared to SA and SH carcasses. Koch et al. (1979) found AH and HA calves had a similar percent carcass bone, a lower percent retail product, and a higher percent carcass fat than BSA and BSH calves, when slaughtered at a Small marbling score endpoint.

Fat Partitioning. Steer carcasses produced from the larger framed cow groups (BSA, BSH, SA, and SH) deposited a greater proportion of total fat internally than steer carcasses produced from AH and HA cross-bred cow groups (P<.03) (Table XV and XVA). Moreover, steers from JA and JH cow

TABLE XV

LEAST SQUARES MEANS, BY CROSSBRED COW GROUP, FOR WARNER-BRATZLER SHEAR VALUES AND CARCASS COMPOSITION

	Crossbred[a] Cow Group							
Trait	HA	AH	SA	SH	BSA	BSH	JA	JH
W-B Shear value,kg	6.27	6.34	6.92	6.76	6.76	6.96	6.40	6.59
Actual[b] Cutability,%	51.43	51.00	52.05	51.86	51.37	50.58	50.45	50.90
Fat Trim,%	20.83	21.79	20.43	20.44	21.78	22.42	22.08	21.62
Retail[c] Product,%	63.20	62.61	63.70	63.57	62.72	61.53	61.94	62.27
Bone,%	14.68	14.70	14.80	14.73	14.74	14.44	14.65	14.99

a - H, Hereford; A, Angus; S, Simmental; BS, Brown Swiss; J, Jersey

b - Actual Cutability, percent closely trimmed, boneless retail cuts from the round, loin, rib, and chuck

c - Retail Product, percent closely trimmed, boneless round, loin, rib, chuck, flank, plate, brisket, shank plus lean trim, adjusted to 25% fat

TABLE XVA

CROSSBRED COW GROUP CONTRASTS AMONG LEAST SQUARES MEANS FOR WARNER-BRATZLER SHEAR VALUES AND CARCASS COMPOSITION

Trait	Contrast			
	C_1	C_2	C_3	C_4
Warner-Bratzler Shear,kg	-.17±.34	-1.19±.23**	-.40±.48	-.05±.47
Actual Cutability,%	.24±.39	-.25±.53	.54±.57	.98±.54+
Fat,%	-.29±.47	.04±.65	-.54±.69	-1.67±.66*
Retail Product,%	.40x±.5	-.18±.61	.60±.65	1.51±.62*
Bone,%	.01±.15	.01±.20	.13±.21	.18±.20

C_1 = Angus dams - Hereford dams
C_2 = Angus X Hereford and Hereford X Angus crossbred cow groups - Simmental X Angus, Simmental X Hereford, Brown Swiss X Angus, and Brown Swiss X Hereford crossbred cow groups
C_3 = Angus X Hereford and Hereford X Angus crossbred cow groups - Jersey X Angus and Jersey X Hereford crossbred cow groups
C_4 = Simmental X Angus, Simmental X Hereford crossbred cow groups - Brown Swiss X Angus and Brown Swiss X Hereford crossbred cow groups
**p<.01, *p<.05, +p<.10

groups tended to have a higher percent internal fat than any other steers and a significantly greater proportion of internal fat than carcass steers from AH and HA cows. Several investigators have found that cattle with dairy breeding tend to deposit a higher proportion of their fat as kidney, heart and pelvic fat than British cattle (Charles and Johnson, 1976; Kempster et al. 1976; and Kempster, 1981).

Steers carcasses from BSA and BSH cows had a higher percent of total fat ($P<.05$) in the form of subcutaneous fat than steers from SA and SH cows. No significant subcutaneous and intermuscular fat partitioning contrast differences were found between calves from AH or HA cows and those from JA, JH, BSA, BSA, SA, or SH cows. These findings support those of Kempster et al. (1976), who reported rates of subcutaneous and intermuscular fat deposition were similar for Angus and Holstein steers; but contradict the findings of Charles and Johnsons (1976), that British cattle had higher subcutaneous fat to intermuscular fat ratios than both Dairy and Exotic type steers.

Untrimmed Wholesale Cut Weight Distribution

The least squares means of the percent untrimmed wholesale cuts on a carcass weight basis are presented in Table XVI and crossbred cow group contrasts are reported in

TABLE XVI

LEAST SQUARES MEANS, BY CROSSBRED COW GROUP, FOR FAT PARTITIONING TRAITS

	Crossbred[a] Cow group							
Traits	HA	AH	SA	SH	BSA	BSH	JA	JH
Internal[b] Fat,%	19.04	18.80	21.03	21.70	21.53	20.97	23.08	22.75
Subcutaneous[bc] Fat,%	25.53	23.81	22.79	25.05	24.29	26.85	23.92	23.81
Intermuscular[bc] Fat,%	27.37	29.51	30.58	27.67	29.15	25.22	29.37	28.94

a - H, Hereford; A, Angus; S, Simmental; BS, Brown Swiss; J, Jersey
b - Percentages calculated on a total fat weight basis
c - Percent of depot fat within the primal cut region

Table XVIA.

There were no significant differences in untrimmed wholesale cut distribution between steers from AH or HA cows and calves from SA, SH, BSA, or BSH cows. There were differences in untrimmed percent round (.5%, $P<.05$), rib (-0.22%, $P<.05$) and flank (-.37%, $P<.05$) between AH and HA produced steers and JA and JH produced steers. Calves from SA and SH cows had lower percent ($P<.05$) wholesale rib and tended to have a lower percent wholesale flank than calves from BSA and BSH cows (Table XVII).

It appears that steers from different crossbred cow groups did not exhibit any major differences in wholesale cut distribution. Similar findings were reported by Berg and Butterfield (1976).

Retail Product Within Each Wholesale Cut

Least squares means for percent retail product (on a wholesale cut weight basis) in each wholesale cut are presented in Table XVII and crossbred cow group contrasts in Table XVIIA.

Steers from SA and SH cows had a higher percent retail product in the round (1.13%, $P<.05$), rib (1.95%, $P<.05$), flank (3.98%, $P<.01$), plate (2.15%, $P<.05$), and shank (1.25%, $P<.05$) than steers out of BSA and BSH cow groups. SA and SH cow groups also tended ($P<.10$) to produce calves with 1.4% more shortloin and 2.43% more brisket than calves from BSA and BSH cow groups. Percent

TABLE XVIA

CROSSBRED COW GROUP CONTRASTS AMONG LEAST SQUARES MEANS FOR FAT PARTITIONING TRAITS

Trait	Contrast			
	C_1	C_2	C_3	C_4
Internal Fat,%[a]	.12±.69	-2.38±.95**	-4.00±1.0**	.30±.96
Subcutaneous Fat,%[a]	-.74±.60	-.08±.82	.81±.88	-1.65±.83*
Intermuscular Fat,%[a]	1.28±.83	.29±1.1	-.72±1.2	1.95±1.2+

C_1 = Angus dams - Hereford dams
C_2 = Angus X Hereford and Hereford X Angus crossbred cow groups - Simmental X Angus, Simmental X Hereford, Brown Swiss X Angus, and Brown Swiss X Hereford crossbred cow groups
C_3 = Angus X Hereford and Hereford X Angus crossbred cow groups - Jersey X Angus and Jersey X Hereford crossbred cow groups
C_4 = Simmental X Angus, Simmental X Hereford crossbred cow groups - Brown Swiss X Angus and Brown Swiss X Hereford crossbred cow groups
**p<.01, *p<.05, +p<.10

TABLE XVII

LEAST SQUARES MEANS, BY CROSSBRED COW GROUP, FOR INDIVIDUAL PERCENTAGE UNTRIMMED WHOLESALE CUTS, ON A CARCASS WEIGHT BASIS

Trait	Crossbred[a] Cow group							
	HA	AH	SA	SH	BSA	BSH	JA	JH
Round,%	24.3	24.7	24.4	24.6	24.0	24.4	24.0	24.0
Sirloin,%	8.1	8.1	8.1	8.2	8.1	8.0	8.0	8.3
Shortloin,%	7.2	6.8	6.9	7.1	7.0	7.1	7.2	7.0
Rib,%	8.0	7.9	8.0	7.9	8.2	8.2	8.2	8.1
Chuck,%	27.7	27.6	28.3	27.7	28.1	27.6	27.7	27.9
Flank,%	6.8	7.1	6.7	6.8	6.9	7.2	7.4	7.2
Plate,%	9.7	9.7	9.6	9.7	9.7	9.7	9.7	9.4
Brisket,%	4.7	4.4	4.3	4.4	4.3	4.4	4.3	4.5
Shank,%	3.6	3.7	3.7	3.7	3.6	3.6	3.6	3.6

a - H, Hereford; A, Angus; S, Simmental; BS, Brown Swiss; J, Jersey

TABLE XVIIA

CROSSBRED COW GROUP CONTRASTS AMONG LEAST SQUARES MEANS FOR PERCENT UNTRIMMED WHOLESALE CUTS ON A CARCASS WEIGHT BASIS

Trait	Contrast			
	C_1	C_2	C_3	C_4
Round,%	-.26±.18	.15±.25	.50±.26*	-.30±.25
Sirloin,%	-.04±.09	.00±.11	-.05±.13	.10±.11
Shortloin,%	.08±.26	-.03±.09	-.10±.10	-.06±.09
Rib,%	.09±.07	-.11±.10	-.22±.11*	-.20±.10*
Chuck,%	.25±.14	-.24±.20	-.14±.21	.13±.20
Flank,%	-.11±.11	.05±.15	-.37±.16*	-.29±.15+
Plate,%	.08±.12	-.03±.16	-.11±.17	-.07±.16
Brisket,%	-.01±.10	.18±.13	.14±.14	.00±.13
Shank,%	-.04±.04	.03±.05	.07±.05	.10±.05

C_1 = Angus dams - Hereford dams

C_2 = Angus X Hereford and Hereford X Angus crossbred cow groups - Simmental X Angus, Simmental X Hereford, Brown Swiss X Angus, and Brown Swiss X Hereford crossbred cow groups

C_3 = Angus X Hereford and Hereford X Angus crossbred cow groups - Jersey X Angus and Jersey X Hereford crossbred cow groups

C_4 = Simmental X Angus, Simmental X Hereford crossbred cow groups - Brown Swiss X Angus and Brown Swiss X Hereford crossbred cow groups

**$p<.01$, *$p<.05$, +$p<.10$

carcass fat differences between these groups (Table XV) (BSA and BSH 1.47% higher carcass fat than SA and SH) may contribute to calves from SA and SH having a higher percent retail product in most wholesale cuts.

Steers from AH and HA cows had 2.38% more plate than calves from JA and JH cows. No other significant differences were encountered between AH and HA cow group calves and those produced from SA, SH, BSA, BSH, JA, or JH cows when slaughtered at a constant marbling score of Small.

Conclusions. Steers from JA, JH, BSA, and BSH cows appeared to deposit fat differently than steers from AH, HA, SA, and SH cows. Calves with Jersey breeding had a higher proportion of fat deposited as kidney, pelvic and heart fat; while calves with Brown Swiss breeding tended to deposit more fat subcutaneously.

Few differences were found in wholesale cut distribution or in the distribution of retail product within each wholesale cut, between calves from AH or HA cows and calves from JA, JH, SA, SH, BSA, or BSH cows. In contrast, several differences were found between SA and SH cow group steers and BSA and BSH cow group steers.

Part II: Sire Breed Comparisons

Carcass Comparisons of
Brahman, Charolais, Limousin Sired Steers

W-B Shear Force Values. When means were adjusted to a constant marbling score, there were no significant differences between Warner-Bratzler Shear values from steer carcasses produced from Brahman and Charolais sires (Table XIX). Additionally, there were no significant differences in Warner-Bratzler Shear values between Charolais and Limousin sired carcasses. Therefore, in this study, steers with similar marbling scores, had comparable objective tenderness ratings.

Carcass Composition. Although the percent of closely trimmed, boneless retail cuts from the round, loin, rib and chuck (actual cutability) were similar for Brahman and Charolais sired steers, Brahman sired carcasses had a lower ($P<.03$) percent carcass retail product and a higher ($P<.05$) percent of total carcass trimmable fat (24.31% Brahman vs 22.16% Charolais) (Table XVIII). Percent carcass bone did not differ significantly between Brahman and Charolais sired steers.

Carcasses produced from Limousin and from Charolais sires did not differ significantly in percent actual cutability, percent retail product and percent carcass trimmable fat. Limousin sired carcasses had a lower

TABLE XVIII

LEAST SQUARES MEANS, BY CROSSBRED COW GROUP, FOR PERCENT RETAIL PRODUCT IN EACH WHOLESALE CUT, ON A UNTRIMMED WHOLESALE CUT WEIGHT BASIS

	Crossbred[a] Cow Group							
Trait	HA	AH	SA	SH	BSA	BSH	JA	JH
Round,%	68.6	68.4	69.8	69.6	69.2	68.0	68.3	68.5
Sirloin,%	65.3	65.5	66.2	66.6	65.8	66.1	64.5	64.5
Shortloin,%	82.9	82.8	84.5	83.8	83.0	81.5	83.5	82.9
Rib,%	61.9	62.1	61.8	62.1	60.2	59.8	60.5	60.7
Chuck,%	67.0	66.0	66.8	66.6	66.5	65.6	65.0	66.0
Flank,%	42.1	40.2	43.1	42.5	39.8	37.9	41.3	40.1
Plate,%	50.9	49.6	49.6	50.2	48.9	46.6	47.4	48.4
Brisket,%	47.1	49.4	49.6	49.1	47.9	45.9	48.4	47.3
Shank,%	50.5	49.6	50.8	50.4	49.6	49.1	50.8	49.7

a - H, Hereford; A, Angus; S, Simmental; BS, Brown Swiss; J, Jersey

TABLE XVIIIA

CROSSBRED COW GROUP CONTRASTS AMONG LEAST SQUARES MEANS FOR RETAIL PRODUCT IN EACH WHOLESALE CUT, ON A UNTRIMMED WHOLESALE CUT WEIGHT BASIS

Trait	Contrast			
	C_1	C_2	C_3	C_4
Round,%	.35±.43	-.65±.45	.12±.48	1.13±.45*
Sirloin,%	-.25±.65	.74±.90	.94±.95	.45±.90
Shortloin,%	.73±.73	-.35±1.0	-.35±1.1	1.40±1.0+
Rib,%	-.07±.70	1.05±.95	1.42±1.0	1.95±.95*
Chuck,%	.30±.50	.12±.69	.98±.73	.65±.70
Flank,%	1.40±1.0	.30±1.5	.42±1.5	3.98±1.5**
Plate,%	.50±.76	1.42±1.0	2.38±1.1*	2.15±1.0*
Brisket,%	.35±.92	.10±.12	.38±.13	2.43±1.3+
Shank,%	.71±.42	.08±.57	-.18±..60	1.25±.58*

C_1 = Angus dams - Hereford dams

C_2 = Angus X Hereford and Hereford X Angus crossbred cow groups - Simmental X Angus, Simmental X Hereford, Brown Swiss X Angus, and Brown Swiss X Hereford crossbred cow groups

C_3 = Angus X Hereford and Hereford X Angus crossbred cow groups - Jersey X Angus and Jersey X Hereford crossbred cow groups

C_4 = Simmental X Angus, Simmental X Hereford crossbred cow groups - Brown Swiss X Angus and Brown Swiss X Hereford crossbred cow groups

**$p<.01$, *$p<.05$, +$p<.10$

percent ($P<.01$) carcass bone than steer carcasses produced by Charolais bulls (14.25% Limousin vs 14.87 Charolais) (Table XVIII).

Fat Partitioning. Percent fat in the internal, intermuscular, and subcutaneous fat depots was calculated on a percent of total fat basis (Table XIX).

Sire breed effects were not an important contributor to variation in percent kidney, heart and pelvic fat, while Brahman sired carcasses had a lower percent ($P<.05$) intermuscular fat (33.43% vs 37.67%) and a greater percent ($P<.01$) subcutaneous fat (23.47 vs 20.43) than carcasses produced from Charolais bulls. Consequently, the ratio of subcutaneous fat to intermuscular fat was higher for Brahman sired carcasses (.70:1) than for Charolais sired carcasses (.54:1). Berg and Walters (1983) reported similar trends between British and Exotic cattle; with British type cattle having a higher subcutaneous fat to intermuscular fat ratio than Exotic type cattle.

When means were adjusted to a constant marbling score of Small, Charolais and Limousin bulls sired steers with similar amounts of fat in the internal, intermuscular, and subcutaneous fat depots (Table XIX).

Percent Untrimmed Wholesale Cuts. Several investigators have reported that at definite physiological maturity endpoints, carcasses from different biological breed types had similar carcass weight distribution (Callow, 1961 and

TABLE XIX

LEAST SQUARES MEANS OF BRAHMAN, CHAROLAIS, AND LIMOUSIN SIRED CALVES FOR WARNER-BRATZLER SHEAR FORCE VALUES AND CARCASS COMPOSITION

Sire Breed	Years	Shear kg	%Actual[a] Cutability	%Retail[b] Product	Fat %	Bone %
Brahman	1976-77	16.1 ±.5	51.06 ±.81	61.70 ±.91	24.31 ±.96	14.77 ±.31
Charolais	1976-77	15.4 ±.4	52.10 ±.66	63.88 ±.75	22.16 ±.80	14.92 ±.25
P<		NS	NS	.03	.05	NS
Limousin	1978-79	13.7 ±.6	51.12 ±.64	62.65 ±.73	20.74 ±.67	14.25 ±.14
Charolais	1978-79	14.1 ±.6	50.85 ±.62	62.47 ±.71	20.53 ±.65	14.87 ±.13
P<		NS	NS	NS	NS	.01

a - Actual Cutability = percent closely trimmed, boneless from the round, loin, rib, and chuck

b - Retail Product = percent closely trimmed, boneless round, loin, rib, chuck, flank, plate, brisket, shank plus lean trim, adjusted to 25% fat

c - Percentages calculated on a percent of total carcass fat basis

Note: Subcu = Subcutaneous; Seam fat = Intermuscular fat

Berg and Butterfield, 1976). Similarly, in this study, no significant differences were found between percent untrimmed wholesale cuts (carcass weight basis) from Brahman and Charolais sired carcasses (Table XX).

Limousin and Charolais sired carcasses did not differ significantly in untrimmed wholesale cut distribution of the round, sirloin shortloin, rib, chuck, flank, and plate and brisket (Table XX). Differences were found for the percent of shank on a carcass weight basis, with a Charolais carcasses having .2% more shank ($P<.01$) than Limousin carcasses. Therefore, there was little alteration in wholesale cut weight distribution, by the incorporation of breeding from these three different sire breed groups.

<u>Percent Retail Product Within Wholesale Cuts</u>. Although no significant differences were found in untrimmed wholesale cut distribution, sire breed differences were found among the percent retail product within certain wholesale cuts (Table XXI). Charolais sired calves had a greater percent retail product within the round ($P<.01$), sirloin ($P<.01$), flank ($P<.01$), plate ($P<.02$), brisket ($P<.04$), and shank ($P<.04$) than Brahman sired calves. There was also a tendency for Charolais sired carcasses to have higher proportion ($P<.1$) of retail product within the shortloin. Brahman and Charolais sire breed differences in percent retail product were found primarily in the hindquarter and

TABLE XX

LEAST SQUARES MEANS OF BRAHMAN, CHAROLAIS, AND LIMOUSIN SIRED CALVES FOR FAT PARTITIONING

Sire Breed	Year	Internal Fat,%^{a}	Seam Fat,%^{ab}	Subcutaneous Fat,%^{ab}
Brahman	1976-77	19.35 ±1.3	33.43 ±2.4	23.47 ±.83
Charolais	1976-77	19.45 ±1.0	37.67 ±1.9	20.43 ±.71
p<		NS	.05	.01
Limousin	1978-79	21.14 ±1.2	23.96 ±1.4	26.82 ±1.1
Charolais	1978-79	21.51 ±1.1	24.39 ±1.4	26.19 ±1.1
p<		NS	NS	NS

a - Percentages calculated on a percent of total carcass fat basis

b - Percent of depot fat within the primal cuts only

NS - Nonsignificant

TABLE XXI

LEAST SQUARES MEANS OF BRAHMAN, CHAROLAIS, AND LIMOUSIN SIRED CALVES FOR INDIVIDUAL PERCENTAGE UNTRIMMED WHOLESALE CUT, ON A CARCASS WEIGHT BASIS

Sire Breed	% Round	% Sirloin	% Shortloin	% Rib	% Chuck	% Flank	% Plate	% Brisket	% Shank
1976-77									
Brahman	24.5 ±.3	7.1 ±.2	7.2 ±.09	8.0 ±.1	27.9 ±.2	7.0 ±.2	8.9 ±.2	4.6 ±.3	3.8 ±.08
Charolais	24.5 ±.3	7.2 ±.2	7.0 ±.08	8.0 ±.1	28.0 ±.09	6.8 ±.2	9.3 ±.2	4.4 ±.2	3.8 ±.07
P<	NS	NS	NS	NS	NS	NS	NS	NS	NS
1978-79									
Limousin	24.2 ±.2	8.1 ±.1	7.0 ±.07	8.1 ±.08	27.9 ±.3	7.1 ±.1	8.9 ±1.0	4.3 ±.09	3.5 ±.03
Charolais	24.2 ±.2	8.1 ±.1	7.0 ±.07	8.1 ±.08	28.0 ±.3	7.0 ±.1	9.3 ±1.0	4.5 ±.09	3.7 ±.04
P<	NS	NS	NS	NS	NS	NS	NS	.10	.01

NS - Nonsignificant

TABLE XXII

LEAST SQUARES MEANS OF BRAHMAN, CHAROLAIS, AND LIMOUSIN SIRED CALVES FOR PERCENT RETAIL PRODUCT IN EACH WHOLESALE CUT, ON A UNTRIMMED WHOLESALE CUT WEIGHT BASIS

	Retail Product(Untrimmed Cut Weight Basis)								
Sire Breed	% Round	% Sirloin	% Shortloin	% Rib	% Chuck	% Flank	% Plate	% Brisket	% Shank
1976-77									
Brahman	67.7	62.5	82.8	58.3	67.4	36.7	47.7	43.3	48.6
	±.5	±1.0	±1.1	±1.3	±1.3	±1.5	±1.4	±2.6	±.6
Charolais	69.5	65.8	84.7	60.3	67.3	44.4	51.4	49.8	50.0
	±.4	±.9	+.9	±1.0	±1.0	±1.3	±1.2	±2.0	±.5
P<	.01	.01	.10	NS	NS	.01	.02	.04	.04
1978-79									
Limousin	68.9	66.2	82.5	62.4	65.6	40.2	48.9	48.4	51.2
	±.5	±1.0	±1.1	±1.3	±1.3	±1.5	±1.4	±2.6	±.6
Charolais	67.8	65.7	82.3	62.7	65.6	40.3	48.9	49.0	50.1
	±.4	±.9	+.9	±1.0	±1.0	±1.3	±1.2	±2.0	±.5
P<	.01	NS	NS	NS	NS	NS	NS	NS	NS

NS - Nonsignificant

in the thin cuts (flank, plate, brisket, and shank) region.

Carcasses from Limousin sires had a higher percent (P<.01) retail product in the round than Charolais sired carcasses (68.9% Limousin vs 67.8% Charolais). There were no other wholesale cut, percent retail product differences between Limousin and Charolais sired carcasses (Table XXI).

Conclusions. It appears that because Limousin and Charolais sired calves are similar in biological type, few differences are found in carcass merit, when both groups are slaughtered at a constant marbling score endpoint of Small.

In contrast, significant sire effects were found between carcasses from Brahman and Charolais sired calves (two biologically diverse breed types). Brahman sired calves were observed to deposit a lower percent intermuscular fat and a higher percent subcutaneous fat than Charolais sired steers. Additionally, when steer means are adjusted to a constant marbling score of Small, carcasses from Brahman sired calves have a lower percent carcass fat, lower percent retail product in the hindquarter and lower percent retail product in the thin cuts than Charolais sired counterparts.

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CHAPTER V

PREDICTION OF CARCASS YIELD GRADE USING BREED AND FEEDLOT HISTORY AS REGRESSION EQUATION VARIABLES

Summary

Two data sources were used in this study. Source I included data from 1810 steers accumulated from 14 independent nutrition feedlot trials conducted at either the Oklahoma Agricultural Experiment Station or the Panhandle State University. Source II data were collected from 482 calves reared from the 1978 through 1981 calf-crops of a crossbreeding study designed to evaluate productivity of various two-breed cross cows. The best five variable yield grade prediction equation developed from Data Source I, was selected by using maximum R^2, which represents the amount of variation that an equation identifies in yield grade and by minimum C(P), which indicates the closeness of fit. The selected equation included days in the feedlot, days in the feedlot^2, days in the feedlot^3, feedlot average daily gain, and final steer weight. Although this was the 'best' five variable model, the equation's C(P) (53.3) indicates that this equation has considerable lack of fit and the equation's R^2 (.26),

indicates that limited variation is accounted for by this equation. Realizing limitations and biases in this equation an attempt was made to develop regression equations from Data Source II, using birth weight, weaning traits, and yearling traits, in addition to feedlot performance traits. A yield grade prediction equation that included 25 had a low R^2 of .21. Problems encountered in developing adequate regression equation may have occurred because the prediction endpoint was a predictor of carcass cutability rather than actual carcass composition.

Introduction

Food service trends in recent years have developed in such a fashion that ground beef consumption has grown at a rapid rate. Additionally, consumer demand for 'leaner' beef has increased dramatically. The combination of these two factors points out an increased need for producing beef carcasses with a more desirable USDA Yield Grade (leaner carcasses). The USDA Yield Grading system is based on the USDA cutability regression equation (USDA, 1965), that estimates the percentage of carcass weight that is in the form of closely trimmed, boneless retail cuts from the round, loin, rib, and chuck.

The current thrust in the beef cattle feeding industry is aimed at producing and slaughtering cattle that will have a minimum carcass quality grade of low Choice.

The carcass beef from cattle fed to Choice generally have a higher percent carcass fat than the 25 percent fat beef often desired in the industrial preparation of hamburger and lean beef foods.

Therefore, the identification and evaluation of alternative systems of beef production seems appropriate to meet consumers desires for leaner beef products.

The objective of this study was to develop regression equations that predict carcass leanness (USDA Yield Grade) using breed type and feedlot performance traits to identify sources of variation in Yield Grade.

Materials and Methods

Steer data were accumulated from two data sources. Source I included data from 1810 cattle pooled from 14 independent nutrition feedlot trials conducted at either the Oklahoma Agricultural Experiment Station or the Panhandle State University. Source II data were collected from calves of the 1978 through 1981 calf-crops of a Oklahoma Agricultural Experiment Station crossbreeding study, designed to evaluate productivity of various two-breed cross cows.

Source I

A description of each of the 16 OSU nutrition feedlot trials follows:

Feedlot Trial 1. Ninety-six Hereford steers were fed either a high (75% silage, dry matter basis), medium (30%), or low (14%) corn silage diet. Rations also differed in level of Monensin fed, with half the steers given 0 ppm Monensin and the remainder fed 36.7 ppm per day (Gill et al., 1976).

Feedlot Trial 2. Data from 240 Angus, Hereford, or Angus X Hereford reciprocal cross steers were used to evaluate the effects of % crude protein level, urea as a source of protein, and Rumensin on feedlot performance (Martin et al. 1976).

Feedlot Trial 3. The feedlot performance of 231 mixed British type steers ,fed high moisture corn diets that included various Rumensin and protein levels was reported by Martin et al. (1978) and by Gill et al. (1978). Rumensin was mixed into the ration at 0, 15, and 30 grams/ton and rations ranged in crude protein from 9% to 13%, on a dry matter basis.

Feedlot Trial 4. Cement kiln dust at four levels (0, .87, 1.75, and 3.48% of the diet) and protein at two levels (9.3 and 11.5% crude protein) were fed to examine their effects on feedlot growth of 46 steers of British breeding and 27 steers of Exotic breeding (Zinn et al., 1979). After 41 days the low protein and 3.48% kiln dust treatments were discontinued because of reduced rate of gain.

Feedlot Trial 5. Average daily gain, feed efficiency, and carcass characteristics were examined using 110 Hereford steers that had been fed different diets. Rations differed in the % roughage in the final feedlot diet, in the rate of % concentrate introduction into the ration, and in the amount of thiopeptin used as a feed additive (Gill et al., 1979a).

Feedlot Trial 6. Gill et al. (1979b) compared feedlot responses of 221 steers of varying percentages of British and Exotic breeding, to different corn moisture levels, levels of protein, and sources of supplemental protein.

Feedlot Trial 7. A detailed report on this study may be found in Gill et al. (1981a). The effect of thiopeptin (a narrow spectrum antibiotic) on feedlot rate of gain was studied on 125 steers. These steers were either Hereford, Angus, or Hereford X Angus reciprocal crosses. Thiopeptin and diet energy density of the starting ration interactions were also studied.

Feedlot Trial 8. A detailed description of Trial 8 can be found in a report by Gill et al. (1981b). In brief, 240 steers (Angus, Hereford, Black Baldy, or Exotic Cross) were fed different roughage levels to evaluate the possible effect of ration dilution in decreasing acidosis, and increasing rumination resulting in subsequently higher feedlot performance.

Feedlot Trial 9 and 10. Trials 9 and 10 examined the effect of calcium and potassium supplement levels on feedlot performance. Trial 9 studied these two minerals on 145 Santa Gertrudis steers (not previously reported); while Trial 10 examined 87 steers that were of either Hereford, Angus, Angus X Hereford reciprocal cross, or Exotic X British cross breeding (Zinn et al., 1982).

Feedlot Trial 11. Steers (n=104) of Exotic and British breeding were fed a ration that included salinomycin at one of five levels (0, 5, 10, or 30 g/ton) to examine its effect on rate and efficiency of feedlot gain (Owens and Gill, 1982).

Feedlot Trial 12. Carcass merit and feedlot performance were measured by Ferrell et al. (1983a) on 58 steers of mixed breeding, fed five levels (0, 5, 10, 15, and 20 g/ton of feed) of the ionophore Salinomycin.

Feedlot Trial 13. Ferrell (1983b) studied the use of the Lasalocid and Monensin ionophore treatments, supplemented at either 0, 22, or 30 ppm. Treatment effects on average daily gain, feed efficiency, and carcass measurements were studied using data from 52 Angus, 42 Hereford, and 45 Exotic X British cross steers fed for 114 days.

Feedlot Trial 14. The feedlot performance of 86 British type steers fed a steam flaked corn - corn silage diet containing 0 or 6% residue from a methane generation feedlot waste plant was evaluated by Martin et al. (1984). Additionally, during the first 29 days of the trial, half of the cattle received .5 mg Decoquinate (a coccidiostat) per kg of body weight, in order to study its effect on subsequent gains.

Carcass Measurements

At the termination of each study, cattle were slaughtered at several different beef commercial packing plants. Carcass data were obtained between 24 and 48 hours postmortem. Carcasses were evaluated by a USDA Meat Grader. Carcass maturity, marbling score, percent kidney, heart, and pelvic fat, and quality grade were determined for each carcass according to specifications outlined by the USDA (1975). Also, longissimus muscle cross-sectional area (using the grid method) and subcutaneous fat cover were measured at the 12th rib interface.

Source II

Data Source. Source II carcass and performance data were obtained from three-breed cross calves produced by mating purebred Charolais and Limousin bulls to Hereford X Angus, Angus X Hereford, Simmental X Angus, Simmental X Hereford, Brown Swiss X Angus, Brown Swiss X Hereford, Jersey X Angus, and Jersey X Hereford two-breed cross cows. The crossbred dams involved in this study were produced in 1973, 1974, and 1975, as described by Belcher and Frahm (1979).

A total of 480 steer calves were studied (129 in 1978, 121 in 1979, 115 in 1980 and 115 in 1981). Calves were born and reared to weaning at the Lake Carl Blackwell Research Range. Thirty-five calves produced in 1978 were reared in dry-lot to weaning. The remaining calves were reared, by their dams, approximately 205 days on native and bermuda grass pasture.

Feedlot History. Weaned calves were trucked to the Southwestern Livestock and Forage Research Station, El Reno, Oklahoma, and placed in the feedlot. Calves of a specific three-breed cross were fed together in a pen assigned at random. The feedlot ration was the same each year and is described in Table V.

Steers were sent to slaughter when they were thought to have had an estimated low choice carcass quality grade. Visual appraisal of finish, lack of gain from the last weigh period, and carcass quality grade of previously slaughtered cattle were used to determine when cattle had reached the desired low choice carcass quality grade.

Carcass Measurements. In 1976 and 1977 steer calves were slaughtered at Wilson's Food Inc. (Oklahoma City); while steers from the 1978 and 1979 calf crops were slaughtered at Bauers Packing Co. (Tulsa). Carcasses were evaluated, 48 hours postmortem, for conformation, maturity, marbling score, percent kidney, heart, and pelvic fat, and quality grade according to specifications outlined by USDA (1965; 1975). Single fat thickness, average fat thickness, and longissimus muscle cross-sectional area were measured at the 12th rib. Cutability (the percent of carcass weight as boneless, closely trimmed retail cuts from the round, loin, rib, and chuck) was estimated by Murphey's equation (Murphey et al., 1960), by the USDA equation (USDA, 1965), and by the Proposed USDA equation (Abraham et al., 1980).

Statistical Analysis. Pearson correlation coefficients between yield grade and feedlot history, feedlot performance, weaning performance and yearling performance were calculated as described by Steel and Torrie (1980). Additionally, actual yield grade and yield grade derived by the predicted equation means and standard errors were calculated, overall and by whole actual yield grades (ie. 1, 2, 3, 4, and 5).

Regression equations that predict yield grade from live animal traits were derived using the all possible regression technique procedure described by Neter et al. (1983) and the Stepwise regression procedure (SAS, 1982).

The original design of this study was that to first develop equations using Data Source I and then test the viability of these equations using data from Source II. However, because of difficulties in developing equations using Source I, prediction equations were also developed using Data Source II.

Results

Equation Development Using Source I Data

Live Animal Traits Considered In Equation Development

Data Source I was used to develop a regression equation that would predict carcass USDA yield grade, implementing feedlot history and performance traits as equation variables. Live animal traits considered in equation development, their means, and their simple correlation coefficient with USDA yield grade are presented in Table XXIII.

Several simple correlation coefficients were significant, however coefficients indicated low association with yield grade. Final feedlot weight had the highest simple correlation coefficient with yield grade (.29, $p<.001$).

TABLE XXIII

TRAITS USED IN SOURCE I EQUATION DEVELOPMENT AND THEIR SIMPLE CORRELATION COEFFICIENT WITH YIELD GRADE

Trait	Abbreviation	r With Yield Grade	Mean±stderr
Starting Feedlot Weight	St.wt	.12***	677.4±2.9
Starting Feedlot Weight^2	St.wt2	.14***	
56 Day Feedlot Weight	56day.wt	.12***	903.0±3.6
56 Day Feedlot Weight^2	56day.wt2	.14***	
56 Day Average Daily Gain	56day.ADG	.08**	3.4± .3
Days In The Feedlot	DOF	-.07*	132.9± .6
Days In The Feedlot^2	DOF2	-.05	
Days In The Feedlot^3	DOF3	-.03	
Feedlot Average Daily Gain	ADG	.19***	3.3± .1
Feedlot Average Daily Gain^2	ADG2	.18***	
Feedlot Average Daily Gain^3	ADG3	.17***	
Final Feedlot Weight	Final.wt	.29***	1125.2±2.7
Final Feedlot Weight^2	Final.wt2	.28***	
Final Feedlot Weight^3	Final.wt3	.28***	
Ration Metabolizable Energy	ME	.05*	3.0± .01
Average Metabolic Weight	Metab.wt	.22***	164.3± .4
Days In The Feedlot X Metabolizable Energy	DOF*ME	-.03	402.4±2.2

* $p<.05$; ** $p<.01$; *** $p<.001$

r - simple correlation coefficient

Equations From Source I. Equations with up to 17 independent variables were considered. However, there was little improvement in R^2 and C(P) in equations with greater than five independent variables. Therefore, in the interest of ease of equation implementation, in a feedlot situation, the best five variable equation was selected.

The following is the best five variable equation, selected using both the maximum R^2 (.25) and minimum C(P) (53.3):

$$\begin{aligned}\text{USDA yield grade} = \; & 79.54 - (1.84 \times \text{Days in the Feedlot, DOF}) \\ & + (.01 \times \text{DOF}^2) \\ & - (.000021 \times \text{DOF}^3) \\ & - (.37 \times \text{Average Daily Gain, ADG, kg}) \\ & + (.0073 \times \text{Final wt., kg}).\end{aligned}$$

Although this is the best 5 variable model, the equation's C(P) would indicate that this equation has considerable lack of fit (MacNeil, 1983).

Walters and Hintz (1981) reported an equation with identical independent variables, but different partial regression coefficients (USDA yield grade = $-7.1527 - (.0668 \times \text{DOF}) + (.0000269 \times \text{DOF}) - (.00000008 \times \text{DOF}^3) + (.009 \times \text{ADG}) + (.50 \times \text{Final wt.})$). This equation was developed using data from Hereford, Angus, and Hereford X Angus steers produced at the USDA Meat Animal Research Center (Clay Center, Neb.).

R^2 was not reported, but the mean predicted yield grade deviated from the mean actual yield grade by .13 yield grade. Hale et al. (1983), evaluated the Walters and Hintz equation using cattle from Source I described in this study and found low simple correlation coefficients between predicted yield grade values, derived from the Walters and Hintz equation and actual yield grade values.

Possible Equation Bias. Differences between predicted and actual yield grade are presented in Table XXIV, by whole numerical actual yield grades (ie. 1, 2, 3, 4, and 5).

In Source I, the average actual yield grade was 3.22 and there were 48 yield grade 1, 447 yield grade 2, 690 yield grade 3, 257 yield grade 4, and 29 yield grade 5 carcasses. Notice that regardless of the actual yield grade, the mean predicted yield grade was close to a yield grade of 3. Consequently, the difference between the predicted yield grade and the actual yield grade was smallest when actual yield grade was close to 3, and the difference increased as actual yield grade approached 1 or 5.

Equation Testing. The equation developed in Source I was tested using data from Source II. Correlation between actual yield grade of carcasses in Source II and predicted yield grade using the Source I equation was .26.

TABLE XXIV

PREDICTED YIELD GRADE (PYG) AND ACTUAL YIELD GRADE (AYG), OVERALL AND BY WHOLE YIELD GRADES

Whole Yield Grade	n	AYG	PYG	PYG-AYG
Overall	1471	3.22±.02	3.15±.01	-.07±.02
1 (less than 1.99)	48	1.66±.03	2.90±.05	1.24±.06
2 (2.0 to 2.99)	447	2.47±.01	2.94±.02	.47±.02
3 (3.0 to 3.99)	690	3.36±.01	3.20±.01	-.16±.01
4 (4.0 to 4.99)	257	4.25±.02	3.39±.02	-.85±.02
5 (greater than 5.0)	29	5.20±.05	3.50±.06	-1.70±.08

Equation Development Using Source II Data

One explanation for the failure of the Source I equation to accurately predict yield grade may have been Source I's great variation in design; different implants, feed additives, trial location, year and season, and type of feedstuff fed. For these reasons, an equation was developed using data from Source II, which was much more uniform in its experimental design.

The traits considered in the development of the Source II equation, their means and simple correlation coefficient with actual yield grade are presented in Table XXV. Equations were developed using birth weight, weaning traits, and yearling traits, as well as feedlot performance traits. A regression equation that included all 25 variables had a R^2 of .21. This suggests that the large variation in animals in Source I was not the main reason that an effective equation could not be developed.

Discussion

Explanation For Equation Inability to Predict Yield Grade

The value of attempting to predict carcass yield grade rests on the assumption that yield grade is closely associated with the percent of a carcass that is in the form of closely trimmed, boneless round, loin, rib, and chuck (actual cutability). However, Hale et al. (1985)

TABLE XXV

TRAITS USED IN SOURCE II EQUATION DEVELOPMENT AND THEIR SIMPLE CORRELATION COEFFICIENT WITH YIELD GRADE

Trait	Abbreviation	r With Yield Grade	Mean±stderr
Birth Weight	Birth.wt	.01	85.7± .6
Weaning Weight	Wean.wt	.04	517.6±3.7
Weaning Conformation Score	Wean.conf	-.01	13.7± .04
Weaning Conditioning Score	Wean.cond	.08	5.1± .02
Weaning Average Daily Gain	Wean.adg	.11***	2.1± .01
Yearling Weight	Year.wt	.21***	955.8±5.4
Yearling Conformation Score	Year.conf	.01	13.4± .03
Yearling Average Daily Gain	Year.adg	.26***	2.7± .02
Starting Feedlot Weight	St.wt	.05	518.1±3.7
Starting Feedlot Weight^2	St.wt2	.04	
60 Day Feedlot Weight	60day.wt	.17**	652.1±4.5
60 Day Feedlot Weight^2	60day.wt2	.17**	
60 Day Average Daily Gain	60day.ADG	.07**	2.7± .04
Days In The Feedlot	DOF	-.09*	264.4±1.8
Days In The Feedlot^2	DOF2	-.10*	
Days In The Feedlot^3	DOF3	-.11*	
Feedlot Average Daily Gain	ADG	.23***	2.6± .02
Feedlot Average Daily Gain^2	ADG2	.22***	
Feedlot Average Daily Gain^3	ADG3	.21***	
Final Feedlot Weight	Final.wt	.22***	1186.9±5.5
Final Feedlot Weight^2	Final.wt2	.22***	
Final Feedlot Weight^3	Final.wt3	.22***	

* $p<.05$; ** $p<.01$; *** $p<.001$

r - simple correlation coefficient

found only a .42 coefficient of determination between actual carcass cutability and carcass cutability predicted from the USDA cutability regression equation (equivalent to yield grade). Difficulties encountered in developing yield grade prediction equations may have been caused by possible problems in the yield grading system. Rather than developing an equation that accounts for the variation of a predictor of carcass cutability (yield grade); perhaps, equations should be developed using actual composition of feedlot gain as the prediction endpoint. Neither source of data (Sources I and II) had actual carcass composition data, in large enough numbers, to adequately derive an equation that would predict carcass composition.

Another problem in developing regression equations was the lack of individual feed intake records in both data sources. An accurate measure of total metabolizable energy consumed during the feedlot period possibly would aid in predicting composition of feedlot gain. The inclusion of this type of equation variable might hinder its use under typical feedlot conditions, because of difficulties in obtaining the necessary information.

Conclusion

These data indicate that predicting yield grade, with equations that use average daily gain, days in the feedlot, metabolizable energy in the ration, and steer weights at different periods is ineffective. No equation developed, accounted for more than 26% of the variation in yield grade. These equations were developed using conventional polynomial regression analysis, possibly more intricate non-linear regression techniques might prove more useful in deriving a viable equation that would accurately predict cutability.

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