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CONSUMER ACCEPTANCE AND SENSORY PANEL EVALUATION OF THE EATING QUALITY OF BEEF AS AFFECTED BY CROSSBREED AND SEX

by

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ABSTRACT

Sensory panel evaluation, objective measurements and consumer panels were used to evaluate meat from bulls and steers representing the six crossbreeds of Limousin and Simmental sires with Angus, Hereford and Beef Shorthorn cows. The test muscles, longissimus dorsi and biceps femoris, were taken from a total of 60 animals.

The effect of the crossbreed and sex on the quality of the meat varied with the muscle and the type of measurement. For the purpose of analysis and discussion, the crossbreeds and sex were separated into their component effects, being the effects attributable to sex, cows, sires, cow x sex, cow x sire, sire x sex and cow x sire x sex. The sex effect analyses showed that steers exhibited less cooking loss, greater texturometer juiciness, and less hardness and cohesiveness than bulls. Steers required less shear force than bulls for the medial core position of the longissimus dorsi muscle, while bulls required less shear force than steers for the proximal core position of the biceps femoris muscle. Sensory panel evaluation rated steers higher in juiciness, greasiness and meatiness, and lower in chewiness and fibrousness than bulls. Shear force, texturometer juiciness and the sensory panel evaluation of hardness, juiciness and fibrousness demonstrated significant effects attributable to the cows. No significant effects attributable to the sires were found. Several effects attributable to the two-term interactions were significant.

The consumer panel was unable to detect differences among the six crossbreeds or between the two sexes. According to the sensory panel evaluation, no one crossbreed or sex was outstandingly different from

the others. No differences were great enough to affect overall consumer acceptability.

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I INTRODUCTION

The ever-increasing consumer demand for quality lean beef and the continually rising costs for the production and marketing of beef necessitate improvement of carcass quality and more efficient production. The type of beef cattle required to satisfy these demands must be a more effective converter of feed to lean than the British breeds presently raised in Canada. As a result, the Canada Department of Agriculture has implemented a foreign cattle breeding program by which European breeds are imported and crossed with the British breeds. The major objective of the program being carried out at the Brandon Research Station is to produce quality beef as economically as possible. From the consumers' viewpoint, the meat must provide quality as well as economy. The need for economy would be met by the reduction in production costs which could help control the rising retail prices. However, the ultimate evaluation of any food product is in the eating quality. Beef must have full flavor, juiciness and tenderness for optimum consumer acceptability. For this reason, researchers in these laboratories assessed the quality of beef by consumer panels, a trained sensory panel and objective measurements. The detailed descriptive analysis by the sensory panel and the objective measurements were used to attempt to define and explain differences in consumer acceptability.

II REVIEW OF LITERATURE

A. FACTORS AFFECTING THE EATING QUALITY OF BEEF

Quality beef is necessary for continued consumer demand. The traditional physical characteristics of beef carcasses used to predict the palatability dimensions of tenderness, juiciness and flavor have been challenged as estimators of consumer acceptance (Covington *et al*., 1970). These physical characteristics include conformation, i.e., the proportion of meat to bone, the grain of the meat (lean), the amount, quality and color of the fat covering, the amount of marbling in the meat, and the firmness, texture and color of the meat.

The following is a review of the effect of marbling, maturity, sex and breed on the eating quality of beef.

1. Marbling

Lean which is well-marbled is associated with increased tenderness. Research by Simone *et al*. (1959) indicated that well-marbled roasts (Choice grade) were significantly more tender than those with less marbling (Good grade) as evaluated by a taste panel. However, Breidenstein *et al*. (1968) and Norris *et al*. (1971) found that the degree of marbling had no statistically significant effect on shear force values or taste panel tenderness scores. The results of Simone *et al*. (1959) and Breidenstein *et al*. (1968) did reveal that the amount of marbling significantly affected flavor and juiciness. The well-marbled roasts and steaks were more flavorful and juicier than those with less marbling. Norris et al. (1971) discovered no significant effect of marbling alone on flavor and juiciness but did find a significant interaction ($P<.05$) between maturity and marbling on flavor. Two levels of marbling, small and moderate, were used. At both levels of marbling, rib steaks from the young carcasses (12 to 18 months) were more flavorful than rib steaks:

(1) with a moderate amount of marbling in the intermediate age group (18 to 30 months),

(2) with a small amount of marbling in the age group approaching maturity.

However, the differences in mean flavor ratings were too small to be of practical value. Field et al. (1966) found that rib roasts from heifer and steer carcasses with moderate amounts of marbling were rated more flavorful than those with modest amounts of marbling. They also demonstrated that rib roasts with modest and moderate amounts of marbling tended to be juicier than roasts with less marbling, holding age constant.

2. Maturity

The effect of maturity on tenderness, juiciness and flavor has been extensively studied. Decreases in tenderness with increasing maturity have been demonstrated (Simone et al., 1959, Tuma et al., 1962a and Henrickson and Moore, 1965). The animals ranged in age from 18 to 90 months at the time of slaughter. Adams and Arthaud (1963) studied the effect of age on tenderness as measured by the Warner-Bratzler shear. Using carcasses from two age groups, 439 and 479 days (14½ to 16 months) old at slaughter, they found that the carcasses of animals in the 439 day old group were more tender than those in the 479 day old group ($P<.05$). The results also indicated a significant simple correlation coefficient of 0.29 between shear values and age of animal at the time of slaughter. Walter et al. (1965) showed decreased tenderness with increasing animal age, using carcasses from animals slaughtered at 15 to 18 months, 20 to 24 months and 8 to 10 years. Similarly, Breidenstein et al. (1968) demonstrated decreased tenderness with increasing maturity as measured by both the Warner-Bratzler shear and a sensory panel.

Other work has indicated a less clear-cut relationship between tenderness and maturity. Ritchey and Hostetler (1964) investigated the effect of 3 age groups, 33 weeks (7½ months), 47 weeks (11 months), and 62 weeks (14½ months), on beef tenderness. No definite relationship between tenderness and age was revealed by either Warner-Bratzler shear measurements or sensory panel evaluations. Similarly, Field et al. (1966) indicated that age (holding marbling constant) had no significant effect on either Warner-Bratzler shear values or sensory panel evaluations for tenderness of steers and heifers, ranging in age from 300 to 699 days (10 to 23½ months) at slaughter. More recently, Norris et al. (1971) reported no significant effect of animal age at slaughter on panel scores for tenderness and Warner-Bratzler shear values. The animals were in the following age categories; 12 to 18 months; 18 to 30 months; and 30 to 38 months.

The effect of age on flavor and juiciness is not clear. No significant effect of age on flavor and juiciness has been demonstrated (Simone et al., 1959, Field et al., 1966, Norris et al., 1971, Henrickson and Moore, 1965, and Breidenstein et al., 1968). Tuma et al., (1963) found that older animals were more juicy but not more flavorful than younger animals. In this study the animals ranged in age from 6 months to 90 months at the time of slaughter. On the other hand, Goll et al.

(1965) found that there was no significant difference in juiciness of animals ranging in age from 15 to 18 months, 20 to 24 months and 8 to 10 years. However, the older animals were rated significantly lower for flavor.

3. Sex

There is much controversy over which produces the more desirable meat--steer or bull. Steers are male animals which have been castrated in order to obtain a better finish. A better finish includes more marbling within the lean of the meat and more fat covering over the exterior of the meat surface. Castration modifies the secondary sex characteristics of the animal by reducing sexual drive and aggressiveness, and thus, makes the animal easier to handle. The conformation of the body is also changed. In the bull, the forequarter musculature is much more developed than in the steer. Also, the bull is much leaner than the steer (Turton, 1962).

According to Wierbicki *et al*. (1955), Brown *et al*. (1962), Brown *et al*. (1963) and Klosterman *et al*. (1954), bulls were more efficient converters of feed to lean than steers. Consequently, the cost of the meat produced is less. However, bulls tend to grade lower than steers because of the reduced exterior fat covering and interior marbling.

Brown *et al*. (1962) found no significant difference in the aroma, flavor, texture, tenderness and juiciness of bull and steer rib steaks as evaluated by a sensory panel. Wierbicki (1955) reported that bulls were slightly less tender than steers but the difference was not significant. On the other hand, Aitken *et al*. (1963) indicated that the sensory panel evaluated meat from steers more tender and flavorful than meat from bulls. Similarly, Adams and Arthaud (1963) found that steers were significantly more tender than bulls ($P<.01$) as measured by the Warner-Bratzler shear.

Field et al. (1966) revealed that steers and heifers ranging in age from 500 to 699 days old ($16\frac{1}{2}$ to $23\frac{1}{2}$ months) were significantly more tender than bulls of the same age. For the 600 to 699 days old (20 to $23\frac{1}{2}$ months) group, the steers and heifers were significantly juicier and more flavorful than the bulls. The steers and heifers also had significantly higher marbling scores than the bulls. Within the age range of 300 to 699 days (10 to $23\frac{1}{2}$ months), the steers and heifers tended to become more tender with increasing age and the consequent increasing marbling, whereas the bulls tended to decrease in tenderness. Holding marbling constant, the bulls from the 300 to 399 days old (10 to $13\frac{1}{2}$ months) group were significantly more tender than the older groups.

4. Breed

Another important factor in producing quality meat is breed. The conformation and size of the cattle have been changed by selective breeding. As a result, the modern beef animal is smaller and more compact than the animal of the past. However, this tendency has not increased the proportion of lean in the carcass or altered its distribution. Further evidence indicating that beef-type conformation does not produce carcasses with a high proportion of lean or beef of superior eating quality has resulted from the studies comparing dairy-bred with beef-bred animals (Barton, 1967).

Branaman et al. (1962) compared Hereford and Shorthorn cattle (beef-type) with Holstein cattle (dairy-type). Although the beef-type cattle had higher dressed weights and graded higher than the dairy-type cattle, there was no significant difference in yield between the wholesale cuts of the kidney knob, plate, chuck, rib, round and loin. When the high-priced cuts--rib, round and loin--were combined, no significant difference in yield between the dairy-bred and beef-bred cattle was found. These results do not support the hypothesis that beef-type cattle yield a higher percentage of the high-priced cuts, holding grade constant. Similarly, there were no significant differences in percentage of separable lean or fat between breeds. No significant differences between overall desirability, aroma, flavor of fat, texture of the lean and tenderness were detected by the sensory panel. The sensory panel did find that the beef-bred cattle were more flavorful ($P<.01$) and juicier ($P<.01$) than the dairy-bred cattle.

Today's consumer demands meat without excess fat (Seltzer, 1955 and Mize, 1962) and this demand is most easily met by animals which have not been bred specially for beef production. The type of animal required to satisfy this demand must grow more rapidly, be larger and less shapely and convert pasture, forage and grain to beef more efficiently than the present British breeds (the Aberdeen Angus, the Hereford and the Beef Shorthorn). Beef cattle must be selectively bred toward increasing the total amount of muscle in the carcass and decreasing the total amount of fat to an acceptable level (Barton, 1967).

To this end, the Canada Department of Agriculture at the Brandon Research Station has crossbred each of the three British breeds--the Aberdeen Angus, the Hereford and the Beef Shorthorn--with one French breed, the Limousin and one Swiss breed, the Simmental.

The Limousin breed evolved as a beef/work animal. Consequently, the body size is larger than that of most cattle. The carcasses have good muscular development, especially on the sirloin and the buttocks. The percentage of muscle in the carcass is approximately 54%. However, it may be as high as 65 to 70% in the better quality beef animals. These cattle fatten easily and do not require rich pasture land. In southern France and North Africa, Limousin bulls have been used to improve other breeds (FAO, 1966).

The Simmental were originally developed as milk, meat and work animals. Now, they are mainly used for milk and meat (FAO, 1966). They grow rapidly and produce a well-muscled body with no excessive tendency to store subcutaneous fat. Yet, the meat is well-marbled, tender and light in color (Engeler, 1961).

From the literature cited, it is evident that quality beef is a result of a complex interaction among marbling, maturity, sex and breed, rather than the result of one of these alone.

B. CONSUMER STUDIES ON BEEF ACCEPTANCE

Although many surveys on consumer attitudes toward beef and its acceptance have been conducted in the United States, none has been conducted in Canada. Consequently, the following is mainly a discussion of the research carried out in the United States.

1. Consumption of Beef in Canada

The Dominion Bureau of Statistics reported that the per capita consumption of beef in 1970 was 85.7 lbs. (Barratt, 1971). This represents an increase of more than 15% over the past decade. Other research by Faryna (1971) indicated demand for steak and roast beef in the Winnipeg area (Table I).

TABLE I

RANK ORDER OF FREQUENCY OF SERVING MEATS IN THE HOME
(FARYNA, 1971)

Frequency of Serving			
1 x per week or more	1 x per month to 3 x per month	less than 1 x per month	not at all in past 12 months
1. steak	1. pork roast	1. turkey (frozen)	1. lamb (unfrozen)
2. chicken (unfrozen)	2. pork chops	2. turkey (unfrozen)	2. lamb (frozen)
3. pork chops	3. roast beef	3. chicken (frozen)	3. turkey (unfrozen)
4. roast beef	4. steak	4. chicken (unfrozen)	4. turkey (frozen)
5. chicken (frozen)	5. chicken (unfrozen)	5. pork chops	5. chicken (frozen)
6. pork roast	6. chicken (frozen)	6. steak	6. chicken (unfrozen)
		7. lamb (unfrozen)	7. pork roast
		8. roast beef	8. steak
			9. roast beef
			10. pork chops

Adapted from Faryna (1971).

2. Visual Studies

In 1955, Seltzer studied consumer preferences for beef by interviewing people in 100,000 households in Phoenix, Arizona. The research indicated that lean appearance (or minimum amount of fat) and color of lean (cherry red color) were the factors considered most important by consumers when selecting beef to buy. In this study, 59% of the participants selected U.S. Good grade when shown pictures of the various grades. Fifty-one percent of the sample was unacquainted with the official U.S.D.A. beef grades.

Rhodes et al. (1955), conducted a more intensive study on the visual preferences for grades of retail beef cuts. The interviews took place at 15 retail food stores in metropolitan St. Louis, Missouri. The study indicated that 33% of the participants were not knowledgeable about the eating qualities of the U.S.D.A. beef grades. In spite of this, the preferences of the "informed" and the "uninformed" participants did not differ greatly. The percentage distribution of first preferences for loin steaks (irrespective of price) was:

(1) Prime	31.7%
(2) Choice	24.3%
(3) Good	21.9%
(4) Commercial	15.4%
(5) No preference at equal prices	6.7%

Consumer preferences for the various physical characteristics of steaks and roasts listed in order of highest preference were:

Steaks	Roasts
(1) amount of external fat	(1) amount of internal fat (other than marbling)
(2) color of lean	(2) color of lean
(3) marbling	(3) marbling
(4) texture	(4) amount of external fat
(5) color of fat	(5) color of fat
(6) amount of bone	(6) amount of bone

Approximately two-thirds of the consumers desired a small amount of outside fat. Consumers did not appear to use the visual characteristics as predicators of eating quality. Approximately one-third of the participants could name one or more of the U.S.D.A. grades. Participants with higher incomes had greater knowledge of the federal grade names. Tenderness was stated as the most important eating characteristic of meat by the majority of participants. Rhodes et al. (1955) concluded by suggesting that the present grading system was not indicative of the eating qualities of beef.

The study by Branson (1957) revealed that the consumers, when shown pictures of the four grades of rib steaks, preferred U.S. Good grade beef. The main reason for this choice was that they "prefer lean meat." Of the Houston families studied, 82% had no knowledge of the official U.S.D.A. beef grades, while of the Denver and Phoenix families interviewed only 65% and 51% respectively had no knowledge of these grades. Consumers were not concerned with the marbling of beef.

Mize and Stringer (1959) also conducted a visual study which dealt with choosing beef for household use. Thirty-nine percent of the consumers indicated that the color of fat and muscle were the main characteristics that they used for choosing beef, while 17% looked for lean meat and 15% looked for freshness. When shown color photographs of Choice and Good grades of T-bone steak, 55% selected the Choice grade and 42% selected the Good grade. Thirty-one percent of the consumers based their decision on the amount of fat present. When given the selection of Choice and Utility grade round steaks, 61% chose the Choice grade and 37% chose the Utility grade. Forty-eight percent of the consumers preferred "the amount of fat" on the steak that they chose.

Mize (1962) discovered that 65% of the participants related tenderness of beef to cooking method, while only 22% related tenderness of beef to selections made at the retail store. Sixty percent of the participants were unsure of their judgement about tenderness. Of the 31% of the families who used specific characteristics to judge tenderness, 16% based their judgements on appearance and/or color.

3. Sensory Evaluation

Rhodes *et al*. (1958) studied the consumer acceptance of Prime, Choice, Good and Standard grades of loin steaks. The husband and wife of each household tasted each pair of steaks and evaluated the steaks on a 9-point hedonic scale. The results indicated much overlapping of the carcass ratings for all grades. In the case of the Choice and Prime grades, the distribution of ratings was very similar. There was greater uniformity among the Choice and Prime grades than the Good and Standard grades.

This study included sensory panel discrimination tests on the same comparisons as the consumer panel performed. The sensory panel also found heterogeneity within each grade. Rhodes *et al*. (1958) had hoped the sensory panel discrimination test could be used to detect consumer acceptability. However, it should be pointed out that the trio test (the discrimination test used) and consumer liking are not the same type of measure. The trio test merely indicates a difference exists, but does not state the magnitude or kind of difference. The results revealed that the trio test used was not a good predictor of consumer acceptance.

According to Naumann *et al*. (1961), laboratory ratings of Good and Choice beef loin steaks were consistent with consumer acceptance ratings. The laboratory panel tended to be more critical and rated the steaks lower than did the consumer panel. They also suggested that tenderness, as judged by a laboratory panel (r = o.47), was a better predictor of consumer acceptance than grade, marbling, juiciness or flavor. Other correlation coefficients were low. These low correlation coefficients were explained in part by differences in sample size, cooking methods, personal preferences and general frame of reference of the two panels.

Field et al. (1964) investigated consumer acceptance of retail cuts of beef from steers and bulls. Steaks and roasts from 19 steers and 19 bulls of the Angus breed were consumed and evaluated by 931 consumer households. Few significant differences were found. Of the loin, rib and round steaks, the loin steaks from the steers were rated significantly more flavorful and more tender than those from the bulls. In the case of the roasts (chuck, rib and rump), the consumers preferred the bull chuck roasts over the steer chuck roasts. The reason for this preference was that the bull chuck roasts had the right degree of leanness ($P<.01$). On the contrary, the consumers preferred the steer rump roasts over the bull rump roasts for the same reason ($P<.05$). When the consumers were asked if they would purchase the same cut of beef again, approximately 90% replied positively. There was no significant difference in positive replied between the bulls and the steers.

In addition to the consumer taste evaluation, a visual preference study for the same retail cuts as above was carried out at the supermarket. Unidentified retail cuts were placed side by side in self-service counters. The only outstanding difference was the preference of bull chuck roasts over steer chuck roasts (Table II). The bull chuck roasts were preferred because they had less intramuscular fat.

TABLE II

NUMBER OF UNIDENTIFIED RETAIL CUTS SELECTED FROM BULL AND STEER CUTS WHILE APPROXIMATELY EQUAL NUMBERS OF THE SAME CUTS WERE SIDE BY SIDE IN SELF-SERVICE COUNTERS (Field _et al_. 1964)

Retail Cuts	Number of Retail Cuts	
	Bull	Steer
Chuck roasts	175	107
Rib steaks and roasts	47	37
Loin steaks	241	255
Round steaks and roasts	132	120

C. OBJECTIVE MEASUREMENTS

The most popular objective measure of tenderness is the shear force value (Cover and Hostetler, 1960). The Warner-Bratzler shearing device registers the force required to shear across the grain of a one-half inch or one inch cylinder of meat. Reported correlations between the Warner-Bratzler shear and sensory panel evaluations of tenderness vary greatly (Table III).

Lack of correlation between objective measurements and sensory panel evaluations could be due to:

(1) the meaning of the correlation coefficient,

(2) properties measured by the instrument, test conditions and data interpretation,

(3) physiological, psychological and other factors affecting the panel,

(4) homogeneity of the test material. In meat, tenderness varies from animal to animal, muscle to muscle and within the same muscle (Szczesniak, 1965).

TABLE III

CORRELATIONS BETWEEN WARNER-BRATZLER SHEAR AND SENSORY PANEL TENDERNESS OF BEEF

Reference	Muscle or Cut	Sample Size	Correlation Coefficient	Significance Level (p)
Burrill *et al.* (1962)	Longissimus dorsi	28	-0.42	0.05
	Semitendinosus	18	-0.34	n.s.
	Semimembranosus	18	-0.45	n.s.
	Biceps femoris	18	-0.29	n.s.
Deatherage and Garnatz (1952)	Shortloin	32	-0.37	n.s.
	Tenderay treated shortloin	32	-0.24	n.s.
Fielder *et al.* (1963)	Loin eye	32	-0.58	0.05
	Rib eye	32	-0.46	0.05
	Top round	32	-0.42	n.s.
	Rump	32	-0.57	0.05
Alysmeyer *et al.* (1966)	Longissimus dorsi	305	-0.62	0.01
Wang *et al.* (1956)	Longissimus dorsi	44	-0.80	0.01
	Semitendinosus	13	-0.51	n.s.

A newer instrument for measuring the texture of foods is the General Foods texturometer. According to Brennan *et al.* (1970), the dimension hardness as measured by the texturometer is a useful measure of hardness as evaluated by a sensory panel. Brennan *et al.* (1970) demonstrated good reproducibility when testing rubber samples. Reproducibility decreased as the sample hardness increased. Sample size must be standardized because hardness readings vary with small differences in sample size. Hardness readings increased with increases in thickness and other dimensions of the sample. The standard deviation for texturometer hardness of uncooked stewing steak was reported as 28.00 (Brennan et al. 1970).

Corey (1970) reported a texturometer hardness value of 91.2 and texturometer cohesiveness value of 0.80 for roast beef. These researchers also found that texturometer hardness and juiciness correlated well with sensory panel evaluations of hardness and juiciness. The simple correlation coefficients were 0.772 and 0.55, respectively. Similarly, the simple correlation coefficients between texturometer hardness and Warner-Bratzler shear values and texturometer cohesiveness and Warner-Bratzler shear values were 0.64 for the former and 0.63 for the latter. All correlations were significant at $P<.01$.

D. TEXTURE PROFILE METHOD

The texture profile method is an extension of the A. D. Little flavor profile method (Cairncross and Sjöstrom, 1950). A texture profile is a descriptive sensory analysis of the texture of a food considering its mechanical, geometrical, fat and moisture characteristics. The degree of each characteristic present and the order in which they appear during mastication are recorded (Brandt et al. 1963). This method requires a trained sensory panel whose members are familiar with the texture classification system, use of the standard rating scales and proper panel procedures (Szczesniak, 1963a). According to Brandt et al. (1963), the major advantages of this method are:

(1) its flexibility since it can be applied to any food product or any textural characteristic,

(2) its objectivity because of its specifically defined reference points and its nomenclature.

Szczesniak *et al.* (1963) correlated the sensory panel evaluations of the standard rating scales with the texturometer readings for hardness, brittleness, chewiness, adhesiveness and gumminess. For hardness and brittleness, the relationship was curvilinear and for chewiness, adhesiveness and gumminess, the relationship was linear.

E. RESEARCH ON THE LONGISSIMUS DORSI AND THE BICEPS FEMORIS MUSCLES

The longissimus dorsi muscle extends from the neck to the pelvis of the beef carcass. Thus, it is present in the chuck, rib, shortloin and sirloin wholesale cuts. On the other hand, the biceps femoris muscle extends from the round to the sirloin, and as a result, it is the main muscle occurring in the rump (Ramsbottom and Strandine, 1948). These researchers used the Warner-Bratzler shear to measure the tenderness of the different beef muscles at several locations along the muscle. The average shear values forthe longissimus dorsi muscle adjacent to the 12th and 13th ribs and the biceps femoris muscle occurring in the round were 7.9 lbs. and 10.7 lbs. respectively.

Sensory panel evaluations and Warner-Bratzler shear values indicated that the longissimus dorsi muscle contains "tender" connective tissue and that the biceps femoris muscle contains "tough" connective tissue (Cover and Hostetler, 1960). According to these workers, "tender" connective tissue is easily masticated and not objectionable to the consumer. Consequently, the longissimus dorsi muscle is considered a tender muscle which can be broiled or roasted. "Tough" connective tissue is very objectionable because it is not degraded by mastication and must be gulped or expectorated. However, as the degree of doneness increases, the connective tissue becomes more tender (Cover and Hostetler, 1960). This tenderizing is due to the hydrolysis of collagen, one of the components of connective tissue, to soluble gelatin (Winegarden, 1952). Cover and Hostetler (1960) concluded that the tenderness of connective tissue increases as:

(1) the internal temperature of the meat rises,

(2) the length of time required to reach this temperature increases,

(3) the length of time the meat is held at the final temperature.

They further concluded that a relatively high internal temperature for a relatively long time is necessary in order to tenderize the "tough" connective tissue. Braising (a moist heat method) and roasting at low oven temperatures (a dry heat method) accomplish this.

Cover and Hostetler (1960) also evaluated the tenderness/toughness of the longissimus dorsi and the biceps femoris muscle fibres by the degree of crumbliness. They defined crumbliness as the "hard, small and dry" fragments remaining in the mouth during mastication. Results of their research indicated as the degree of doneness increases, crumbliness increases for both muscles.

Griswold (1962) summarized the research in this area by stating:

(1) as the degree of doneness increases, the muscle fibres of the loin (longissimus dorsi) toughen and become stringy because there is little connective tissue to hold the muscle fibres together,

(2) as the degree of doneness increases, the muscle fibres of

the round (biceps femoris) become more friable, due to the hydrolysis of the collagen to soluble gelatin. The overall impression is one of increased tenderness.

In conclusion, the longissimus dorsi muscle is most tender when cooked to rare (61^{o}C.), whereas the biceps femoris muscle is most tender when roasted to well done (80^{o}C.) or braised to well done (100^{o}C.) (Cover and Hostetler, 1960).

Another factor affecting the tenderness of cooked meat is the rate of heat penetration. According to Cover (1941), slow heat penetration produces more tender meat than rapid heat penetration. Slow heat penetration occurs through low oven temperatures. However, low oven temperatures are not always feasible because they are difficult to maintain and the roasting times are very long (Griswold, 1962). Consequently, dry roasting at the recommended oven temperatures of 149^{o}C. to 163^{o}C. is a compromise between:

(1) the slow heat penetration of low oven temperatures,

(2) the faster cooking time of high oven temperatures.

III METHOD

A. TREATMENT OF ANIMALS AND MEAT

Breeding and management of the animals were described by G. W. Rahnefeld et al. (unpublished data). Figure 1 shows the experimental plan. Each of the Aberdeen Angus, the Hereford and the Shorthorn cows were crossbred with the Limousin and the Simmental sires resulting in six crossbreeds. When the animals reached 1,000 $\pm$ 20 lbs., both bulls and steers from each crossbreed were slaughtered for experimental purposes. Six animals per treatment (crossbreed x sex) were slaughtered but only five animals (replications) were used for this experiment. Data were collected on 60 animals.

After slaughtering, the carcasses were hung for three days. On the fourth day, the section of the longissimus dorsi muscle adjacent to the 12th thoracic vertebra and the biceps femoris muscle were excised from the right side, placed in polyethylene bags and held overnight at 2^oC. The meat was then wrapped in polyethylene coated freezer paper and stored at -32^oC. to -40^oC. until required for experimental purposes. During the storage period, the frozen meat was transported from Brandon to this laboratory in styrofoam containers.

The experimental design for evaluating the meat samples was a balanced incomplete block design as shown in Figure 2 (Cochran and Cox, 1957). This particular design was selected because:

(1) it ensured that each treatment was tasted with every other treatment and thus, an unbiased estimate of each treatment effect could be obtained.

No. of Animals (Replications)	Crossbreed	Sex	Muscle
5	Limousin x Angus	Bull	Longissimus dorsi
		Steer	Biceps femoris
5	Limousin x Hereford	Bull	Longissimus dorsi
		Steer	Biceps femoris
5	Limousin x Shorthorn	Bull	Longissimus dorsi
		Steer	Biceps femoris
5	Simmental x Angus	Bull	Longissimus dorsi
		Steer	Biceps femoris
5	Simmental x Hereford	Bull	Longissimus dorsi
		Steer	Biceps femoris
5	Simmental x Shorthorn	Bull	Longissimus dorsi
		Steer	Biceps femoris

5 x 6 x 2 = 60 animals

60 x 2 = 120 muscles

FIGURE 1

THE EXPERIMENTAL PLAN FOR EVALUATING THE EFFECTS OF CROSSBREED, SEX AND MUSCLE ON THE CONSUMER ACCEPTANCE AND THE SENSORY QUALITY OF BEEF

Ip	Iq
L x A x B	S x A x B
L x A x St	S x A x St
L x H x B	S x H x B
L x H x St	S x H x St
L x SH x B	S x SH x B
L x SH x St	S x SH x St

Sire Confounded

IIp	IIq
L x A x B	L x A x St
L x H x B	L x H x St
L x SH x B	L x SH x St
S x A x B	S x A x St
S x H x B	S x H x St
S x SH x B	S x SH x St

Sex Confounded

IIIp	IIIq
L x A x B	L x A x St
L x H x B	L x H x St
L x SH x B	L x SH x St
S x A x St	S x A x B
S x H x St	S x H x B
S x SH x St	S x SH x B

Sire x Sex Confounded

IVp	IVq
L x A x B	L x A x St
L x H x B	L x H x St
L x SH x B	L x SH x St
S x A x St	S x A x B
S x H x St	S x H x B
S x SH x St	S x SH x B

Sire x Sex Confounded

Vp	Vq
L x A x B	L x A x St
L x H x B	L x H x St
L x SH x B	L x SH x St
S x A x St	S x A x B
S x H x St	S x H x B
S x SH x St	S x SH x B

Sire x Sex Confounded

L = Limousin
S = Simmental
A = Aberdeen Angus
H = Hereford
SH = Shorthorn
B = Bull
St = Steer

FIGURE 2

BALANCED INCOMPLETE BLOCK DESIGN USED
FOR EVALUATING THE MEAT SAMPLES

(2) it permitted confounding of certain treatment effects with the blocks as outlined in Figure 2 (Goulden, 1952). This results in more error control and hence the overall precision of the experiment is increased.

(3) it permitted the panelists to taste 6 treatments per session since the 12 treatments in a complete replicate were too many for the panelists to taste in one session.

From the overall experimental design, blocks of 6 treatments (crossbreed x sex) were selected randomly to determine the order of evaluation of the 12 treatments x 5 replications as in Figure 3. Due to limitations of the experiment, no attempt was made to compare the two muscles from the same animal. The same experimental design and order of evaluation was used for both muscles.

The meat samples as designated in Figure 3 were thawed 15 hours at 23.5°C. and were placed in a home style electric refrigerator at 2°C. for 7 days to complete the aging period (Figure 3). Thus, the total aging time was 10 days, 3 days on the carcass and 7 days in the excised state.

B. COOKING PROCEDURE

Three home style electric ranges were used throughout the experiment. All meat samples were cooked to the internal temperature of 70°C., as measured by copper-constantin thermocouples inserted into the centre of the thickest portion of the meat and recorded on a Honeywell recording potentiometer. The longissimus dorsi muscles were broiled; the biceps femoris muscles were roasted slowly at 149°C. Six treatments were cooked each day.

Day 0	Day 1	Day 2	Day 3
L x A x B	L x A x B	L x A x B	S x A x B
L x H x B*	L x A x St	L x H x B	S x A x St
L x SH x B	L x H x B	L x SH x B	S x H x B
S x A x St**	L x H x St***	S x A x B	S x H x St
S x H x St	L x SH x B	S x H x B	S x SH x B
S x SH x St	L x SH x St	S x SH x B	S x SH x St

Day 4	Day 5	Day 6	Day 7
L x A x St	L x A x St	L x A x B	L x A x B
L x H x St	L x H x St	L x H x B	L x H x B
L x SH x St	L x SH x St	L x SH x B	L x SH x B
S x A x B	S x A x B	S x A x St	S x A x St
S x H x B	S x H x B	S x H x St	S x H x St
S x SH x B	S x SH x B	S x SH x St	S x SH x St

Day 8	Day 9
L x A x St	L x A x St
L x H x St	L x H x St
L x SH x St	L x SH x St
S x A x B	S x A x St
S x H x B	S x H x St
S x SH x B	S x SH x St

L = Limousin
S = Simmental
A = Aberdeen Angus
H = Hereford
SH = Shorthorn
B = Bull
St = Steer

FIGURE 3

THE ORDER OF EVALUATION OF THE TWELVE TREATMENTS x FIVE REPLICATIONS

*Due to experimental error, L x H x St was used.

**Due to experimental error, L x A x St was used for the biceps femoris muscle.

***Due to experimental error, L x H x B was used.

The cooking procedures were as follows:

(1) <u>Longissimus dorsi muscle</u>

(a) Muscle sections were weighed the afternoon prior to cooking.

(b) From each muscle section, 2 steaks, approximately 1 inch in thickness, were cut. A thermocouple was randomly assigned to each steak and inserted.

(c) Steaks were broiled approximately 2½ inches below the element, 3 at a time. Steaks were turned when the internal temperature reached approximately 45°C.

(d) Steaks were cooled 30 minutes and weighed.

(2) <u>Biceps femoris muscle</u>

(a) Roasts were weighed the afternoon prior to cooking and were paired so that roasts of similar weights were cooked in the same oven.

(b) Each pair of roasts was randomly assigned to an oven, to which 2 thermocouples were attached. Thermocouples were randomly assigned to the 2 roasts and inserted.

(c) Roasts were placed in the ovens at 4:00 P.M. the afternoon prior to cooking. Automatic timing devices were set to commence the roasts cooking in the morning.

(d) On reaching 70°C. internal temperature, roasts were removed from the oven, cooled one hour and weighed.

C. OBJECTIVE MEASUREMENTS

1. Percentage Drip Loss on Thawing

The meat was weighed in the frozen and the thawed state. The thawed weight was obtained after the meat samples had aged seven days in the refrigerator. The percentage drip loss was calculated.

2. Percentage Cooking Loss

The meat was weighed before and after cooking. Total cooking losses (drip plus evaporation) were calculated in percentages.

3. Shear Force

The Warner-Bratzler shear (Model #69061103) was used to estimate meat tenderness.

(a) Longissimus dorsi muscle. The steak from the proximal end of the muscle section was used for all objective measurements. One-half inch cores were removed parallel to the length of the muscle from the medial, central and lateral positions. The direction of the grain was disregarded because the muscle samples were too small to permit coring with the grain. Each core was sheared twice.

(b) Biceps femoris muscle. From the centre of each roast, a piece, 3 cm. thick, was obtained and used for all the objective measurements. Three one-half inch cores parallel to the grain were removed from the proximal, central and posterior positions.

4. Texturometer Measurements.

For both muscles, the dimensions of juiciness, hardness, cohesiveness and springiness were measured by a General Foods Brabender texturometer (Model CT X-2, Serial 1021).

(a) Juiciness. A sample, 3/4" x 3/4" x 1/4" in size weighing approximately 2.50 grams, was removed in front of the central core. The sample was placed between two pieces of Whatman no. 50 hardened filter paper and then subjected to the chewing action of the masticator as outlined by Friedman et al., 1963. The test conditions were:

Volts	0.50
Chartspeed	750 mm.
Plunger	20 mm. nickel
Sample cup	large platform
Clearance	1 mm.
Chewing speed	12 bites/min.

For this dimension, the machine was set so that the chart did not record. Chewing occurred parallel to the grain for the biceps femoris muscle. The wetted areas of the two pieces of filter paper were measured by a polar planimeter. The total of the two areas estimated the juiciness.

(b) Hardness, cohesiveness and springiness. A sample, 3/4" x 3/4" x 1/4" in size, was removed posterior to the central core position. The sample was subjected to the chewing action of the masticator and the recorded curves were interpreted as outlined by Friedman et al., 1963. The test conditions were as outlined in (a). Chewing occurred across the grain for the biceps femoris muscle.

D. SENSORY EVALUATION

1. Evaluation by the Consumer Panels

Samples from the biceps femoris muscle were rated on a 5-point hedonic scale by a consumer panel consisting of 25 untrained judges. The panelists were consumers shopping at the Polo Park Shopping Centre. They were not classified in any way, and different ones were obtained for every session. The size of the longissimus dorsi muscle section did not provide enough meat for consumer evaluation.

The panel sessions were conducted between 3:00 and 4:30 p.m. on three consecutive cooking days, Tuesday, Wednesday and Thursday. Panelists rated the meat samples seated at a desk in the air-conditioned mall. Each panelist received a tray set with the following items:

(1) Six 3/4" x 3/4" x 1/4" meat samples in 3/4 oz. coded, covered plastic creamers.

(2) A 5-point hedonic scale questionnaire (Figure 4).

(3) A water cup, serviette, pencil and toothpick.

The samples were presented in a randomized order for each panelist. Rinsing the mouth after tasting each sample was left to the discretion of each panelist. For participating, the panelists received a pamphlet entitled "Beef and Beef Dishes".[1]

The samples were prepared in the Foods and Nutrition laboratory at the University of Manitoba. Samples were removed from the medial side of the muscle. In order to obtain ¼ inch uniform thickness, the meat was sliced on an electric gravity slicer (Omega Mignon 200), set on number 7. From these slices, experienced laboratory assistants cut samples 3/4" x 3/4" in size, and then randomly placed them in the appropriately coded creamers. The samples for each tray were placed in plastic bags and then were held and transported in a styrofoam container until required for the panel.

2. <u>Evaluation by the Trained Sensory Panel</u>

Samples from both muscles were evaluated for flavor and texture dimensions by a five member trained panel. The panel consisted of graduate students and staff members of the Department of Foods and Nutrition, University of Manitoba, who were willing to participate for the six-month period. Some of the panelists had considerable experience with the descriptive analysis method.

(a) <u>Training sessions</u>. Two one-hour training sessions per week

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[1]Published by the Canadian Cattleman's Association.

Please taste the sample and circle the phrase which best describes how much you like this product.

Code _____	Code _____	Code _____	Code _____	Code _____	Code _____
Like Very Much	Like Very Much	Like Very Much	Like Very Much	Like Very Much	Like Very Much
Like Moderately	Like Moderately	Like Moderately	Like Moderately	Like Moderately	Like Moderately
Neither Like Nor Dislike	Neither Like Nor Dislike	Neither Like Nor Dislike	Neither Like Nor Dislike	Neither Like Nor Dislike	Neither Like Nor Dislike
Dislike Moderately	Dislike Moderately	Dislike Moderately	Dislike Moderately	Dislike Moderately	Dislike Moderately
Dislike Very Much	Dislike Very Much	Dislike Very Much	Dislike Very Much	Dislike Very Much	Dislike Very Much
COMMENTS	COMMENTS	COMMENTS	COMMENTS	COMMENTS	COMMENTS

FIGURE 4

HEDONIC QUESTIONNAIRE USED BY CONSUMER PANEL TO EVALUATE BEEF SAMPLES were held over the two-month period, March to May, 1971. Additional sessions were scheduled during May and June to maintain the panelists sensory acuity.

All panelists were previously familiar with the texture scales developed by Szczesniak et al. (1963a), the four basic tastes and examples of food irritants. In the first session, panelists examined samples of blade, rib and round steak; in the second session, panelists examined samples of blade, rib and round roasts. Panelists were asked to record individually:

(1) the pertinent flavor and texture dimensions (Figure 5).

(2) the appropriate range of each dimension (Table IV).

(3) any foods which would represent points within the specified range (Table IV).

The dimensions were clarified and defined by group discussion and the terms not useful were discarded. The relevant dimensions were hardness, chewiness, juiciness, fibrousness, greasiness and meatiness. For the remaining sessions, samples of either steak or roast were presented along with standard scales. Throughout these sessions, the texture scales developed by Szczesniak et al. (1963a) were refined so that foods representing a narrower range of each dimension were used (Table IV).

During the first four weeks, the panelists rated the meat samples in relation to the standard on the scale. For example, for fibrousness a panelist might rate the sample equal to the bamboo shoot or bamboo shoot plus. Each panelist rated the coded samples individually and then the group discussed the ratings and retasted the samples if necessary. Definitions of the dimensions were continually revised.

For the final four weeks, the standards were assigned values

<u>HARDNESS</u>:	is the force required to compress the meat between the molar teeth.
<u>CHEWINESS</u>:	is the number of chews required before ½" x ½" x ¼" piece of meat is ready for swallowing.
<u>JUICINESS</u>:	is the amount of moisture in the mouth and remaining in the meat after 6 chews.
<u>FIBROUSNESS</u>:	is the size and number of fibres remaining in the mouth after 8 to 12 chews.
<u>GREASINESS</u>:	is the greasy film which coats the top of the mouth after the sample has been completely masticated.
<u>MEATINESS</u>:	is the intensity of the meaty flavor remaining in the mouth after complete mastication.

FIGURE 5

DEFINITIONS OF THE SENSORY DIMENSIONS
FOR THE EVALUATION OF BEEF

TABLE IV

STANDARD SCALES USED BY PANELISTS FOR THE EVALUATION OF BEEF

Dimension	Intensity	Food Product	Brand	Particulars	Preparation
Hardness	1	Cheddar cheese	Safeway	Medium	¼" cubes
	4	Water chestnuts	China Lily	-	sliced ¼" thick and then in half
	6	Caramels	Kraft	Vanilla	sliced in half
Juiciness	5	Ripe olive	Town House	Select pitted	sliced in sixths lengthwise
Fibrousness	1	Meat, meat by-product and chicken loaf	Swift's Premium	-	3/4" square
	3-4	Bamboo shoots*	China Lily	-	¼" cubes with visible fibres
	6	Pineapple tidbits*	Libby's	-	1 tidbit
Greasiness	2	Soda cracker	Christie's	Unsalted	1 biscuit
	4	Carlton cracker	Christie's	-	1 cracker
	6	Shortcake biscuit	Peek Frean's	-	½ biscuit
Meatiness	1	Monosodium glutamate	Accent	-	10 mgm/100 ml of water in creamers
	3	Monosodium glutamate	Accent	-	20 mgm/100 ml of water in creamers
	5	Monosodium glutamate	Accent	-	30 mgm/100 ml of water in creamers
	7	Monosodium glutamate	Accent	-	40 mgm/100 ml of water in creamers

*For evaluation, the fibres were separated with 1-2 chews.

along 7-point scales where a value of 7 represented the highest intensity and a value of 1 represented the lowest intensity. From then on, the panelists used these scales and rated the samples numerically. Group discussion and retasting after the panelists had rated the samples individually was continued.

All tasting for the training sessions took place in the air-conditioned laboratory at a large table to promote group discussion.

(b) Sensory evaluation. The panelists evaluated the samples in an air-conditioned, sound-proof sensory panel room. Each panelist was seated at a well-lighted booth and was instructed to rate the samples individually. No group discussion followed the panel. Occasionally, meetings were held to discuss problems of the individual panelists and those of the group as a whole.

The steak from the posterior end of the longissimus dorsi muscle section and the lateral side of the biceps femoris muscle, were used for the trained sensory panel meat samples. Four samples, each 3/4" x 3/4" x 1/4" in size, were randomly assigned to 3/4 oz. coded creamers with lids. The trays were arranged immediately prior to the panel time to ensure the freshness of the standards. Each panelist received a tray set with the coded creamers containing the meat samples, the standards for the texture and flavor scales, the appropriate evaluation form (Figure 6) and other necessary items. The panelists were permitted to swallow or expectorate the meat samples, as desired, and were given as much water to drink between samples as they wished. All samples and standards were served at room temperature.

Name: ____________

Date: ____________

PARAMETER	SAMPLE CODE NO.					
Hardness						
Chewiness						
Juiciness						
Fibrousness						
Greasiness						
Meatiness						

FIGURE 6

SCORE SHEET FOR SENSORY ANALYSIS
OF STEAK AND ROAST BEEF

IV RESULTS AND DISCUSSION

A. ANALYSIS OF DATA

The data were analyzed for each independent variable to determine the portion of the total variance explained by that independent variable over and above the independent variables of lower order. The dependent variables included the objective measurements and all the dimensions of the sensory panel evaluations, whereas the independent variables included sire, cows and sex for the main effects, sire x cow, sire x sex and cow x sex for the two-term interactions and sire x cow x sex for the three-term interaction. For the significant main effects and interactions, the regression coefficients were calculated and used for estimating the treatment effects and hence, the treatment means.

B. OBJECTIVE MEASUREMENTS

1. Percentage Drip Loss on Thawing

No significant differences in drip loss on thawing among crossbreeds were found. The large differences which appeared during the preliminary run averaged out over the five replicates.

2. Percentage Cooking Loss

There were no significant differences among crossbreeds for the longissimus dorsi muscle. However, there was a significant sex difference for the biceps femoris muscle at $P<.01$ (Figure 7). Bulls (25.43%) demonstrated higher percentage cooking losses than steers (23.03%).

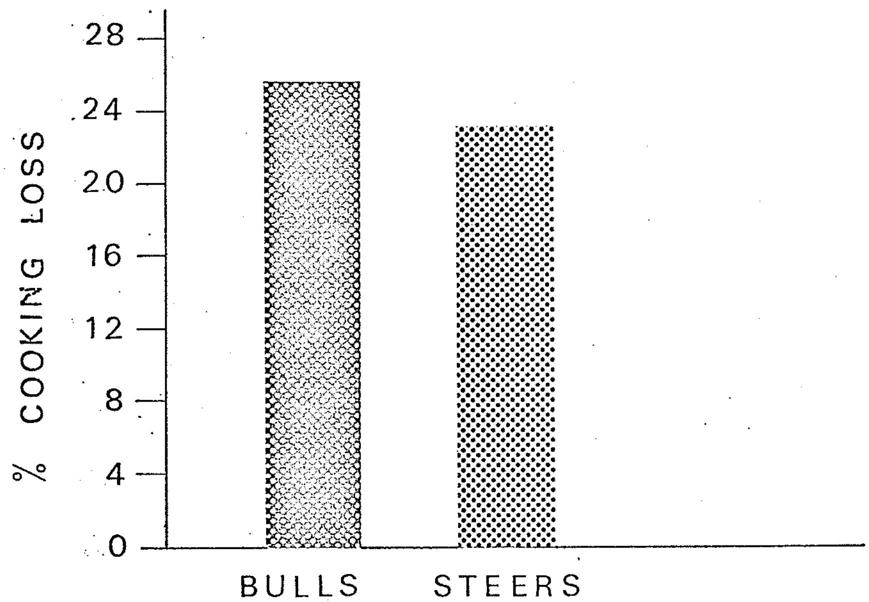

FIGURE 7

SIGNIFICANT SEX EFFECT FOR % COOKING LOSS OF BICEPS FEMORIS MUSCLE

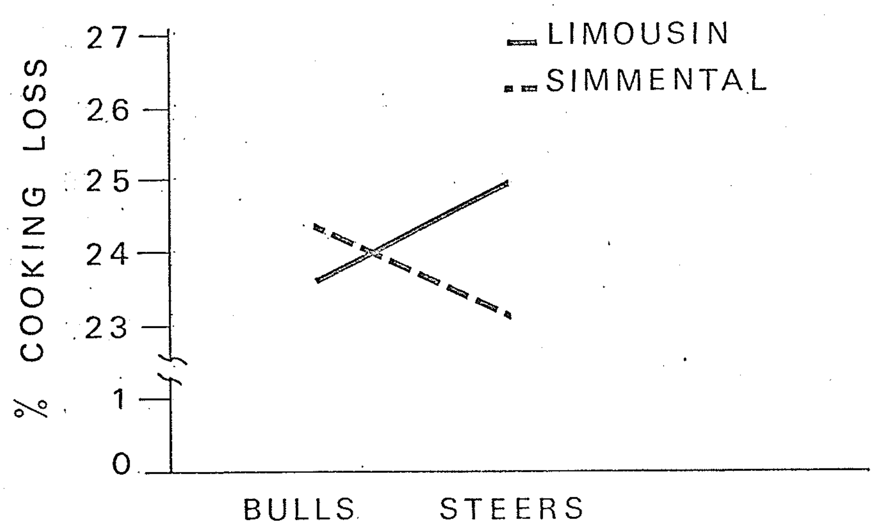

FIGURE 8

SIGNIFICANT SIRE X SEX INTERACTION FOR % COOKING LOSS OF BICEPS FEMORIS MUSCLE

Lipid analyses on these same muscles carried out in these laboratories indicated that the steers had higher intramuscular lipid levels than the bulls at $P<.05$ (A. T. Gillis, unpublished data). With less intramuscular fat, there would be a higher water content in the muscle (Hoke and Hedrick, 1969 and Goll *et al.*, 1965), and consequently, greater evaporation would occur. This would result in greater total cooking losses. In this experiment, the components of cooking loss, evaporation and drip loss, were not calculated. Thus, it was not known whether the increased cooking loss was due to evaporation or drip loss.

A significant sire x sex interaction ($P<.05$) also occurred (Figure 8). Limousin sired bulls and steers acted differently than Simmental sired bulls and steers. The individual comparisons were not tested for significance.

3. Shear Force

In the case of the longissimus dorsi muscle, no significant differences in shear force among the crossbreeds were found for the central and lateral core positions. However, for the medial core position, a significant sex difference was revealed ($P<.05$). Figure 9 shows that the bulls required significantly more shear force (5.56 lb.) than the steers (4.74 lb.).

In the case of the biceps femoris muscle, there were no significant differences in shear force for the posterior core position. For the proximal core position, the bulls (7.40 lb.) demonstrated significantly lower shear force values than the steers (9.00 lb.). This difference is shown in Figure 10. For the central core location, no significant differences were revealed by the overall analysis of variance. However, when the individual comparisons among the cow effects were

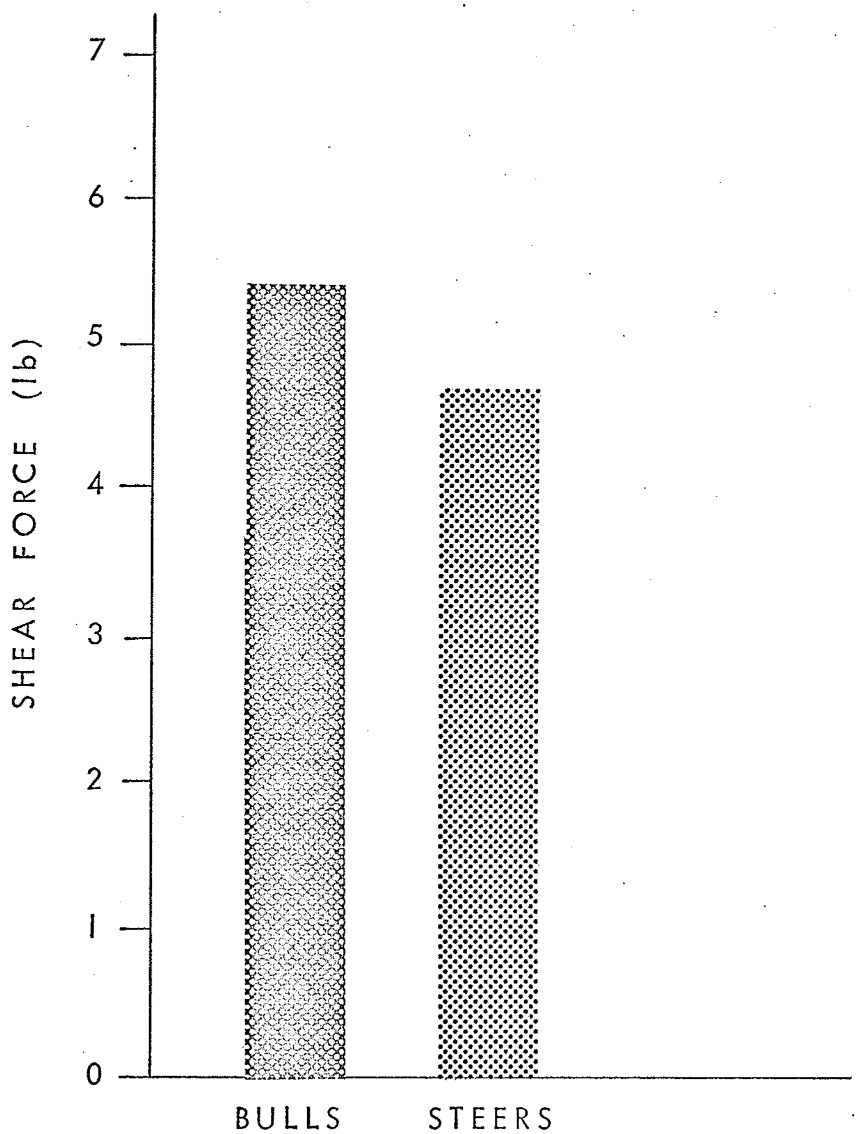

FIGURE 9

SIGNIFICANT SEX EFFECT FOR WARNER-BRATZLER SHEAR MEDIAL VALUES OF LONGISSIMUS DORSI MUSCLE

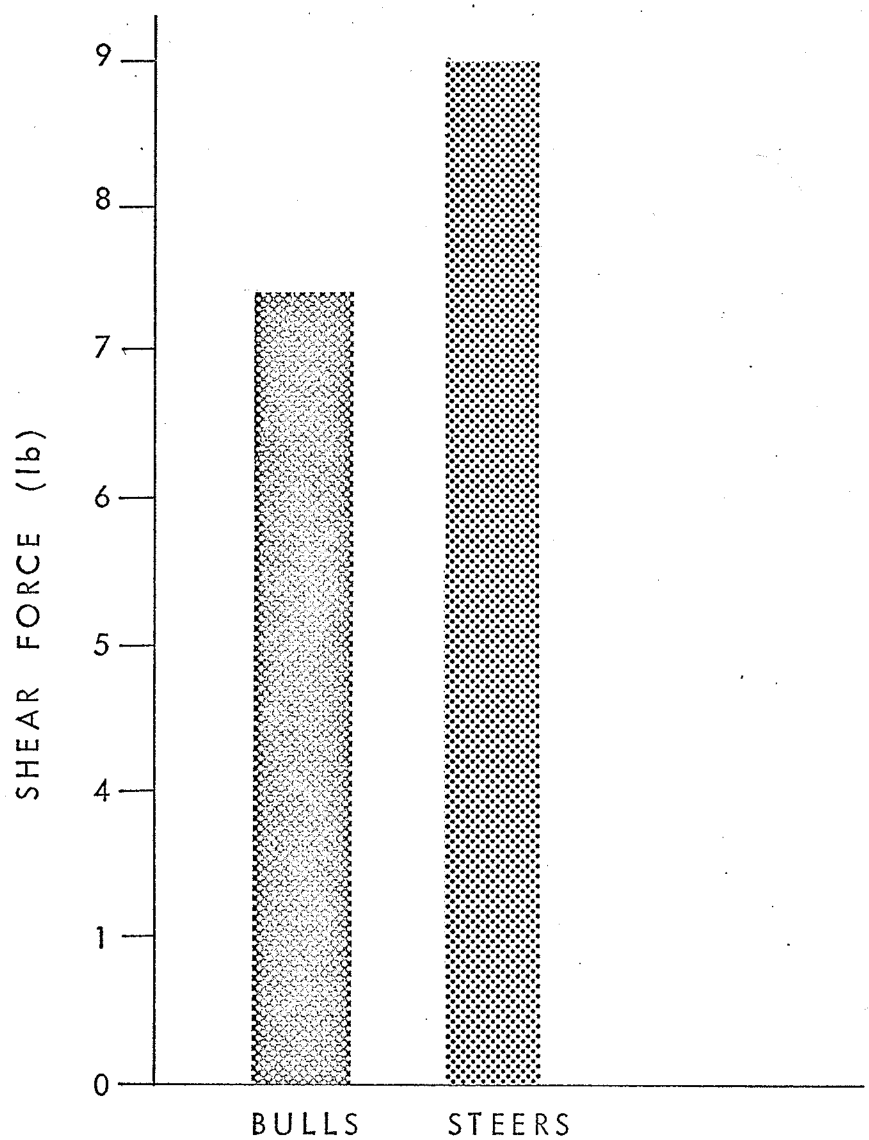

FIGURE 10

SIGNIFICANT SEX EFFECT FOR WARNER-BRATZLER SHEAR PROXIMAL VALUES OF BICEPS FEMORIS MUSCLE tested, two of them were significant (Figure 11). Shorthorn crosses required significantly less shear force than the Hereford and Angus crosses ($P<.05$). The Hereford crosses were not significantly different from the Angus crosses. The treatment means for shear force were:

Shorthorn	Angus	Hereford
5.00 lb.	5.71 lb.	5.76 lb.

Figure 12 represents the significant sire x cow interaction ($P<.05$). The differences between the individual comparisons were not tested.

Differences due to core location were found for both muscles. The lateral core position of the longissimus dorsi muscle demonstrated significantly higher shear force values than both the medial and central core positions ($P<.05$). No significant difference between the medial and central core position occurred. The treatment means of the three core positions are shown below:

Central	Medial	Lateral
4.98 lb.	5.15 lb.	5.64 lb.

Other researchers have reported that the medial core position was more tender than the lateral core position (Martin *et al.*, 1970, Hedrick *et al.*, 1968, Walter *et al.*, 1965 and Tuma *et al.*, 1962a).

In the case of the biceps femoris muscle, the proximal core position demonstrated significantly higher shear force values than both the central and posterior core positions ($P<.01$). No significant differences between the central and posterior core positions were revealed. The treatment means of the three core positions are shown below:

Proximal	Central	Posterior
8.20 lb.	5.49 lb.	4.89 lb.

These findings were in disagreement with Ramsbottom *et al.*, 1945 who

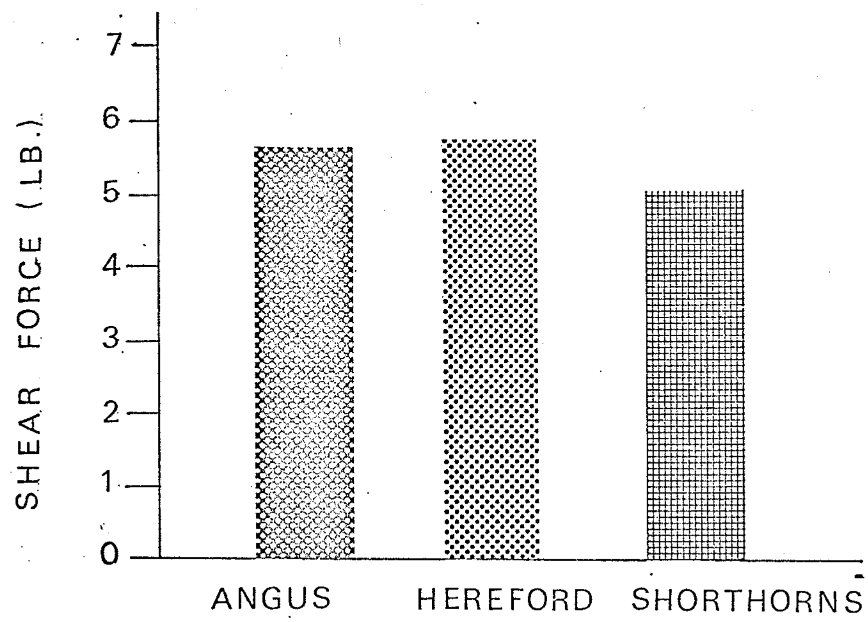

FIGURE 11

SIGNIFICANT COW EFFECT FOR WARNER-BRATZLER SHEAR CENTRAL VALUES OF BICEPS FEMORIS MUSCLE

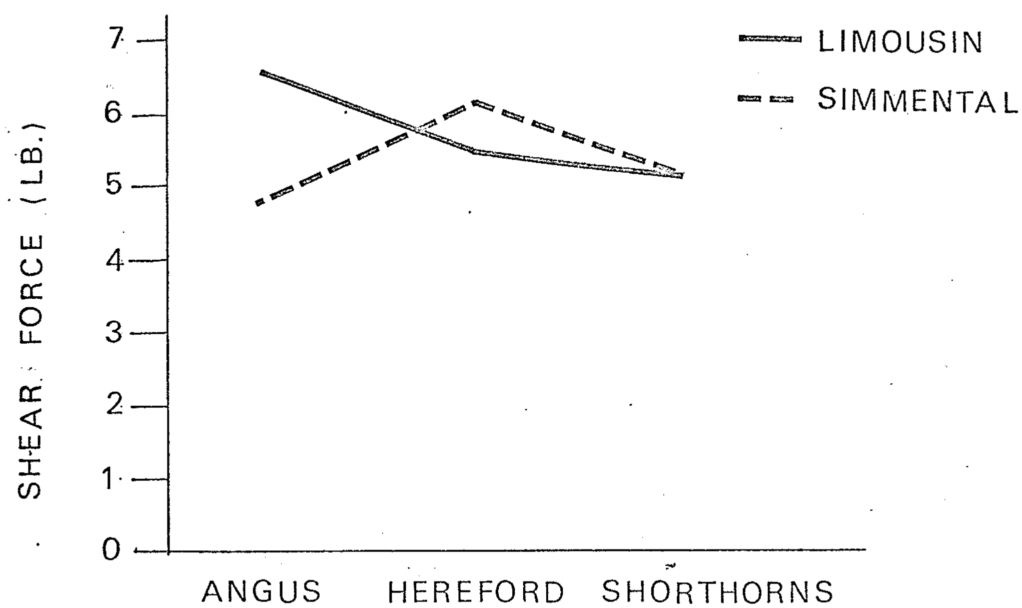

FIGURE 12

SIGNIFICANT SIRE X COW INTERACTION FOR WARNER-BRATZLER SHEAR CENTRAL VALUES OF BICEPS FEMORIS MUSCLE showed that the shear force value for cooked biceps femoris muscle tended to increase from origin to insertion (proximal to posterior). Cover et al. (1962) found no significant differences in shear force due to core position in steaks from the biceps femoris muscle.

4. Texturometer Measurements

(a) Juiciness. There were no significant differences in texturometer juiciness among the crossbreeds for the longissimus dorsi muscle. However, for the biceps femoris muscle, a significant sex effect ($P<.05$) occurred (Figure 13). This effect indicated that the steers (25.55 $cm.^2/5$ gm.) were juicier than the bulls (22.79 $cm.^2/5$ gm.). According to Laakkonen et al. (1970), water is the major component of cooking losses during the cooking of meat. Consequently, if the higher percentage cooking losses reported for bulls (p. 35) was due to greater moisture evaporation, it would be reasonable to suggest that the texturometer juiciness, a type of press fluid measurement, would be decreased since the total moisture content would be reduced.

The cohesiveness of the muscle fibres might also have been a factor affecting texturometer juiciness. Since the bull meat was significantly more cohesive (p. 48) than the steer meat, one would expect the free water to be more tightly held in the microstructure of the muscle fibres, and as a result, it would be more difficult to squeeze the water out of the meat. Hence, the press fluid, which was used for estimating the juiciness, would be less. The opposite effect would be true for the steers.

The results were contrary to those of Gaddis et al. (1950). These researchers found that the percentage press fluid tended to decrease as the intramuscular lipid levels increased. They also

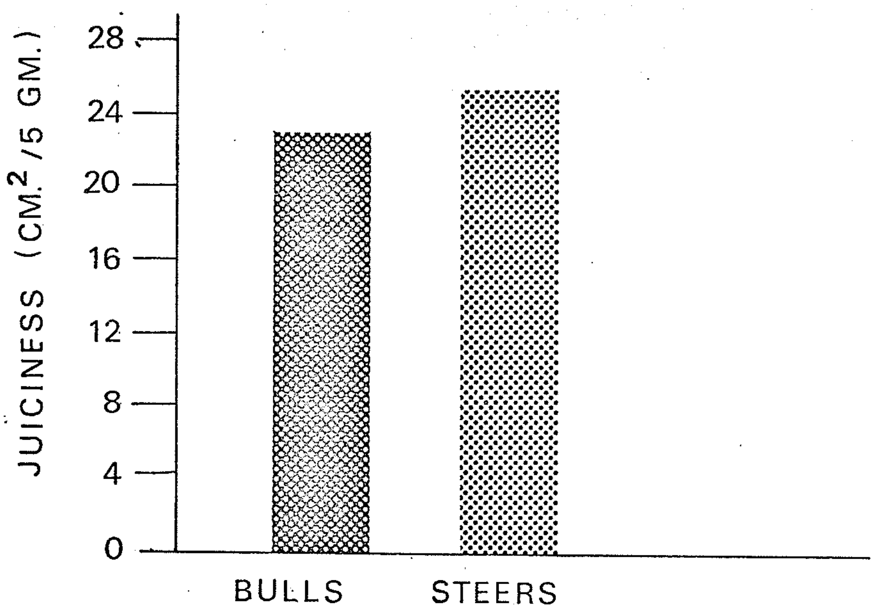

FIGURE 13

SIGNIFICANT SEX EFFECT FOR TEXTUROMETER JUICINESS OF BICEPS FEMORIS MUSCLE

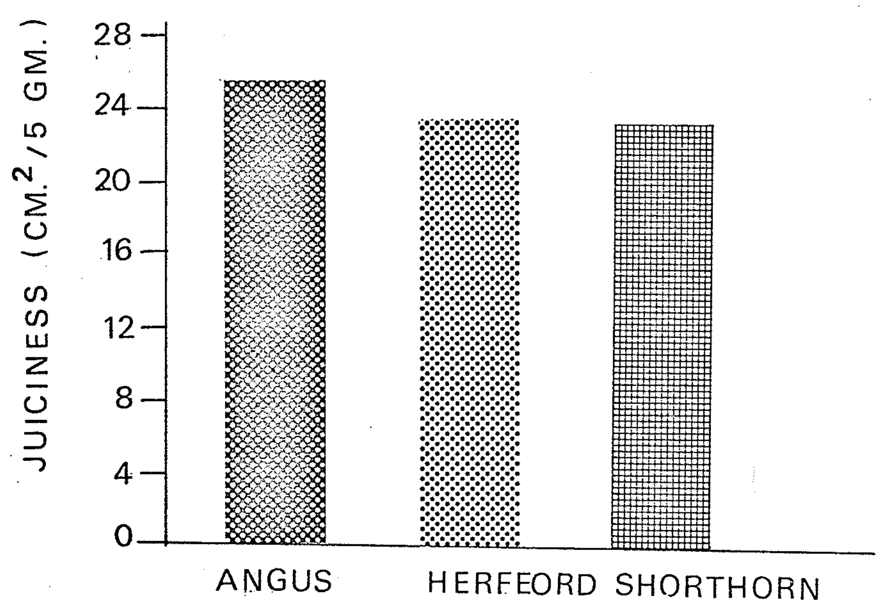

FIGURE 14

SIGNIFICANT COW EFFECT FOR TEXTUROMETER JUICINESS OF BICEPS FEMORIS MUSCLE suggested that the press fluid would be less with higher intramuscular lipid levels because the fat tends to hold back some of the moisture which would otherwise be squeezed out as juice. Because increased intramuscular lipid levels result in higher juiciness scores as rated by a sensory panel, these researchers concluded that the percentage press fluid and panel scores for juiciness would not correlate well.

It should be pointed out that Gaddis et al. (1950) used meat from steers and not meat from both bulls and steers. The decreased cohesiveness found for the steer meat (p. 48) might have outweighed the effect of the increased intramuscular lipid levels. If this was the case, the free water would be less tightly held in the muscle fibre microstructure and thus, more easily squeezed out as juice.

Although the overall analysis did not detect a significant effect due to cows, some of the individual comparisons among the cows were significant (Figure 14). The Angus crosses were significantly juicier than both the Hereford crosses and the Shorthorn crosses ($P<.05$). The Shorthorn crosses were not significantly different from the Hereford crosses. These means were:

Angus	Hereford	Shorthorn
25.74 cm.^{2}/5 gm.	23.73 cm.^{2}/5 gm.	23.04 cm.^{2}/5 gm.

A difference in the intramuscular lipid levels due to the cows could be a possible explanation. However, no data were available to confirm this explanation.

(b) Hardness, cohesiveness and springiness. For the longissimus dorsi muscle, a significant sex effect, cow x sex interaction and sire x cow interaction ($P<.05$) were found. Meat from bulls was significantly harder than meat from steers (Figure 15). These treatment means were

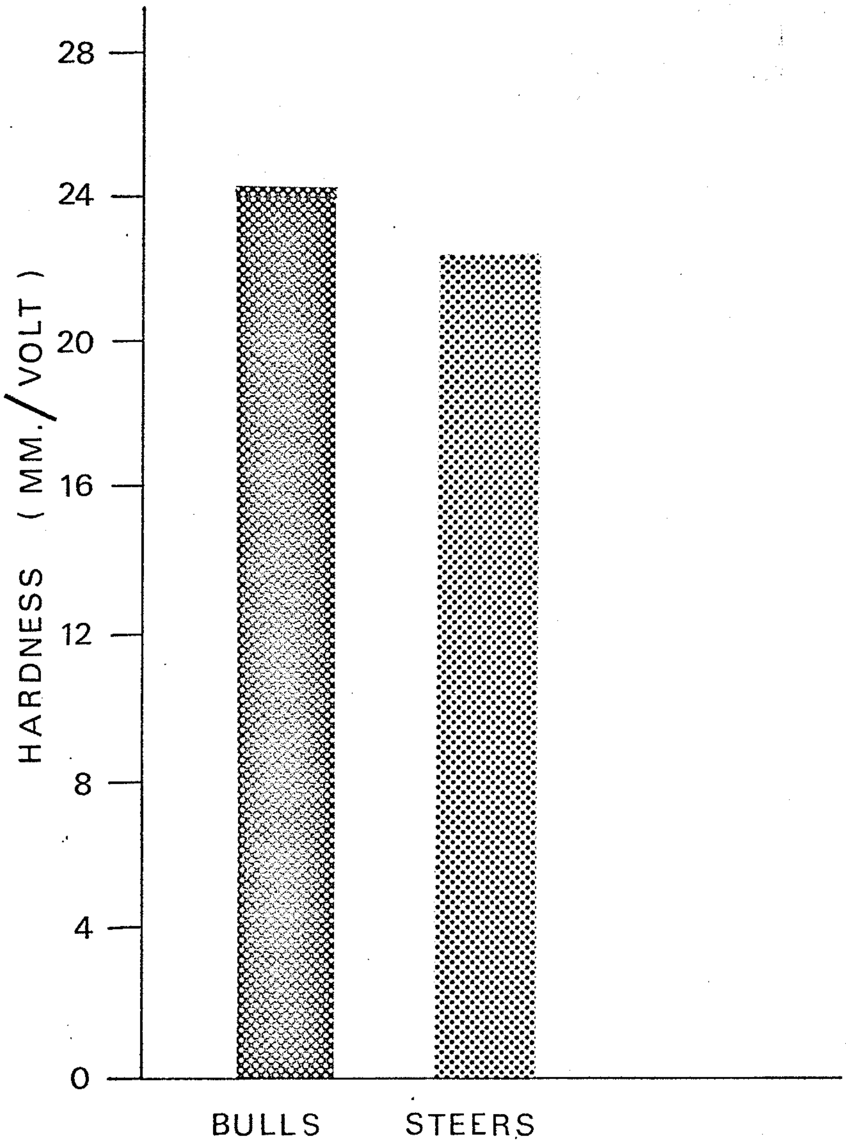

FIGURE 15

SIGNIFICANT SEX EFFECT FOR TEXTUROMETER HARDNESS OF LONGISSMUS DORSI MUSCLE

24.20 mm./volt and 22.52 mm./volt respectively for bulls and steers.

Figure 16 shows the cow x sex interaction. On testing the individual comparisons, the Shorthorn steers were significantly softer than the Shorthorn bulls at $P<.01$. Similarly, the Hereford steers were significantly softer than the Hereford bulls at $P<.05$. The Angus steers and bulls were not significantly different. The Angus bulls were significantly softer than the Shorthorn bulls ($P<.05$). However, the Hereford bulls were not significantly different from either the Angus or Shorthorn bulls. The treatment means in mm./volt are presented in Table V.

TABLE V

TREATMENT MEANS OF THE SIGNIFICANT COW x SEX INTERACTION FOR TEXTUROMETER HARDNESS OF THE LONGISSIMUS DORSI MUSCLE

Sex	Texturometer Hardness mm./volt		
	Shorthorn	Hereford	Angus
Bulls	25.31^{a}	24.14^{a}	23.15^{a}
Steers	22.01^{b}	21.96^{b}	23.59^{a}

[a, b]Those means within a column followed by the same superscript do not differ significantly. All others differ significantly. Comparisons cannot be made among columns.

For the steers, there were no significant differences in hardness due to the cows.

The significant sire x cow interaction is shown in Figure 17. The individual comparisons were not tested for significance.

In the case of the biceps femoris muscle, no significant differences in hardness among the crossbreeds were revealed.

The mean for texturometer hardness in the experiment was 23.36

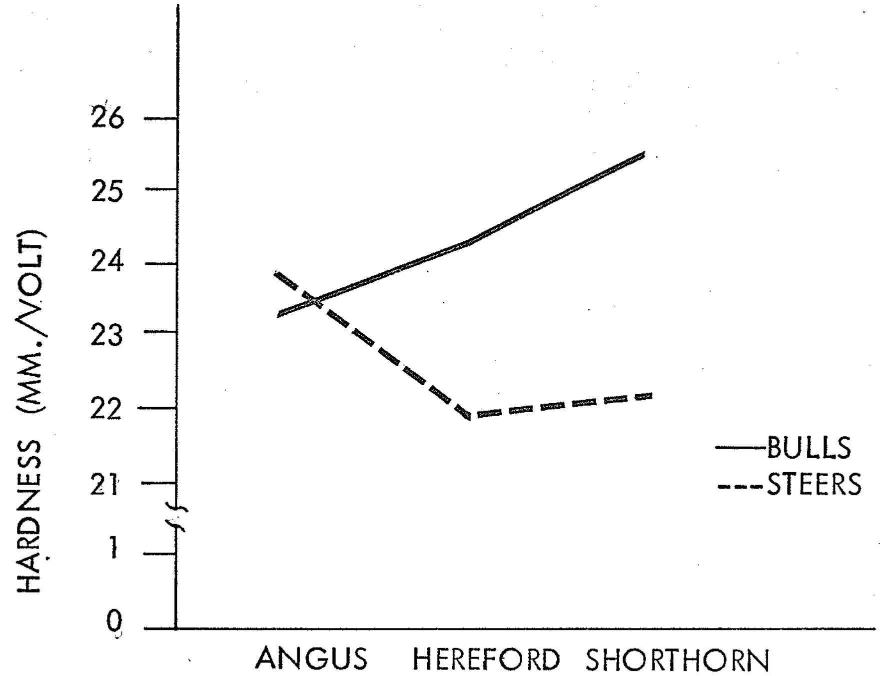

FIGURE 16

SIGNIFICANT COW X SEX INTERACTION FOR TEXTUROMETER HARDNESS OF LONGISSIMUS DORSI MUSCLE

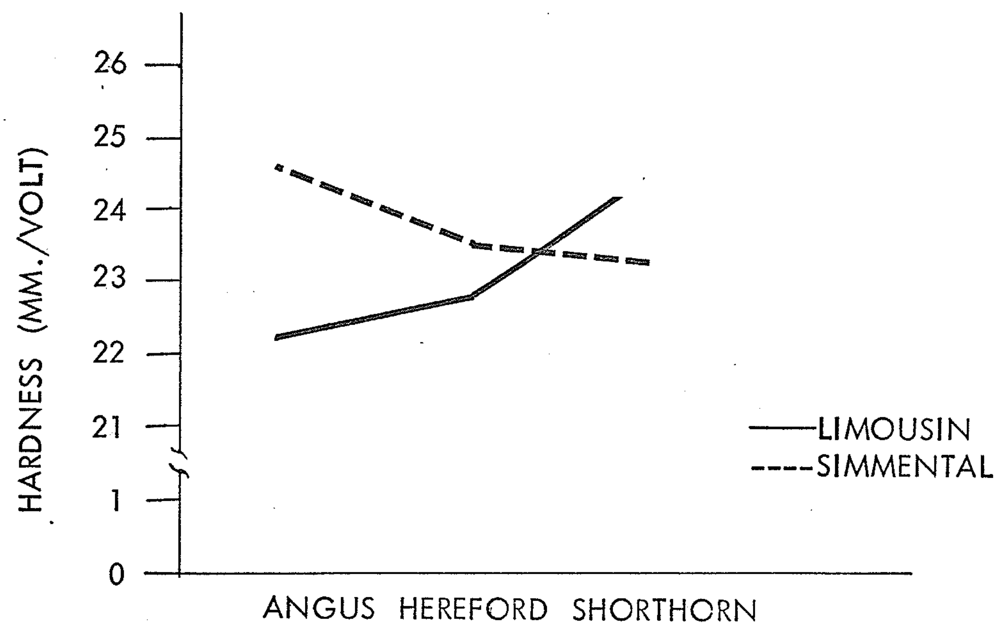

FIGURE 17

SIGNIFICANT SIRE X COW INTERACTION FOR TEXTUROMETER HARDNESS OF LONGISSIMUS DORSI MUSCLE mm./volt (excluding the effects of the significant independent variables). This was approximately one-quarter of the texturometer hardness value (91.2) for roast beef reported by Corey (1970). However, Corey did not report or cite references for either the units of measurement or the size of the sample used. Thus, a valid comparison could not be made.

For the longissimus dorsi muscle, there were no significant differences in cohesiveness among the crossbreeds. However, for the biceps femoris muscle, the bulls (0.86) were significantly more cohesive than the steers (0.78) as shown in Figure 18. This could have been a result of the decreased marbling (G. W. Rahnefeld et al., unpublished data) and the lower intramuscular lipid levels (A. T. Gillis, unpublished data) which occurred in the bulls. One would expect that, in lean with less marbling and the consequent lower intramuscular lipid levels, the muscle fibres would be more closely aligned and as a result, they would be more cohesive. Cohesiveness refers to the ability of the muscle fibres to remain together resisting disintegration by mastication.

No significant differences in springiness among the crossbreeds were revealed for either muscle.

C. SENSORY EVALUATION

1. Evaluation by the Consumer Panels

As reported in the Method (p. 27) consumer liking was carried out only on the biceps femoris muscle. No significant differences among the crossbreeds were revealed. This could have been caused by the great variation in consumer likes and dislikes. What one consumer likes very much, another might dislike. The net effect of such observations would be to cancel each other and would result in no overall difference.

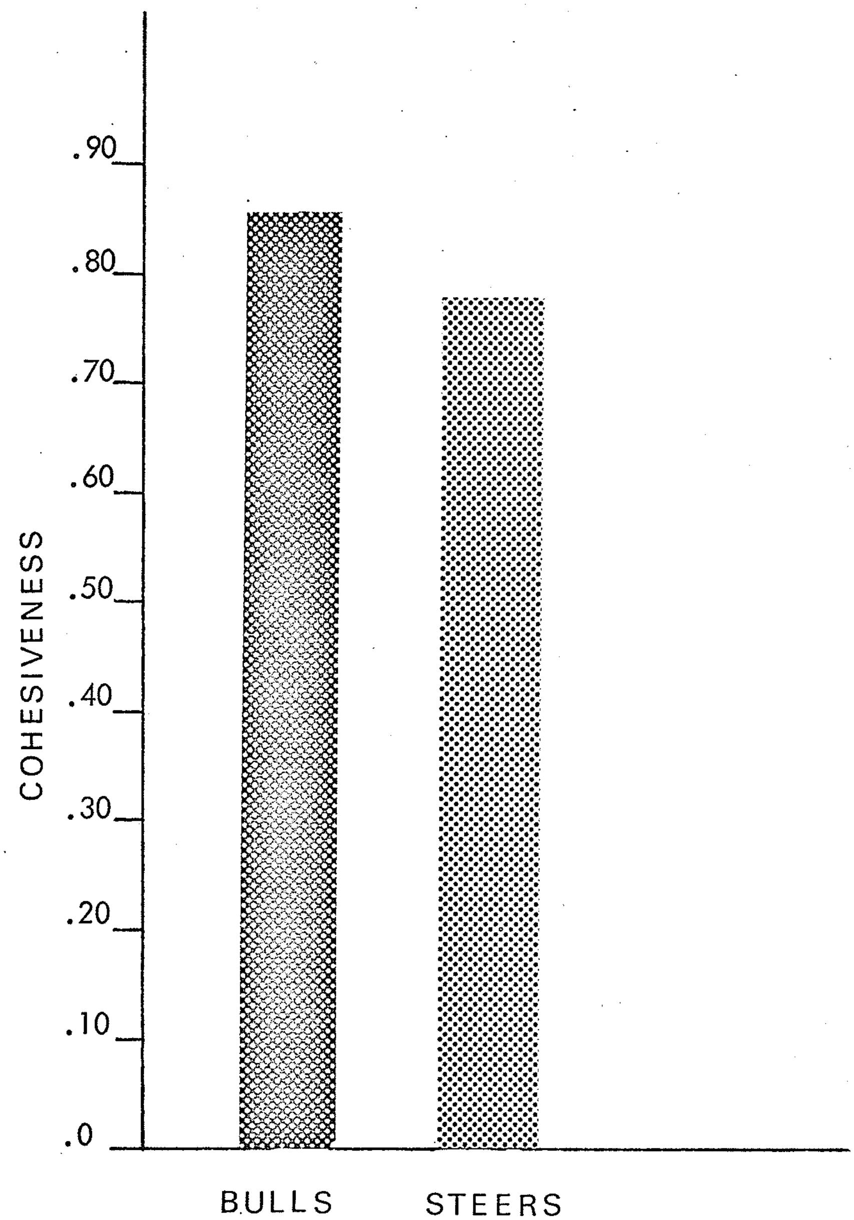

FIGURE 18
SIGNIFICANT SEX EFFECT FOR TEXTUROMETER COHESIVENESS OF BICEPS FEMORIS MUSCLE.

2. Evaluation by the Trained Sensory Panel

(a) Hardness. For the longissimus dorsi muscle, the sire x cow interaction was the only significant effect (Figure 19). The individual comparisons were not carried out. Table VI presents the treatment means including the sire x cow interactions.

TABLE VI

TREATMENT MEANS OF SENSORY PANEL HARDNESS FOR THE LONGISSIMUS DORSI MUSCLE INCLUDING THE EFFECT OF THE SIGNIFICANT SIRE x COW INTERACTION

Cow	Hardness (mm./volt)	
	Bull	Steer
Angus	3.51	3.71
Hereford	3.51	3.71
Shorthorn	4.05	3.11

It is interesting to note that both the texturometer and the sensory panel detected a significant difference in hardness due to the sire x cow interaction. The Simmental crosses for both these measurements appeared to demonstrate similar tendencies whereas the Limousin crosses appeared to demonstrate dissimilar tendencies.

For the biceps femoris muscle, a significant effect due to cows was revealed when the individual comparisons were tested (Figure 20). The Hereford crosses were significantly harder than the Shorthorn crosses ($P<.01$), but none of the other comparisons among crossbreeds was significant. The treatment means were as follows:

Hereford	Angus	Shorthorn
4.19	3.90	3.79

(b) Chewiness. In the case of the longissimus dorsi muscle,

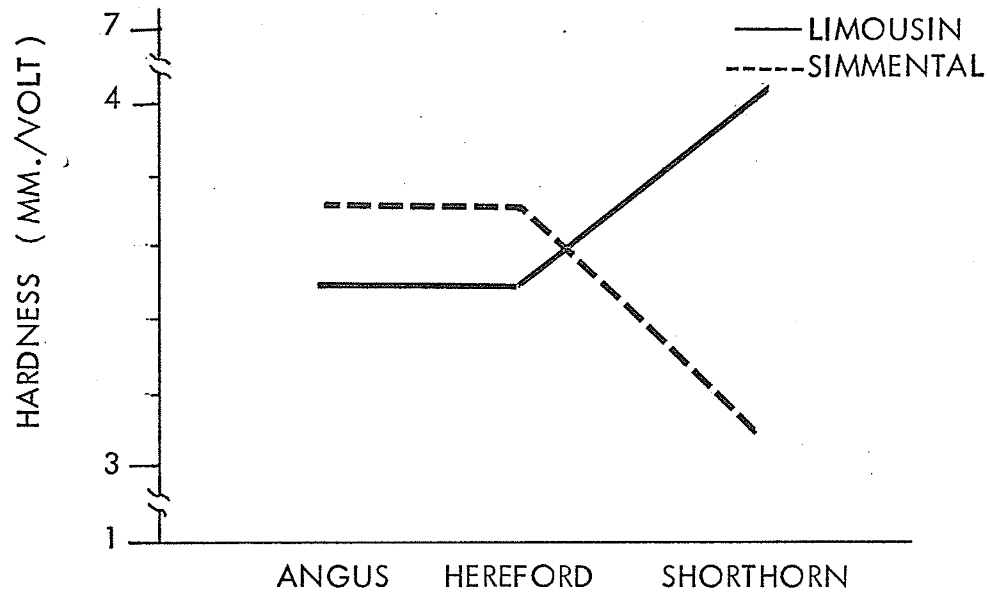

FIGURE 19

SIGNIFICANT SIRE X COW EFFECT FOR SENSORY PANEL HARDNESS OF LONGISSIMUS DORSI MUSCLE

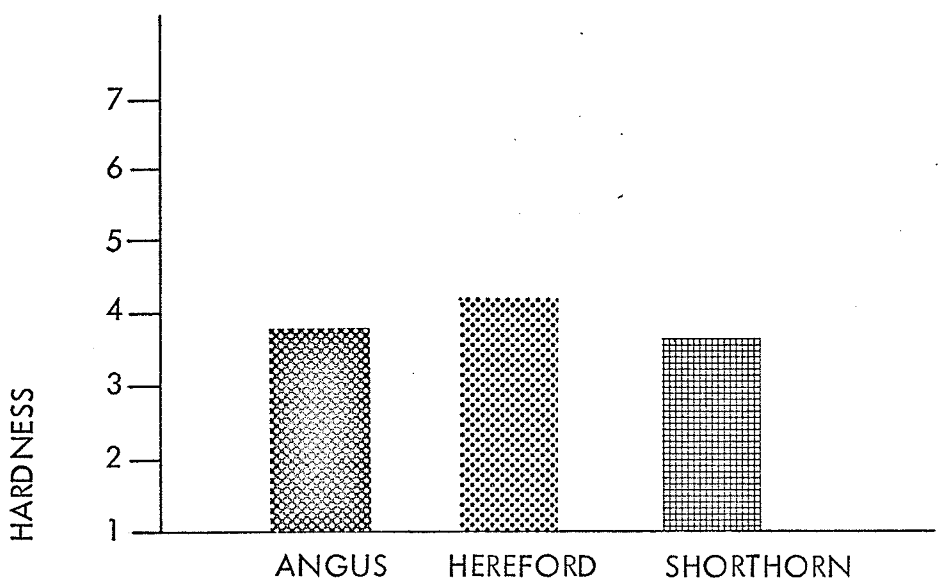

FIGURE 20

SIGNIFICANT COW EFFECT FOR SENSORY PANEL HARDNESS OF BICEPS FEMORIS MUSCLE the meat from bulls was significantly chewier than the meat from the steers ($P<.05$). It seems reasonable that meat which was harder (p. 44) would require more mastication. However, the estimated means for chewiness of bull and steer meat were 22.80 chews and 20.78 chews respectively (Figure 21). This difference of two chews was too small to be of practical significance.

No significant differences among the crossbreeds for the biceps femoris muscle were found.

(c) Juiciness. For the longissimus dorsi muscle, a significant cow effect occurred (Figure 22). The Hereford crosses were significantly juicier than the Angus crosses ($P<.01$), while there were no significant differences between the Hereford crosses and the Shorthorn crosses and between the Shorthorn crosses and the Angus crosses. The treatment means were:

Hereford	Shorthorn	Angus
3.50	3.28	2.91

Ramsey *et al*. (1963) found no significant differences in the juiciness between Hereford and Angus loin steaks as evaluated by a sensory panel.

It should be noted that the texturometer did not reveal a difference in juiciness among the crossbreeds for the longissimus dorsi muscle. No data were available on marbling and intramuscular lipid levels as affected by the cows. If there were differences perhaps the degree of marbling was affecting the panelists perception of juiciness. Researchers have demonstrated that meat with more marbling was rated juicier by trained sensory panels than meat with less marbling (Breidenstein *et al*., 1968, Field *et al*., 1966, and Simone *et al*., 1959).

For the biceps femoris muscle, sex significantly affected

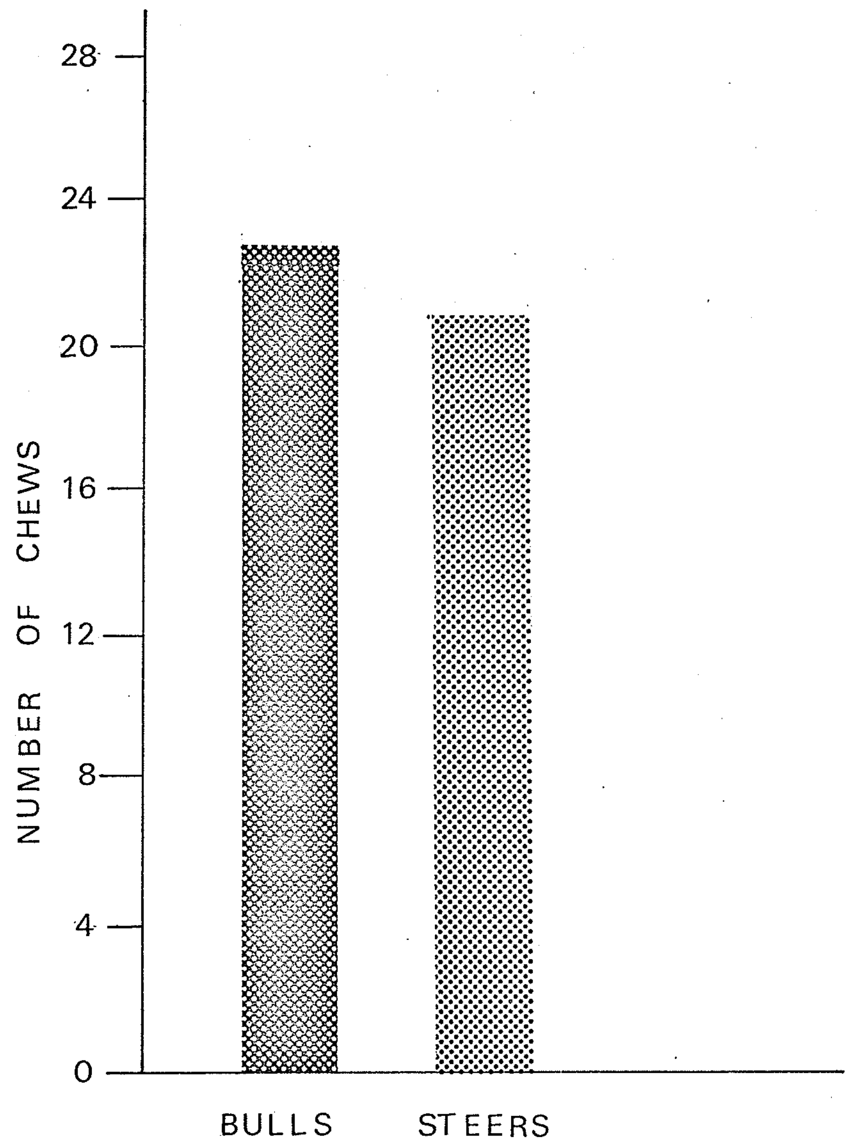

FIGURE 21

SIGNIFICANT SEX EFFECT FOR SENSORY PANEL CHEWINESS OF LONGISSIMUS DORSI MUSCLE

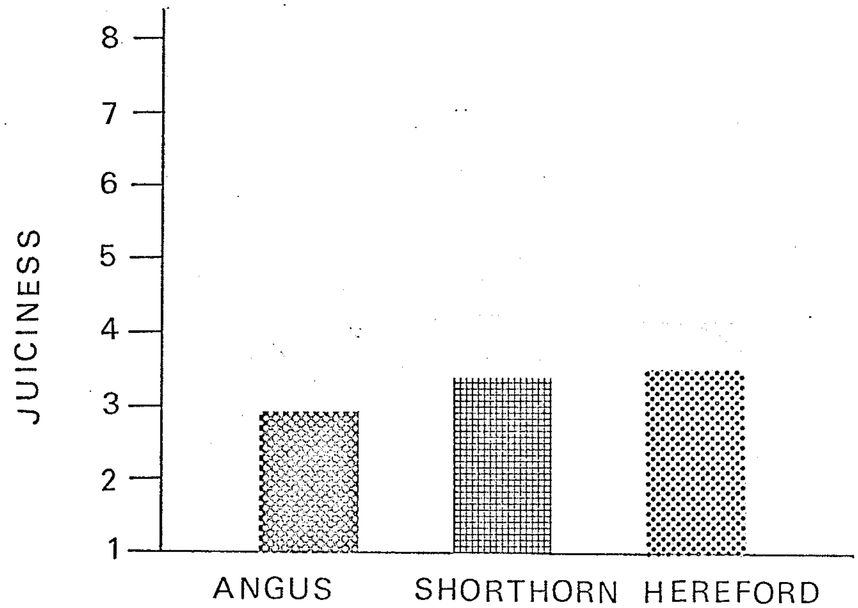

FIGURE 22

SIGNIFICANT COW EFFECT FOR SENSORY PANEL JUICINESS OF LONGISSIMUS DORSI MUSCLE

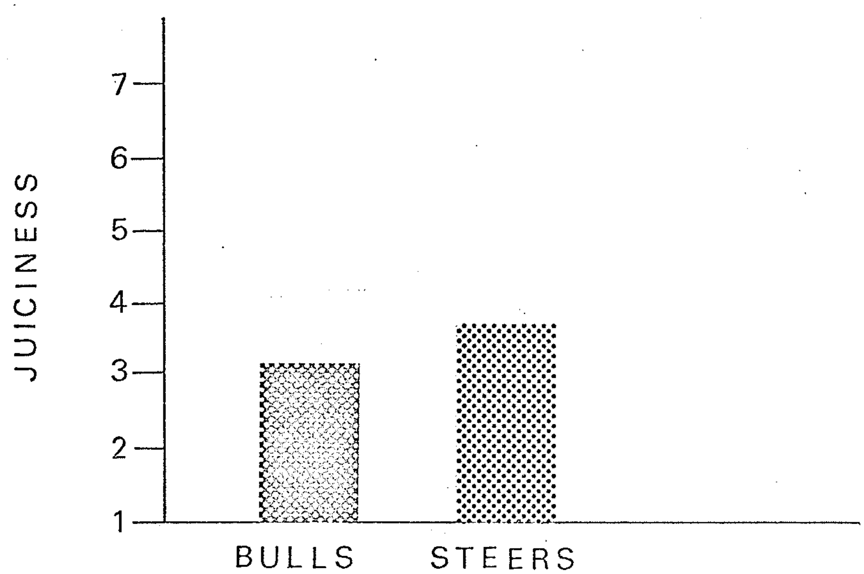

FIGURE 23

SIGNIFICANT SEX EFFECT FOR SENSORY PANEL JUICINESS OF BICEPS FEMORIS MUSCLE juiciness as evaluated by the sensory panel ($P<.05$). The steers (3.69) were juicier than the bulls (3.13) as shown in Figure 23. One would expect steer meat with more marbling (G. W. Rahnefeld _et al_., unpublished data) and higher intramuscular lipid levels (A. T. Gillis, unpublished data) to be juicier than bull meat with less marbling and lower intramuscular lipid levels (Breidenstein _et al_., 1968, Field _et al_., 1966 and Simone _et al_., 1959).

(d) _Fibrousness_. For the longissimus dorsi muscle, the sex effect was significant ($P<.01$). The bulls (2.22) were significantly more fibrous than the steers (1.86) as shown in Figure 24. In the present grading system, the fineness of the grain of the meat is considered. A finer grained meat grades higher. A fine grain has finer connective tissue and less of it, whereas a coarse grain has coarse connective tissue and more of it. Since the bulls tended to grade lower than the steers (G. W. Rahnefeld _et al_., unpublished data), the bulls would tend to have a coarser grain and hence, coarser connective tissue. If this were so, it would explain the increased fibrousness in the bulls over the steers as detected by the sensory panel. These results did not support work by Brown _et al_. (1962). They found that bulls were not significantly different in texture from steers as evaluated by a sensory panel.

A significant difference in fibrousness due to the cows was revealed for the biceps femoris muscle ($P<.01$). The Hereford crosses were significantly more fibrous than either the Angus or Shorthorn crosses. However, the Shorthorn crosses were not significantly less fibrous than the Angus crosses (Figure 25). The treatment means were:

Hereford	Angus	Shorthorn
3.35	2.98	2.94

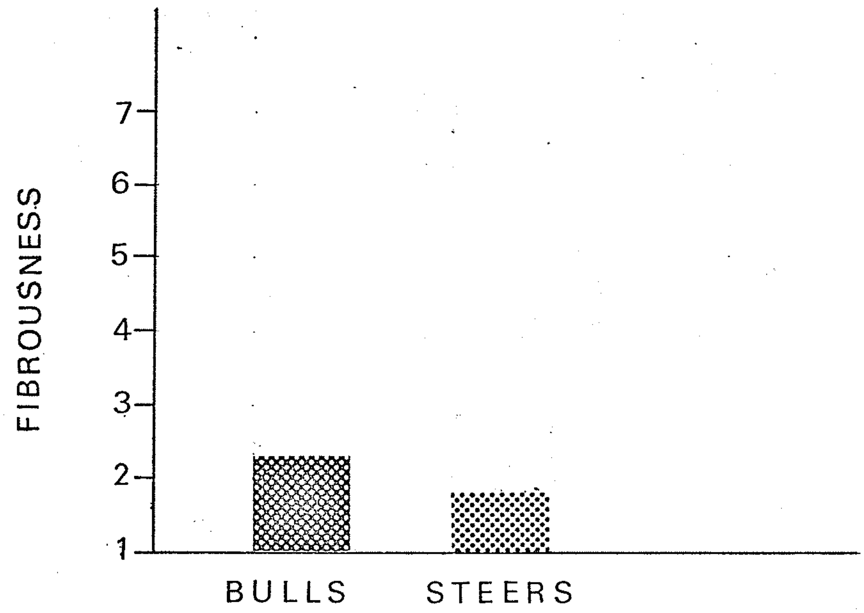

FIGURE 24

SIGNIFICANT SEX EFFECT FOR SENSORY PANEL FIBROUSNESS OF LONGISSIMUS DORSI MUSCLE

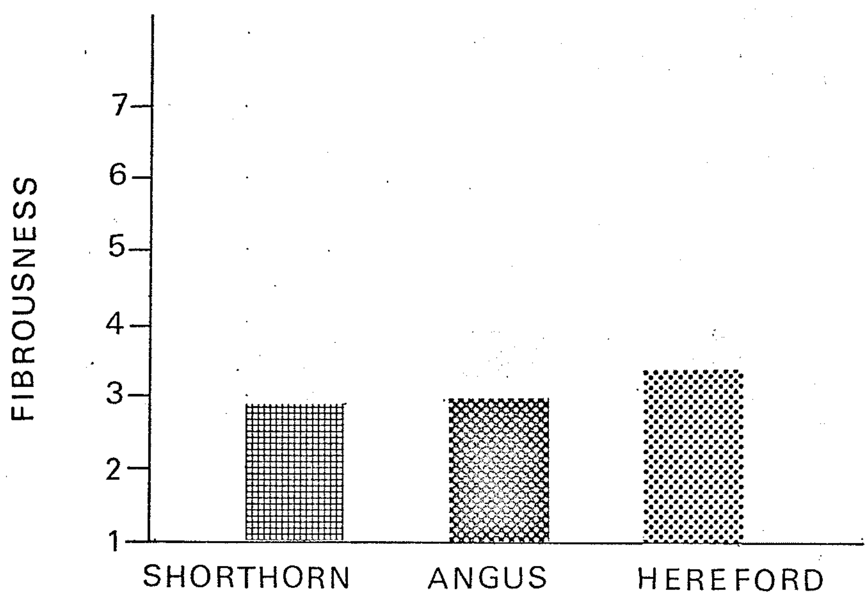

FIGURE 25

SIGNIFICANT COW EFFECT FOR SENSORY PANEL FIBROUSNESS OF BICEPS FEMORIS MUSCLE

(e) Greasiness. There were no significant differences in greasiness among the crossbreeds for the longissimus dorsi muscle. In the case of the biceps femoris muscle, a significant sex effect occurred ($P<.01$). Figure 26 represents the increased greasiness ratings for steers (3.43) over that of the bulls (3.11). This would be due to the higher intramuscular lipid levels in the steers over the bulls (A. T. Gillis, unpublished data).

(f) Meatiness. No significant differences in meatiness among the crossbreeds were detected by the sensory panel for the longissimus dorsi muscle. However, a significant sex difference and sire x sex interaction ($P<.05$) occurred for the biceps femoris muscle (Figures 27 and 28 respectively). The steers (5.70) were meatier than the bulls (5.36). According to several researchers, meat with more marbling and the consequent higher intramuscular lipid levels was rated more flavorful than meat with less marbling (Breidenstein *et al*., 1968, Field *et al*., 1966 and Simone *et al*., 1959). The individual comparisons of the sire x sex interaction were not tested for significance. The treatment means are reported in Table VII.

D. CORRELATION COEFFICIENTS

Correlation coefficients indicating the linear relationship between each variable were calculated. Overall, the correlation coefficients were low, but because the sample size (60) was relatively large, significance was attained with low correlation coefficients. The longissimus dorsi muscle tended to have higher correlation coefficients than the biceps femoris muscle and thus, more of these coefficients were significant at ($P<.01$) than were those of the biceps femoris.

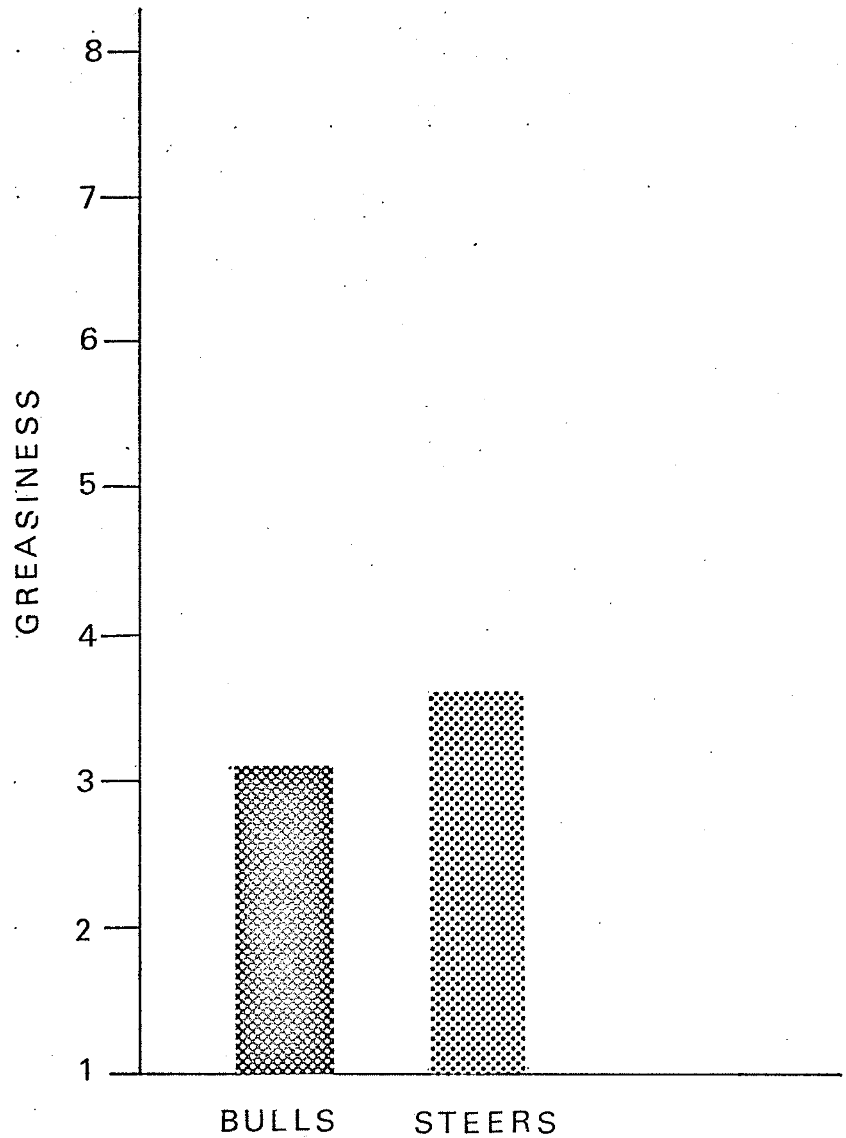

FIGURE 26

SIGNIFICANT SEX EFFECT FOR SENSORY PANEL GREASINESS OF BICEPS FEMORIS MUSCLE

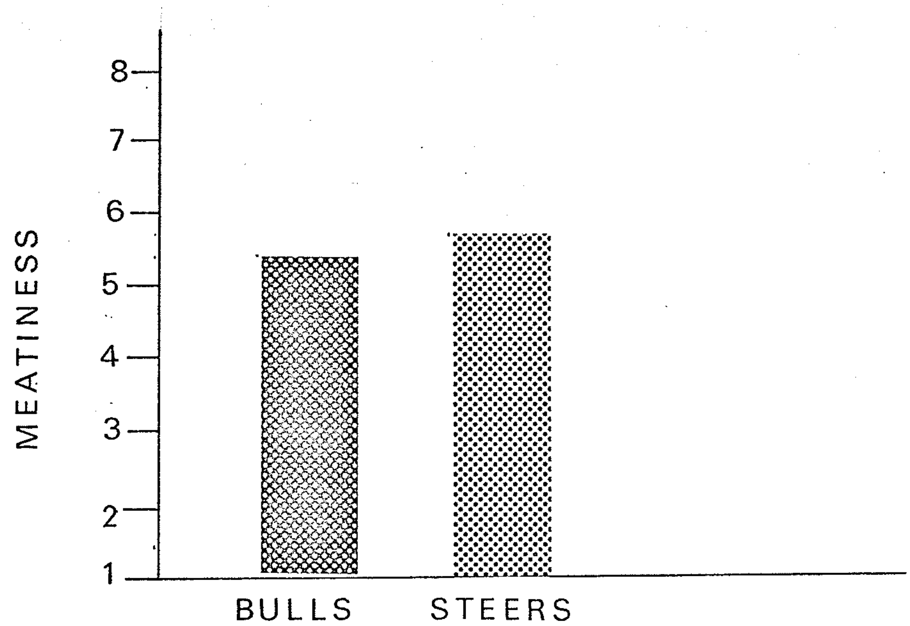

FIGURE 27

SIGNIFICANT SEX EFFECT FOR SENSORY PANEL MEATINESS OF BICEPS FEMORIS MUSCLE

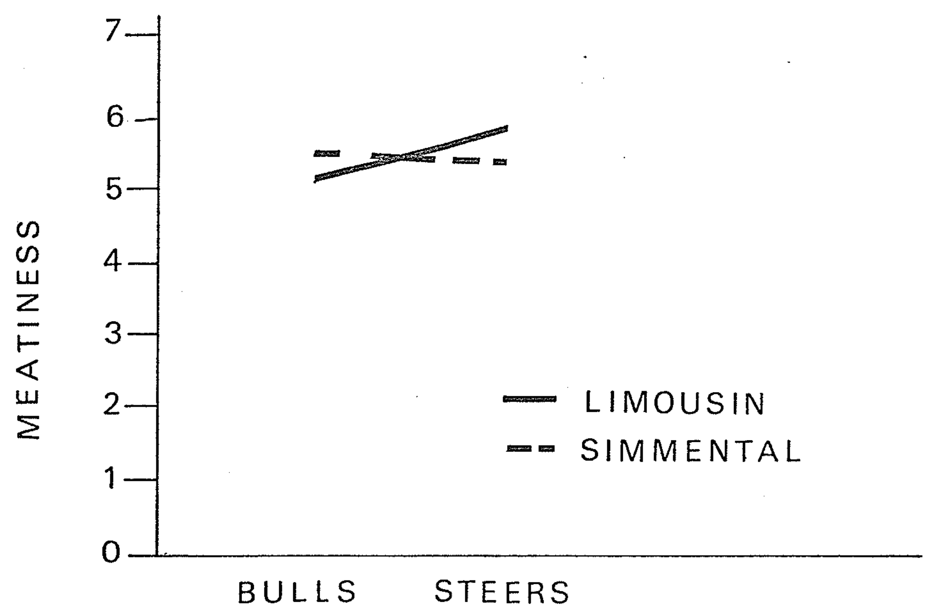

FIGURE 28

SIGNIFICANT SIRE X SEX INTERACTION FOR SENSORY PANEL MEATINESS OF BICEPS FEMORIS MUSCLE

TABLE VII

TREATMENT MEANS OF SENSORY PANEL MEATINESS
FOR THE BICEPS FEMORIS MUSCLE INCLUDING
THE EFFECT OF THE SIGNIFICANT
SIRE x SEX INTERACTION

Sire	Meatiness	
	Bull	Steer
Limousin	5.16	5.92
Simmental	5.56	5.48

The correlation coefficients between the Warner-Bratzler shear values (WBS) and the texturometer hardness for the longissimus dorsi muscle and the biceps femoris muscle are reported in Tables VIII and IX, respectively. In all but one example, the correlations were positive. Thus, as one of the values increased, the other value increased. A significant negative correlation would indicate that as one of the values increased, the other value would decrease. An example of a negative correlation occurred between the Warner-Bratzler shear proximal and the Warner-Bratzler shear posterior values ($r = -0.22$) in Table IX. However, this correlation was not significant.

From Table VIII, it is evident that shear values from the various positions are different. It appears that 18.5% of the variation in the Warner-Bratzler shear central values and 28.1% of the variation in the Warner-Bratzler shear lateral values were attributable to Warner-Bratzler shear medial values for the longissimus dorsi muscle. Similarly, 43.6% of the variation in the Warner-Bratzler shear lateral values was attributable to Warner-Bratzler shear central values for the longissimus dorsi muscle. For the biceps femoris muscle, none of the correlation coefficients between the Warner-Bratzler shear positions was significant.

The correlation coefficients between the texturometer hardness and the Warner-Bratzler shear were low but significant in four out of six cases. For the longissimus dorsi muscle, the Warner-Bratzler shear medial values and the Warner-Bratzler shear central values accounted for 7.8% and 11.6% of the variation in texturometer hardness, respectively. For the biceps femoris muscle, the Warner-Bratzler shear central values accounted for 10.2% of the variation in texturometer hardness, while the Warner-Bratzler shear posterior values accounted for 6.8% of the varia-

TABLE VIII

CORRELATION COEFFICIENTS BETWEEN THE WARNER-BRATZLER SHEAR (WBS) VALUES AND THE TEXTUROMETER HARDNESS FOR THE LONGISSIMUS DORSI MUSCLE

	WBS Medial	WBS Central	WBS Lateral	Texturometer Hardness
WBS Medial	1.00			
WBS Central	0.43**	1.00		
WBS Lateral	0.53**	0.66**	1.00	
Texturometer Hardness	0.28*	0.09	0.34**	1.00

*Significant at P<.05

**Significant at P<.01

TABLE IX

CORRELATION COEFFICIENTS BETWEEN THE WARNER-BRATZLER SHEAR (WBS) VALUES AND THE TEXTUROMETER HARDNESS FOR THE BICEPS FEMORIS MUSCLE

	WBS Proximal	WBS Central	WBS Posterior	Texturometer Hardness
WBS Proximal	1.00			
WBS Central	0.17	1.00		
WBS Posterior	-0.22	0.11	1.00	
Texturometer Hardness	0.09	0.32*	0.26*	1.00

*Significant at P<.05

**Significant at P<.01

tion in texturometer hardness. None of the Warner-Bratzler shear values was a good predictor of each other or of texturometer hardness.

Tables X and XI indicate the linear relationship between the objective measurements--the Warner-Bratzler shear values, texturometer hardness and texturometer juiciness--and the panel evaluation of the sensory dimensions for the longissimus dorsi muscle and the biceps femoris muscle, respectively. These correlation coefficients were much lower than those reported by Corey (1970) as discussed on p. 16. Ideally, it would be desirable if the objective measurements could accurately predict the sensory panel evaluations. Because the correlation coefficients were so low, it appears that none of the objective measurements was a good predictor of the sensory dimensions as evaluated by the panel. According to the results in Table X, the Warner-Bratzler shear medial values would be the best predictors of the sensory panel evaluations of hardness, chewiness and fibrousness for the longissimus dorsi muscle. However, only 17.6%, 34.8% and 24.0% of the variation in hardness, chewiness and fibrousness, respectively could be attributed to the Warner-Bratzler shear medial values. For the biceps femoris muscle, the Warner-Bratzler shear posterior values would be the best predictor of sensory panel hardness. However, it only accounted for 11.6% of the variation in sensory panel hardness. Ninety percent or more of the variation would have to be attributable to either the Warner-Bratzler shear medial values for the longissimus dorsi muscle or the Warner-Bratzler shear posterior values for the biceps femoris muscle before one could conclude that these objective measurements were accurate predictors of the sensory panel hardness, chewiness and fibrousness.

The correlation coefficients between the texturometer hardness

TABLE X

CORRELATION COEFFICIENTS BETWEEN OBJECTIVE MEASUREMENTS AND SENSORY DIMENSIONS FOR THE LONGISSIMUS DORSI MUSCLE

Sensory Dimensions	Objective Measurements				
	WBS Medial	WBS Central	WBS Lateral	Texturometer Hardness	Texturometer Juiciness
Hardness	0.42**	0.36**	0.31*	0.15	0.08
Chewiness	0.59**	0.58**	0.45**	0.03	-0.04
Juiciness	-0.14	0.06	0.06	0.13	-0.02
Fibrousness	0.49**	0.37	0.47*	0.30*	0.05

*Significant at P<.05

**Significant at P<.01

TABLE XI

CORRELATION COEFFICIENTS BETWEEN OBJECTIVE MEASUREMENTS AND SENSORY DIMENSIONS FOR THE BICEPS FEMORIS MUSCLE

Sensory Dimensions	Objective Measurements				
	WBS Proximal	WBS Central	WBS Posterior	Texturometer Hardness	Texturometer Juiciness
Hardness	-0.26*	0.00	0.34**	0.16	-0.29*
Chewiness	-0.13	0.00	0.15	0.24	0.22
Juiciness	-0.03	-0.15	-0.03	-0.07	0.05
Fibrousness	-0.11	0.00	0.20	0.15	-0.12

*Significant at P<.05

**Significant at P<.01

and the sensory panel hardness were unexpectedly low for the two muscles. A possible explanation could be the thickness of the sample used for the texturometer measurement. Samples one-quarter inch thick (the same thickness as for the sensory panel evaluations) were tested. It was felt in planning the experimental work that, if the texturometer hardness was to be a valuable predictor of the sensory panel hardness, the samples for both measurements should be the same thickness. However, Friedman et al. (1963) and Brennan et al. (1970) recommended a sample thickness of one-half inch. There is a possibility that the one-quarter inch sample thickness was too thin to yield an adequate estimation of hardness. With the thicker samples, one might obtain a more representative sample of meat than was obtained for the one-quarter inch sample thickness and thus, it might correlate better with the sensory panel evaluation of hardness. The texturometer hardness measurements were carried out on one meat sample per roast or steak, whereas the sensory panel evaluation of hardness was determined from approximately 10 evaluations (5 panelists x 2 samples per panelist) per roast or steak.

A low correlation (r = 0.04) was found between texturometer juiciness and sensory panel juiciness. It appears that the nature of the texturometer measurement differed from that of the sensory panel measurement. Texturometer juiciness measured the amount the juiciness released by the meat after a constant force was applied three times. The sample remained intact. However, sensory panel juiciness was the amount of juice released by the meat after the sixth chew. The sample was partially disintegrated.

Correlation coefficients were also calculated between each of the sensory dimensions evaluated by the panel. Tables XII and XIII present these coefficients for the longissimus dorsi muscle and the biceps femoris muscle, respectively.

For both muscles, the correlation coefficients verified that the sensory dimensions measured were distinguishably different. A correlation coefficient of 0.90 or greater between any two of the dimensions would be necessary to conclude that the two dimensions measured were the same. However, for both muscles, an appreciable amount of the variation in chewiness and fibrousness could be attributed to hardness and vice versa. In the case of the longissimus dorsi muscle, 69.3% of the variation in chewiness and 10.9% of the variation in fibrousness was attributed to hardness. In the case of the biceps femoris muscle, 28.1% of the variation in chewiness and 22.1% of the variation in fibrousness was attributed to hardness. Similarly, chewiness accounted for 18.5% and 21.2% of the variation in fibrousness for the longissimus dorsi muscle and the biceps femoris muscle, respectively.

TABLE XII

CORRELATION COEFFICIENTS BETWEEN THE SENSORY DIMENSIONS EVALUATED BY THE SENSORY PANEL FOR THE LONGISSIMUS DORSI MUSCLE

Sensory Panel Textural Dimensions	Hardness	Chewiness	Juiciness	Fibrousness
Hardness	1.00			
Chewiness	0.77**	1.00		
Juiciness	-0.18	-0.05	1.00	
Fibrousness	0.33**	0.43**	0.24	1.00

*Significant at P<.05

**Significant at P<.01

TABLE XIII

CORRELATION COEFFICIENTS BETWEEN THE SENSORY DIMENSIONS EVALUATED BY THE SENSORY PANEL FOR THE BICEPS FEMORIS MUSCLE

Sensory Panel Textural Dimensions	Hardness	Chewiness	Juiciness	Fibrousness
Hardness	1.00			
Chewiness	0.53**	1.00		
Juiciness	-0.04	-0.14	1.00	
Fibrousness	0.47*	0.46**	0.12	1.00

*Significant at P<.05

**Significant at P<.01

V SUMMARY AND CONCLUSION

The effect of crossbreed and sex on the quality of the meat varied with the muscle--the longissimus dorsi and the biceps femoris--and the type of measurement--objective, sensory panel evaluation or consumer panel evaluation. For the purpose of analysis and discussion, the crossbreeds and sex were separated into their component effects. These included bulls, steers, cows, sires, cow x sex, cow x sire, sire x sex and cow x sire x sex.

The sex effect--bulls versus steers--was significant for the percentage cooking loss, shear force values, texturometer juiciness, hardness and cohesiveness, and the sensory panel evaluation of chewiness, juiciness, fibrousness, greasiness and meatiness. The percentage cooking loss from the biceps femoris muscle was greater for the bulls than the steers. For the medial core position of the longissimus dorsi muscle, the bulls required more shear force than the steers, whereas for the proximal core position of the biceps femoris muscle, the bulls required significantly less shear force than the steers. The texturometer measurements indicated that the steers were juicier and less cohesive than the bulls for the biceps femoris muscle, whereas the bulls were harder than the steers for the longissimus dorsi muscle. In the case of the panel evaluation of the sensory dimensions for the longissimus dorsi muscle, the bulls were chewier and more fibrous than the steers, while in the case of the biceps femoris muscle, the steers were juicier, greasier and meatier.

Shear force, texturometer juiciness and the sensory panel evaluation of hardness, juiciness and fibrousness demonstrated significant effects attributable to the cows. For the central core position of the biceps femoris muscle, the Shorthorn crosses required less shear force than the Hereford crosses or the Angus crosses. According to the texturometer measurement of juiciness, the Angus crosses of the biceps femoris muscle were juicier than the Hereford crosses or the Shorthorn crosses, while the sensory panel evaluation of the biceps femoris muscle detected no significant differences attributable to the cows. The complex interaction of the intramuscular lipid with the panelists perception of juiciness could have been responsible for the lack of agreement between the two measurements. The sensory panel evaluation of the biceps femoris muscle indicated that the Hereford crosses were harder and more fibrous than the Angus crosses and the Shorthorn crosses. For the longissimus dorsi muscle, the sensory panel rated the Hereford crosses juicier than the Angus crosses.

No significant effects attributable to the sires were found.

Several effects attributable to the two-term interactions were significant. A cow x sex interaction for texturometer hardness of the longissimus dorsi muscle was revealed. The Hereford and Shorthorn crossed bulls were respectively harder than the Hereford and Shorthorn crossed steers. For the Angus crosses, there was no difference between the texturometer hardness of the bulls and the steers. Further analysis indicated the effect attributable to cows within each sex. From these comparisons, the Shorthorn crossed bulls were harder than the Angus crossed bulls, but the Hereford crossed bulls were not different from either of the two. No significant differences attributable to cows were found with the steers. The individual comparisons of the significant sire x cow and sire x sex interactions were not investigated for significance. These included the sire x cow interaction for the sensory panel hardness of the longissimus dorsi muscle and the sire x sex interaction for the percentage cooking loss and sensory panel meatiness of the biceps femoris muscle.

Throughout the analysis, the three-term interactions were not significant.

The low simple correlation coefficients between the objective measurements and the panel evaluation of the sensory dimensions suggested that the objective measurements were not the same type of measurement. More work should be carried out using the texturometer for estimating the hardness of meat before any conclusions can be made. Because of the inherent variation within each muscle as well as the great variation between animals of the same breeding, meat is a particularly complex foodstuff to be evaluated by objective measurements.

The failure of the consumer panel to detect differences due to crossbreeds or sex indicated the superior sensitivity of the sensory panel. Although the sensory panel found statistically significant differences among the crossbreeds, these differences were less than one unit on the sensory scales. It was the opinion of the panelists that all the crossbreeds and either sex produced very acceptable meat for the longissimus dorsi and biceps femoris muscles. The meat was fine grained, tender, juicy and had a full flavor. No one crossbreed or sex was outstandingly different from the others.

Any differences found by the sensory panel or objective measurements were not great enough to affect overall consumer acceptability.

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APPENDICES

A. COMPOSITE ANALYSIS OF VARIANCE TABLE OF OBJECTIVE MEASUREMENTS WITH SIGNIFICANT EFFECTS FOR THE LONGISSIMUS DORSI MUSCLE

		Shear Force			Texturometer Hardness		
	d.f.	SS	MS	F	SS	MS	F
REGRESSION	20	24.132			597.027		
BLOCKS	9	8.049			468.025		
$\text{REGRESSION}_{(\text{adj.})}$	11	16.083			129.024		
Sex	1	7.951	7.951	6.154*	34.241	34.241	7.436**
Sire	1	0.058	0.058	<1	3.894	3.894	<1
Cow	2	0.108	0.054	<1	3.681	1.840	<1
Cow x Sex	2	5.631	2.815	2.179	37.181	18.590	4.037*
Sire x Sex	1	0.215	0.215	<1	6.824	6.824	1.482
Sire x Cow	2	1.615	0.807	<1	31.410	15.705	3.410*
Sire x Cow x Sex	2	0.242	0.121	<1	10.574	5.287	1.148
ERROR	39	50.236	1.288		179.567	4.604	
TOTAL	59	76.947	1.304		776.593	13.163	

*Significant at $P<.05$

**Significant at $P<.01$

B. COMPOSITE ANALYSIS OF VARIANCE TABLE OF OBJECTIVE MEASUREMENTS WITH SIGNIFICANT EFFECTS FOR THE BICEPS FEMORIS MUSCLE

	d.f.	% Cooking Loss			WBS Proximal			WBS Central			Texturometer Juiciness			Texturometer Cohesiveness		
		SS	MS	F	SS	MS	F	SS	MS	F	SS	MS	F	SS	MS	F
REGRESSION	20	116.533			103.563			49.449			470.983			0.178		
BLOCKS	9	25.217			31.240			20.099			191.680			0.018		
REGRESSION(adj.)	11	91.317			72.423			29.350			279.303			0.606		
Sex	1	63.234	63.234	27.129**	30.362	30.362	4.200*	0.621	0.621	<1	81.774	81.774	5.600*	0.065	0.065	7.421**
Sire	1	3.682	3.682	1.579	0.079	0.079	<1	0.071	0.071	<1	18.611	18.611	1.277	0.011	0.011	1.270
Cow	2	3.039	1.519	<1	2.665	1.333	<1	7.657	3.828	2.783	80.032	40.016	2.746	0.037	0.018	2.096
Cow x Sex	2	1.972	0.986	<1	25.034	12.517	1.942	1.379	0.689	<1	72.047	36.023	2.472	0.009	0.004	<1
Sire x Sex	1	10.025	10.251	4.301*	0.048	0.048	<1	1.959	1.959	1.424	0.069	0.069	<1	0.007	0.007	<1
Sire x Cow	2	8.404	4.202	1.802	5.997	2.999	<1	15.715	7.857	5.712**	0.049	0.024	<1	0.019	0.010	<1
Sire x Cow x Sex	2	2.062	1.031	<1	9.572	4.789	<1	2.344	1.172	<1	17.532	8.766	<1			
ERROR	39	90.900	2.331		251.254	6.442		53.640	1.375		568.228	145.699		0.341	0.009	
TOTAL	59	207.435	3.516		380.587	6.451		103.088	1.747		1,039.209	176.137		0.520	0.009	

*Significant at P .05

**Significant at P .01

C. COMPOSITE ANALYSIS OF VARIANCE TABLE OF SENSORY DIMENSIONS WITH SIGNIFICANT EFFECTS FOR THE LONGISSIMUS DORSI MUSCLE

	d.f.	Hardness			Chewiness			Juiciness			Fibrousness		
		SS	MS	F	SS	MS	F	SS	MS	F	SS	MS	F
REGRESSION	20	9.391			148.679			13.341			4.581		
BLOCKS	9	2.153			29.080			4.757			1.966		
REGRESSION(adj.)	11	7.238			119.599			8.584			2.615		
Sex	1	1.414	1.414	3.892	48.962	48.962	5.484*	0.170	0.170	<1	1.581	1.581	8.545**
Sire	1	0.469	0.469	1.290	18.530	18.530	2.075	0.589	0.589	1.266	0.051	0.051	<1
Cow	2	0.017	0.017	<1	7.852	3.926	<1	3.685	1.843	3.962*	0.305	0.153	<1
Cow x Sex	2	0.833	0.417	1.146	16.995	8.497	<1	1.102	0.551	1.185	0.180	0.090	<1
Sire x Sex	1	0.065	0.065	<1	0.281	0.281	<1	0.017	0.017	<1	0.132	0.132	<1
Sire x Cow	2	4.409	2.205	6.068*	26.504	13.252	1.484	0.917	0.459	<1	0.292	0.146	<1
Sire x Cow x Sex	2	0.105	0.053	<1	2.837	1.418	<1	2.122	0.106	2.282	0.087	0.043	<1
ERROR	39	14.168	0.363		348.200	8.928		18.136	0.4650		7.218	0.185	
TOTAL	59	23.559	0.399		532.591	9.027		31.477	0.533		91.799	0.200	

*Significant at $P<.05$

**Significant at $P<.01$

D. COMPOSITE ANALYSIS OF VARIANCE TABLE OF SENSORY DIMENSIONS WITH SIGNIFICANT EFFECTS FOR THE BICEPS FEMORIS MUSCLE

	d.f.	Hardness			Juiciness			Fibrousness			Greasiness			Meatiness		
		SS	MS	F	SS	MS	F	SS	MS	F	SS	MS	F	SS	MS	F
REGRESSION	20	7.923			17.192			5.347			6.636			11.647		
BLOCKS	9	3.953			8.410			1.814			4.280			7.067		
REGRESSION(adj.)	11	3.971			8.781			3.533			2.356			4.581		
Sex	1	0.206	0.206	<1	3.450	3.450	5.321*	0.002	0.002	<1	1.189	1.189	8.433**	1.396	1.396	6.665*
Sire	1	0.102	0.102	<1	0.090	0.090	<1	0.134	0.134	<1	0.0	0.0	<1	0.050	0.050	<1
Cow	2	1.675	0.838	2.847	2.131	1.066	1.643	2.159	1.080	3.600*	0.225	0.113	<1	0.331	0.165	<1
Cow x Sex	2	1.219	0.610	2.072	0.451	0.225	<1	0.457	0.228	<1	0.387	0.193	1.371	0.128	0.064	<1
Sire x Sex	1	0.066	0.066	<1	0.004	0.002	<1	0.471	0.471	1.568	0.0	0.0	<1	1.266	1.266	6.048*
Sire x Cow	2	0.469	0.234	<1	0.644	0.322	<1	0.125	0.062	<1	0.083	0.041	<1	0.004	0.002	<1
Sire x Cow x Sex	2	0.120	0.060	<1	0.197	0.099	1.522	0.150	0.075	<1	0.482	0.241	1.708	1.386	0.693	3.310
ERROR	39	11.476	0.294		25.285	0.648		11.707	0.300		5.497	0.141		8.166	0.209	
TOTAL	59	19.399	0.329		42.477	0.720		17.954	0.304		12.133	0.206		19.813	0.336	

*Significant at P<.05

**Significant at P<.01

E. TABLE OF DATA FOR THE BICEPS FEMORIS MUSCLE

		% Cooking Loss	% Drip Loss	WBS Proximal	WBS Central	WBS Posterior	Text'r Hardness	Text'r Cohesiveness	Text'r Springiness	Text'r Juiciness	S.P. Hardness	S.P. Chewiness	S.P. Juiciness	S.P. Fibrousness	S.P. Greasiness	S.P. Meatiness	Consumer Liking
Ip	LxAxB	26.56	8.39	4.90	5.40	6.80	30.40	0.83	49.32	22.10	4.40	24.20	2.40	3.20	2.20	5.60	3.60
	LxAxSt	25.78	4.44	13.60	5.80	5.40	29.73	0.71	47.27	30.10	3.40	20.40	3.40	2.40	2.80	5.80	3.44
	LxHxB	25.76	6.32	4.10	6.30	10.80	29.33	1.00	47.27	23.00	4.60	23.00	3.60	3.80	3.00	5.20	3.24
	LxHxB	23.52	7.56	8.40	4.80	4.70	29.47	0.82	45.90	19.90	4.80	29.20	3.40	4.60	3.20	5.60	3.48
	LxSHxB	26.49	5.60	8.80	4.80	6.10	28.13	0.80	45.90	20.70	3.60	22.60	2.20	2.40	3.00	5.00	3.88
	LxSHxSt	22.57	5.51	8.60	4.00	3.90	28.93	0.73	47.27	27.10	2.80	23.80	2.40	3.20	3.00	5.40	3.92
Iq	SxAxB	26.11	7.09	9.50	7.20	6.50	43.80	0.90	46.58	23.50	3.80	26.80	2.80	3.00	3.80	5.20	3.64
	SxAxSt	22.78	9.17	4.60	4.20	5.60	39.20	0.88	47.27	34.10	4.20	26.00	3.60	3.60	3.40	5.00	4.12
	SxHxB	26.00	7.19	7.20	7.40	6.00	43.00	0.96	46.58	18.40	4.60	26.20	4.40	3.60	3.20	5.00	4.00
	SxHxSt	22.57	7.31	13.60	9.20	5.50	41.20	0.80	45.55	26.80	4.20	25.60	3.20	3.20	2.80	4.80	3.48
	SxSHxB	22.59	8.73	5.30	3.40	5.00	32.20	0.90	47.27	21.80	3.40	20.80	3.80	2.60	3.40	5.60	3.76
	SxSHxSt	21.63	5.36	10.80	18.10	5.90	41.20	0.32	44.53	17.60	3.60	19.80	3.40	2.80	3.20	5.40	3.48
IIp	LxAxB	24.50	5.66	7.80	5.70	4.80	19.20	0.72	45.90	33.10	3.60	22.80	3.60	3.20	3.40	5.80	4.04
	LxHxB	24.89	4.17	9.30	4.90	5.20	30.67	0.75	46.58	15.50	4.60	23.60	2.80	4.00	3.20	5.60	3.92
	LxSHxB	21.41	5.67	8.00	6.50	3.30	28.20	0.84	43.84	26.30	3.40	22.00	3.20	3.20	3.40	5.60	4.08
	SxAxB	26.65	9.11	7.70	6.50	5.70	28.00	0.83	44.53	30.90	3.80	24.20	3.00	3.20	2.80	5.60	3.60
	SxHxB	26.45	9.32	6.90	5.40	5.10	29.60	0.83	50.69	26.20	3.60	22.80	3.40	2.40	3.20	6.20	3.64
	SxSHxB	26.47	7.87	10.10	4.40	3.70	28.60	0.88	44.53	20.30	3.40	24.60	2.80	3.20	3.40	5.40	4.08
IIq	LxAxSt	26.56	5.72	4.60	4.50	5.70	27.00	0.86	43.84	21.90	5.20	28.60	3.20	3.80	3.20	5.60	3.28
	LxHxSt	23.22	7.28	5.30	3.90	4.70	24.80	0.84	43.84	23.80	4.00	26.20	4.80	2.80	3.80	6.20	3.04
	LxSHxSt	24.81	5.51	8.10	4.30	5.30	27.00	0.81	43.16	14.60	4.40	25.20	2.60	2.80	4.00	5.40	3.84
	SxAxSt	21.51	8.19	6.70	3.70	4.50	25.80	0.82	43.84	21.60	3.80	19.80	4.40	2.80	3.40	5.60	3.76
	SxHxSt	22.94	8.22	13.00	5.00	3.60	28.20	0.83	44.53	28.50	4.00	23.60	3.60	2.80	3.20	4.60	3.44
	SxSHxSt	23.49	5.69	9.40	4.80	4.40	27.60	0.81	43.84	23.20	3.80	21.80	4.60	3.20	4.40	5.00	3.88
IIIp	LxAxB	26.39	5.84	10.80	6.50	5.30	30.20	0.80	49.32	18.70	5.40	29.60	1.40	3.40	3.20	5.40	3.92
	LxHxB	24.63	6.14	6.10	4.60	4.90	28.60	0.81	49.32	17.70	5.00	27.20	3.20	2.80	2.80	4.80	4.56
	LxSHxB	25.01	--	6.80	4.80	3.20	28.60	0.89	44.53	26.10	3.40	21.40	4.00	2.20	3.40	5.20	3.84
	SxAxSt	23.32	5.65	7.70	5.90	3.90	27.20	0.77	43.84	25.30	4.40	24.60	3.80	3.00	3.80	5.60	3.96
	SxHxSt	19.37	5.87	11.30	3.90	4.50	30.00	0.91	49.32	24.30	4.20	27.00	3.80	2.60	3.40	5.60	3.92
	SxSHxSt	19.85	7.86	9.40	5.10	3.70	29.20	0.85	47.27	24.00	4.40	23.80	4.60	2.80	3.60	5.60	4.04
IIIq	LxAxSt	24.25	8.14	13.00	5.90	3.70	28.60	0.85	45.21	31.60	3.40	25.40	3.00	3.20	4.60	5.60	3.76
	LxHxSt	20.84	6.79	9.60	4.50	4.50	29.20	0.82	43.84	28.80	3.20	22.60	4.20	3.60	3.80	5.60	3.68
	LxSHxSt	23.93	10.12	9.30	4.20	4.90	30.60	0.75	43.84	22.00	4.00	24.80	4.00	3.80	3.80	5.80	3.60
	SxAxB	23.89	8.51	5.90	5.00	5.20	29.60	0.78	52.75	24.40	3.80	25.40	3.40	3.40	3.20	5.20	3.48
	SxHxB	25.25	6.35	9.70	9.70	4.50	25.40	1.00	44.53	33.90	3.60	24.00	3.20	3.00	3.80	5.60	3.60
	SxSHxB	24.98	8.06	7.50	6.60	4.10	29.00	0.88	44.53	29.60	4.00	21.20	1.00	3.00	2.80	4.80	3.68
IVp	LxAxB	27.02	6.93	6.30	8.00	3.90	26.80	0.86	43.84	23.30	3.60	23.40	4.80	3.20	2.80	6.40	3.60
	LxHxB	24.49	7.39	6.30	4.90	4.00	22.60	0.84	43.84	22.90	3.60	23.60	3.20	3.00	2.60	6.20	3.16
	LxSHxB	25.90	8.79	5.40	4.60	5.70	16.60	0.75	43.84	24.70	4.60	23.60	3.20	3.20	3.40	5.60	2.96
	SxAxSt	22.23	6.51	6.90	4.70	4.60	23.40	0.76	44.53	24.90	4.20	20.60	4.20	2.60	3.80	6.60	3.76
	SxHxSt	25.39	6.59	5.60	6.80	5.80	27.40	0.92	43.84	23.20	4.60	23.80	3.20	3.20	3.00	6.20	3.80
	SxSHxSt	24.85	4.96	11.00	4.90	4.40	22.20	0.81	43.84	27.30	4.60	23.20	4.20	3.40	3.80	6.00	3.92
IVq	LxAxSt	23.27	7.00	5.60	5.90	4.30	24.00	0.73	48.64	25.40	3.60	22.80	4.60	2.40	3.20	6.00	3.72
	LxHxSt	23.37	7.12	16.40	5.60	5.90	23.20	0.83	47.27	23.00	3.60	21.20	4.40	3.40	2.40	6.60	3.52
	LxSHxSt	22.24	6.28	9.40	4.20	4.10	19.40	0.80	48.64	25.20	3.40	20.60	4.20	2.80	3.20	6.00	3.68
	SxAxB	24.63	4.52	9.10	3.90	4.90	27.60	0.79	49.32	22.00	3.40	20.40	4.20	2.80	2.80	6.40	3.64
	SxHxB	26.22	4.63	7.40	5.80	4.30	25.80	0.80	44.53	20.20	4.60	26.20	4.00	4.60	2.60	5.00	3.56
	SxSHxB	25.73	6.24	8.40	4.40	4.50	20.20	0.79	43.84	23.50	3.80	22.80	2.20	3.00	2.60	5.20	3.72
Vp	LxAxB	25.44	7.83	8.00	7.50	3.70	22.00	0.90	49.32	22.90	2.80	22.20	2.40	2.20	3.20	5.40	3.64
	LxHxSt	24.14	7.08	9.00	5.30	5.70	21.20	0.71	49.32	22.00	3.60	24.00	3.80	2.80	3.40	6.40	3.56
	LxSHxB	27.79	7.37	9.30	5.30	5.60	24.80	0.87	48.64	18.90	3.40	26.60	3.60	2.60	2.80	6.00	3.88
	LxAxSt	22.30	5.80	8.80	5.50	4.60	28.40	0.78	46.58	27.50	4.20	23.20	4.40	3.00	3.00	6.20	3.60
	SxHxSt	21.69	5.33	5.00	5.80	4.40	28.00	0.92	44.53	23.80	4.20	25.20	4.60	4.80	3.40	5.60	3.64
	SxSHxSt	22.88	7.71	5.90	4.30	4.80	27.80	0.79	48.64	18.70	3.80	27.60	2.00	3.20	3.60	6.60	4.08
Vq	LxAxSt	23.17	6.29	6.70	7.70	4.00	29.20	0.78	46.58	25.70	4.00	22.40	2.40	2.40	3.60	5.40	3.84
	LxHxSt	23.22	6.98	7.30	5.60	4.90	29.20	0.79	50.69	28.70	4.00	26.00	3.20	3.00	3.60	5.00	3.56
	LxSHxSt	24.87	7.31	7.00	5.50	5.70	24.60	0.80	49.32	23.60	3.60	23.00	3.60	2.40	3.20	5.60	3.72
	SxAxB	23.58	9.70	10.00	5.40	3.10	25.00	0.99	45.55	25.40	3.20	20.20	2.00	2.40	3.20	4.40	3.84
	SxHxB	26.07	6.79	4.50	5.30	5.90	29.60	0.87	45.90	24.30	5.20	23.60	3.20	3.20	3.40	5.60	3.52
	SxSHxB	22.14	8.57	9.60	5.40	4.00	29.00	0.77	45.21	26.00	4.40	22.00	2.60	3.20	2.80	4.60	3.52

L=Limousin, S=Simmental, A=Angus, H=Hereford, SH=Shorthorn, B=Bull and St=Steer

F. TABLE OF DATA FOR THE LONGISSIMUS DORSI MUSCLE

		% Cooking Loss	% Drip Loss	WBS Medial	WBS Central	WBS Lateral	Text'r Hardness	Text'r Cohesiveness	Text'r Springiness	Text'r Juiciness	S.P. Hardness	S.P. Chewiness	S.P. Juiciness	S.P. Fibrousness	S.P. Greasiness	S.P. Meatiness
Ip	LxAxB	31.92	12.19	7.35	6.05	6.40	26.13	0.83	45.21	28.00	3.20	21.40	2.40	2.80	2.60	3.40
	LxAxSt	34.00	9.75	5.10	3.75	6.10	27.73	0.62	40.42	33.80	3.00	18.80	3.00	1.60	3.00	4.40
	LxHxB	36.98	15.89	7.20	3.95	7.35	32.13	0.87	45.90	32.60	4.60	24.00	2.20	2.60	2.60	5.00
	LxHxB	33.55	11.08	5.35	5.55	5.95	28.40	0.75	52.06	30.30	3.20	19.60	4.20	2.00	3.00	4.20
	LxSHxB	31.74	14.09	5.25	4.90	6.00	30.93	0.84	47.27	29.10	4.00	22.00	3.60	2.80	3.00	4.40
	LxSHxSt	32.09	11.05	4.75	4.20	7.30	24.53	0.84	47.27	38.70	3.40	20.60	2.00	1.60	3.40	3.60
Iq	SxAxB	31.55	10.06	5.10	4.75	4.50	24.00	0.81	46.58	34.70	2.40	17.60	2.00	1.20	3.00	3.20
	SxAxSt	31.16	13.26	5.20	4.90	5.30	27.60	0.87	45.21	38.30	4.60	24.40	2.20	1.60	3.20	3.40
	SxHxB	25.22	6.78	5.90	5.75	8.85	29.40	0.84	49.32	37.20	3.80	22.80	5.00	3.00	2.80	4.00
	SxHxSt	30.09	10.83	6.30	5.30	5.75	26.00	0.85	50.01	34.20	4.40	23.60	3.80	2.00	2.60	3.00
	SxSHxB	25.71	12.60	6.15	8.00	5.85	27.40	0.76	49.32	29.80	3.40	21.00	3.40	2.00	3.00	3.40
	SxSHxSt	28.50	8.06	4.80	4.20	4.35	27.00	0.67	47.27	33.00	2.60	18.20	3.00	1.80	3.20	3.40
IIp	LxAxB	32.35	6.77	5.15	4.15	5.15	23.00	0.76	49.32	34.90	3.60	21.40	4.00	2.00	4.20	4.00
	LxHxB	34.01	6.35	5.40	4.30	4.40	24.20	0.75	49.32	31.10	3.40	22.00	3.20	1.80	3.00	3.00
	LxSHxB	32.49	9.05	6.85	6.40	7.60	27.40	0.84	50.69	35.30	3.60	21.00	3.40	2.20	3.00	3.80
	SxAxB	33.04	11.75	4.70	8.20	6.75	27.40	0.83	57.54	35.30	3.80	22.40	2.60	2.20	2.80	3.80
	SxHxB	32.48	11.37	4.70	5.45	6.15	27.40	0.73	50.01	33.90	3.80	22.20	4.40	1.80	3.00	4.20
	SxSHxB	33.92	6.97	5.85	4.55	5.40	25.80	0.79	48.64	28.40	3.60	21.80	2.60	2.60	3.20	3.20
IIq	LxAxSt	35.99	7.10	5.55	5.65	5.25	21.60	0.81	43.84	31.50	3.20	21.60	2.60	2.00	3.60	5.40
	LxHxSt	34.68	10.01	5.35	3.95	3.80	19.40	0.86	43.84	29.70	4.00	23.80	3.20	2.40	3.20	5.20
	LxSHxSt	34.62	8.51	7.25	15.55	10.50	21.20	0.74	44.53	28.90	5.00	31.00	2.40	2.80	3.20	4.20
	SxAxSt	33.19	7.85	4.35	3.60	4.20	24.00	0.74	43.84	28.80	3.20	21.20	2.20	1.20	2.80	4.80
	SxHxSt	33.89	12.20	4.45	4.25	4.20	21.20	0.76	44.53	30.00	3.80	20.00	1.80	1.80	3.40	4.60
	SxSHxSt	33.68	3.70	3.35	3.80	4.10	23.40	0.82	43.84	26.80	3.20	18.80	4.00	1.80	3.00	4.80
IIIp	LxAxB	31.20	8.80	4.75	4.85	6.75	24.20	0.81	44.87	31.80	3.60	21.80	3.00	1.80	2.40	4.40
	LxHxB	31.01	10.26	4.45	4.15	6.30	22.80	0.73	43.84	28.40	2.20	19.60	4.80	2.40	2.80	4.40
	LxSHxB	32.60	8.90	6.50	6.60	6.30	26.20	0.77	30.83	25.50	4.60	26.80	3.40	2.40	2.60	4.20
	SxAxSt	32.10	12.42	4.30	3.95	5.60	21.20	0.80	44.53	31.00	3.00	16.60	2.00	1.40	3.20	3.60
	SxHxSt	30.19	9.78	5.15	3.75	5.60	20.20	0.86	43.84	29.20	3.40	20.20	2.20	1.60	3.00	3.20
	SxSHxSt	32.19	10.06	5.65	6.05	4.80	19.00	1.47	40.07	28.40	3.00	23.40	3.80	1.60	3.60	5.20
IIIq	LxAxSt	33.13	12.52	3.85	5.20	4.25	25.40	0.78	44.53	29.00	3.60	22.40	3.20	2.60	4.00	4.60
	LxHxSt	43.96	10.38	5.30	6.45	6.10	25.00	0.72	44.53	34.00	3.60	22.80	3.80	2.40	3.20	4.20
	LxSHxSt	30.33	11.19	4.05	3.80	4.45	24.00	0.80	43.84	33.60	4.00	21.60	3.40	2.00	2.80	3.60
	SxAxB	33.43	8.98	6.75	4.50	6.00	28.20	0.95	43.84	37.40	4.20	23.40	3.20	2.20	2.40	4.00
	SxHxB	34.21	11.05	4.90	3.35	4.80	24.40	0.80	44.53	31.00	3.40	18.80	4.00	1.80	3.40	4.20
	SxSHxSt	28.80	9.80	4.65	5.35	7.25	23.00	0.87	43.84	32.30	3.80	21.60	3.20	2.60	3.40	4.40
IVp	LxAxB	35.35	9.90	4.75	3.90	5.20	16.00	0.76	43.84	26.40	4.00	22.80	2.60	2.00	3.40	5.20
	LxHxB	33.92	11.93	5.20	5.70	5.60	17.80	0.82	43.84	23.10	4.00	25.60	2.80	1.40	3.20	4.60
	LxSHxB	31.17	7.16	4.25	5.75	6.25	24.00	0.78	44.18	22.00	4.60	27.20	2.80	1.80	3.60	4.80
	SxAxSt	26.36	12.39	4.30	3.75	5.05	25.80	0.81	43.84	26.80	3.40	18.40	3.80	1.40	3.00	4.80
	SxHxSt	34.33	10.78	5.10	4.00	6.05	20.40	0.74	43.84	30.80	3.60	20.00	3.00	2.00	3.40	5.20
	SxSHxSt	28.03	9.57	5.25	3.65	4.15	17.40	0.75	44.53	27.40	3.40	20.20	3.00	1.80	3.00	4.40
IVq	LxAxSt	30.06	11.12	3.15	4.05	3.45	17.00	0.77	44.53	32.30	3.80	21.00	3.20	1.80	3.40	5.00
	LxHxSt	30.40	10.35	4.80	3.15	4.75	19.60	0.78	44.53	29.90	3.60	22.40	3.60	1.60	2.80	4.80
	LxSHxSt	30.04	9.50	3.60	4.20	3.80	18.40	0.77	43.84	28.40	3.00	18.20	3.40	1.40	2.80	4.80
	SxAxB	32.51	11.82	10.00	7.20	6.90	21.60	0.75	43.84	31.40	5.40	33.80	3.00	3.00	2.60	3.40
	SxHxB	31.80	10.51	5.65	4.65	5.90	21.40	0.80	44.53	24.40	3.40	21.60	2.60	2.20	3.20	5.80
	SxSHxB	28.29	10.41	4.60	4.10	5.35	24.00	0.73	44.87	28.10	3.00	20.20	3.40	2.40	2.60	4.40
Vp	LxAxB	36.15	11.99	5.50	3.85	4.70	24.60	0.72	48.64	31.60	4.00	23.20	3.40	2.40	3.60	5.60
	LxHxSt	32.30	11.64	5.30	4.45	4.80	19.60	0.91	43.84	26.30	3.60	19.20	3.80	2.60	3.00	6.20
	LxSHxB	34.62	7.85	4.60	4.90	6.25	25.60	0.84	44.53	35.80	4.80	24.20	3.80	2.20	3.00	5.20
	SxAxSt	32.24	5.49	4.05	3.55	5.00	25.40	0.76	43.84	26.20	3.40	18.60	4.00	2.20	3.60	5.60
	SxHxSt	31.27	12.18	3.95	5.30	5.75	19.00	0.81	43.84	26.00	4.00	22.80	3.20	1.80	3.80	5.20
	SxSHxSt	34.23	7.60	4.85	5.50	6.00	21.00	0.95	45.90	33.00	2.60	20.80	3.40	2.60	3.60	5.40
Vq	LxAxSt	30.55	7.14	3.75	3.15	5.10	17.80	0.77	44.18	30.80	3.00	15.60	3.20	1.80	2.80	4.40
	LxHxSt	28.15	11.00	3.95	6.75	6.85	21.00	0.80	44.18	27.90	2.80	23.00	4.60	1.80	3.00	4.60
	LxSHxSt	30.91	12.84	5.60	3.40	5.80	21.80	0.79	44.18	33.60	3.40	22.40	3.40	1.60	3.20	4.80
	SxAxB	34.23	14.72	5.05	5.65	4.95	18.80	0.81	43.84	23.20	4.00	20.00	2.40	1.60	2.60	3.20
	SxHxB	22.80	6.59	3.60	4.40	5.05	21.80	0.83	43.84	28.40	3.60	23.00	3.80	2.20	2.80	4.00
	SxSHxB	27.37	10.95	6.20	4.60	6.55	21.20	0.86	43.84	23.90	2.60	21.00	4.20	2.20	2.80	3.80

L=Limousin, S=Simmental, A=Angus, H=Hereford, SH=Shorthorn, B=Bull and St=Steer