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I am submitting herewith a thesis written by Joey Wayne Lusby entitled "Effect of Feeding Management on Yield, Histological, Palatability and Quality Characteristics of Beef." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Technology and Science.

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EFFECT OF FEEDING MANAGEMENT ON YIELD, HISTOLOGICAL, PALATABILITY AND QUALITY CHARACTERISTICS OF BEEF

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Joey Wayne Lusby

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ABSTRACT

Thirty-nine steers were allotted in three feeding treatments (pasture, limit-grain-fed and grain fed Ad libitum) so the effect of feed source (pasture versus limit-fed) and level of energy intake (pasture and limit-fed versus fed Ad libitum) on certain carcass, cooked meat and histological characteristics could be evaluated.

The pasture steers had higher percentages, on a live weight basis of edible offal ($P < .01$) and inedible offal ($P < .0001$) than the limit-fed steers. Pasture steers had lighter slaughter weights ($P < .01$), lighter chilled carcass weights ($P < .0001$), less fat over the 12th rib ($P < .0001$), smaller loin eyes ($P < .05$) and produced less total pounds ($P < .0001$) of retail meat than the limit-fed steers. As expected, the pasture steers had lower estimated percent fat ($P < .05$) expressed as a percent of the dressed carcass. There was no difference in percent lean between pasture and limit-fed steers. Carcasses from the pasture steers had less finish over the first sacral vertebra ($P < .05$) and chilled at a significantly faster rate but there was no statistical difference in post-mortem muscle pH. Taste panelists rated steaks from the pasture steers lower for tenderness ($P < .0001$), flavor ($P < .01$) and overall acceptability ($P < .001$). Warner-Bratzler Shear values were higher ($P < .0001$) for the pasture steers.

The limit-fed steers had higher marbling scores ($P < .001$) and thus higher quality grades ($P < .0001$) than the pasture steers.

Steers on the high energy diet were heavier at slaughter ($P < .0001$), had heavier hot carcass ($P < .0001$) and chilled carcass weights ($P < .0001$) and yielded more pounds of retail meat ($P < .0001$) than either the pasture or limit-fed groups. The Ad libitum fed steers had larger ($P < .01$) loin eyes, more fat over the 12th rib ($P < .0001$) and higher yield grades ($P < .0001$). Steers on the high energy diet were more highly marbled ($P < .0001$) and had higher quality grades ($P < .0001$). Estimations of carcass composition, based on the 9-10-11 rib separation, showed a higher percentage of fat ($P < .0001$) and bone ($P < .01$) in the Ad libitum fed steers as compared to the low energy fed steers. Ad libitum fed steers had lower percentages of inedible offal ($P < .0001$), head ($P < .001$) and shank ($P < .0001$) on a live weight basis. Due to greater fat thickness ($P < .01$) (measured at the first sacral vertebra) carcasses of the Ad libitum fed steers chilled at a significantly slower rate. The pH was lower at six hours ($P < .0001$) and 12 hours ($P < .05$) post-mortem in the high energy fed steers but at 24 hours was the same as the low energy fed steers. An inverse relationship was found between temperature and pH. Carcasses with lower muscle temperatures had higher pH values, indicating the lower temperature inhibited enzymatic activity and glycogen breakdown. Taste panelists rated steaks from the Ad libitum fed steers higher on tenderness ($P < .01$), juiciness ($P < .05$) and overall acceptability ($P < .001$). Warner-Bratzler Shear values were lower ($P < .01$) for steaks from the high energy fed steers.

There were no statistical differences found in sarcomere lengths but there was a trend that agreed with both taste panel tenderness and

Warner-Bratzler Shear scores. The pasture cattle had the shortest sarcomeres ($\bar{X}$ = 2.33μ) while there was no difference between the limit fed and Ad libitum fed steers ($\bar{X}$ = 2.42μ, $\bar{X}$ = 2.41μ, respectively).

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CHAPTER I

INTRODUCTION

Recent increases in production, processing and marketing costs have caused consumers and producers to look more closely at meat prices and profit margins for slaughter cattle. The sudden increase in grain prices coupled with a spiraling inflation in the 1970's caused a substantial increase in the price of meat at the retail level. Overpopulation and a diminishing food supply world wide have necessitated a closer scrutiny of slaughter cattle production practices. Some feed grains presently used in finishing rations for cattle might be used more efficiently as a protein source in the human diet. Approximately 50 percent of the cattle slaughtered annually grade USDA Choice and Prime. Over the years consumers have come to identify tender, juicy meat with these grades. However, if beef animals could be fed to the USDA Good grade and still be accepted by the consumer, a savings of 1,000 pounds of feed per animal yearly (Merkel and Pearson, 1975) could be realized. Also, in the early 1970's consumers showed increasing awareness of the level of fat in their diet and continued searching for ways to decrease intake of animal fats. Consumer demand for leaner meat coincides with the apparent dictates of the current economic situation. Present beef production practices are geared toward feeding slaughter cattle to a point which may be beyond economic efficiency and consequently the cost of meat is increased. The logical

alternative to a more expensive grain finishing regime is the use of less expensive forages to produce acceptable beef with less fat trim. Cattle fed primarily grass and other roughages usually grade USDA Good or Standard. This method is less expensive and it produces leaner cattle. Thus, the consumer demand for leaner beef is consistent with the most economical means of producing meat for consumption. The feasibility of marketing thinly finished, forage fed beef has been examined over a period of years, but consumers have not been well pleased with cattle finished on grass alone. Therefore, defining the differences between cattle finished on different regimes and using feeds from less expensive sources is very pertinent. This research was undertaken to elucidate and explain differences in meat from steers fed forage versus grain and a high versus low energy level.

CHAPTER II

REVIEW OF LITERATURE

A. EFFECT OF DIET AND ENERGY LEVEL ON GROWTH AND SENSORY CHARACTERISTICS OF BOVINE MUSCLE

The economic feasibility of grain supplementation of forage diets to provide marketable beef has long been acknowledged. However, a bulk of past research has labeled such beef of poorer eating quality than beef from cattle maintained on grain diets. Bull, Snapp and Rusk (1941) reviewed studies of several experiment stations during the 1930's comparing grain and forage feeding of cattle and concluded the inferior eating quality assigned to forage fed animals seemed to be due to lack of exterior fat covering. Wanderstock and Miller (1948) reported meat from pasture fed cattle received significantly lower palatability scores than meat from grain-fed cattle.

In 1954, Brown reported forage finished beef yielded a yellow fat and greater lean body mass than grain finished beef but there was no detectable difference in organoleptic traits. In contrast, Meyer et al. (1960) reported higher sensory ratings for juciness, ($P < .001$) tenderness ($P < .05$) and flavor ($P < .001$) for grain-fed beef and found the most distinct organoleptic differences to be in flavor of the fat ($P < .001$) when compared to grain-finished beef.

One problem of forage feeding beef cattle is the lower net energy yield of the pasture diet which results in slower weight gains

and lower slaughter weight when cattle are slaughtered on an age constant basis. Oltjen, Rumsey and Putnam (1971) found that feeding a pelleted forage increased feed intake and daily gain of beef cattle. Pelleted alfalfa hay proved to be an adequate finishing diet because it allowed for increased feed consumption and a sufficient level of energy and protein. Oltjen et al. (1971) concluded the lower plane of nutrition available to cattle on grass, due to low consumption, rather than inferiority of the grass was the reason for slower weight gain in forage-fed cattle. Similar results were reported by Ralston et al. (1966) who found pelleted wheat chaff and alfalfa stimulated feed intake and animal weight gain which made forage supplementation more profitable.

Since it is important to increase quality as well as quantity of the lean portion of the beef carcass, investigations of carcass composition of animals raised under different feeding regimes are of interest. Hiner and Bond (1971) stated the quantity of meat produced on different feeding regimes could be measured by comparing rate of gain, feed conversion, carcass cutability, thickness of fat covering and rib eye size. Quality of meat could be characterized by its color, texture, marbling, tenderness and flavor. Henrickson, Pope and Hendrickson (1965) found calves gained faster ($P < .01$) and were more efficient ($P < .05$) when fed a high level of energy as compared to a moderate level of energy. Utley, Hellwig and McCormick (1975) compared steers fed an all-forage diet to steers fed a high energy diet and found forage-fed steers had less marbling ($P < .05$), lower yield grades ($P < .05$) and less fat covering over the rib eye ($P < .05$) than steers fed the high energy diet.

Guenther et al. (1965) compared steers fed high and moderate planes of nutrition found rib eye area greater in steers fed the high nutritional diet. Jacobson and Fenton (1956) compared palatability of beef produced on high, medium and low levels of nutrition and concluded that animals maintained on a high level of nutrition produced beef with superior flavor, more desirable tenderness and higher yields of both lean and fat. Guenther et al. (1965) showed beef calves maintained on a higher plane of nutrition produced more lean ($P < .05$) than those maintained at a lower energy intake when compared on an age-constant basis; however, when slaughtered on a weight constant basis carcass lean content was not affected by nutritional level. Likewise, Henrickson et al. (1965) reported no difference in chemical composition or organoleptic acceptance of muscles from beef cattle reared on diets of varying energy levels when taken to constant finishing weights.

Conflicting reports on the effect of nutrition on carcass characteristics seem to be related to differences in the experimental design of the various studies. Berg and Butterfield (1968) suggested a possible reason for discrepancies between some studies was that the animals were not slaughtered over a sufficiently wide weight range to give an accurate account of the developmental patterns of bovine fat, lean and bone.

Waldman, Tyler and Burngardt (1971) compared bone, muscle and fat proportions of carcasses from beef cattle fed a high versus medium energy diet. Cattle on the medium diet were restricted to 60 to 70 percent of the weight gain of the high energy fed cattle. No appreciable differences were found in bone, muscle or fat components of the carcasses from cattle on the two diets.

Waldman et al. (1971) concluded carcass composition at final weight was not dependent on time required to reach that weight. Zinn, Durham and Hedrick (1970) evaluated carcass composition at final slaughterweight by slaughtering animals at 30 day intervals during a 270 day feeding trial and reported that average daily gains increased with increasing time on feed up to 180 days. Marbling scores and carcass grades increased ($P < .05$) up to 240 days on feed.

Recent research reported at the 28th Annual Reciprocial Meat Conference discussed the use of forage and grain in finishing diets. Bidner (1975) acknowledged that forage-fed animals gained slower as a result of the low energy diet but further concluded that if cattle are fed to comparable weights and grades, the type of diet would have little influence on organoleptic properties of the meat. Bidner (1975) further stated if cattle were fed a constant time or to a constant age instead of to a constant weight; the carcass composition, chemical constituents and eating properties would be affected.

B. HISTOLOGICAL AND HISTOCHEMICAL DIFFERENCES IN BOVINE MUSCLE

Marsh and Leet (1966); and Howard and Judge (1968) pointed out the relationship of the contractile state of the muscle to meat quality. Herring, Cassens and Briskey (1965) demonstrated that the more tender muscles of a beef carcass have longer sarcomeres and lower resistance to shear than less tender muscles ($r = -.80$, $P < .01$). The temperature to which prerigor meat is exposed can affect the degree of sarcomere

shortening. Voyle (1969) reported shorter sarcomere in muscle fibers exposed to colder temperatures. The phenomenon of cold shortening in muscle has been studied extensively since first described by Locker and Hagyard (1963) and it is generally accepted that excessive shortening in muscle will decrease meat tenderness (Marsh and Leet, 1963; Herring et al. 1965).

Sarcomere length is somewhat related to muscle pH. Since the decline in pH is a result of anaerobic glycolytic metabolism during development of rigor (Sahlin, Harris and Hultman, 1975), then the degree of sarcomere shortening can be measured by or related to pH decline. Cook (1967) showed that stretched muscle (reverse of contraction) had higher pH values. This inverse relationship supports the hypothesis that pH can be a measure of the extent of contraction during rigor.

Herring et al. (1965) reported a significant correlation ($r = -.67$) between sarcomere length and fiber diameter and found fiber diameter closely related ($r = .73$, $P < .01$) to differences in shear force. This bears out the fact that as sarcomere length decreases there is a concomitant increase in fiber diameter and decreased muscle fiber tenderness.

C. RELATIONSHIP OF POST-MORTEM TEMPERATURE, pH AND RIGOR MORTIS

Voyle (1969) studied histological differences in muscle held at varying temperatures after slaughter and found shorter sarcomeres in muscle fibers exposed to colder temperatures. Muscle fibers which

passed through rigor at higher temperatures were less likely to exhibit cold shortening which resulted in improved texture and tenderness of the meat. Busch, Parrish and Goll (1967) measured the development of isometric tension in muscle held at 2, 16, and 37°C and found that tension development which indicated contraction was maximal at 2°C and was two times greater than that developed at 37°C.

Cook (1967) attempted to control the extent of contraction during rigor by altering the physical state of the post-mortem muscle and found variations in sarcomere length were associated with pH changes after slaughter. In his study, stretched muscle exhibited higher pH values than minced or unexcised muscle.

Ultimate muscle pH and rate of pH decline post-mortem has been related to the rate and extent of cellular ATP hydrolysis. As ATP was depleted to form the actin-myosin complexes of rigor, muscle pH fell. Infante, Klaupiks and Davies (1964), and Ward, Edwards and Benson (1965) reported a relationship between ATP breakdown and decreased sarcomere length. Less extensive shortening should therefore be accompanied by less drastic pH decline and higher ultimate pH. Since ATP is the source of energy for contraction at the myofibrillar level, the extent of ATP degradation is indicative of the extent of contraction. Thus any treatment or carcass condition causing rapid breakdown of ATP would lead to increased shortening and would be expected to have adverse effects on meat tenderness. The decrease in level of ATP as shortening progresses should be accompanied by a decline in muscle pH. This decline can be explained by the change from aerobic to anaerobic

metabolism within the muscle after slaughter. Both ATP breakdown and pH decline occur in the glycolytic catabolism that accompanies the contractions of rigor. The accumulation of both lactate and pyruvate as a result of anaerobic energy utilization should be accompanied in the muscle tissue by a decline in intracellular pH (Sahlin et al. 1975). The decline of pH due to the release and accumulation of hydrogen ions during the glycolytic processes can thus be said to be rigor related and could be used to follow its progression and extent. Hotta and Terai (1966) discussed muscle contraction at the molecular level as an interaction between ATP and the myofibrillar proteins and suggested studying the extent of contraction by following ATP activity in post-mortem muscle. Infante et al. (1964) further demonstrated the role of ATP in the contractile mechanism. By stretching muscle tissue, thus creating an induced state of relaxation, they were able to reduce ATP breakdown by one-half. Likewise, Sink et al. (1965) followed the course of ATP breakdown as a method to observe the rigor pattern. By measuring the length of time required for the delay phase and the onset phase of rigor in both excised muscle and muscle left intact on the carcass, they showed that extreme shortening seemed to be accompanied by a short delay phase. When the delay phase of rigor can be prolonged, as would be possible by holding the muscle at higher temperatures, sarcomere shortening and pH decline could be controlled.

The pH decline in post-mortem muscle is known to be influenced by temperature. Cassens and Newbold (1967) followed pH changes in ox muscle post-morten and found that for the first few hours after

slaughter pH decline was more rapid at 1°C than at 5°C. Howard and Judge (1968) determined sarcomere length at different positions in bovine muscle and found significant differences in the contractile state at different muscle sites. They related these differences to varying amounts of tension that could develop depending on the varying rates of heat removal during carcass chilling on certain muscle areas. Howard and Judge (1968) reported subcutaneous fat measurements to be consistently correlated with shear values for bovine muscle. Parrish et al. (1969) acknowledged the temperature dependence of the contraction mechanism and demonstrated the extent to which rate of cooling of a carcass affected muscle fiber shortening and resulting meat texture. They summized that on some beef carcasses, thicker muscle mass and greater fat covering may have allowed internal muscle temperature to remain high even in the presence of low surrounding temperatures. A well insulated muscle could feasibly maintain a sufficiently high temperature to allow for depletion of the energy supplies necessary for extensive rigor before the cold temperature necessary to induce extreme shortening could penetrate to the interior of the muscle. Herring et al. (1965) in a study to determine the extent to which sarcomere length and fiber diameter was influenced by the tension created on the muscle, recognized the importance of the amount of external fat, fat firmness and fat distribution on the carcass to histological changes that occurred post-mortem.

Martin, Fredeen and L'Hirondelle (1975) measured pH after slaughter in pork carcasses and reported rapid rigor development was

associated with low pH, greater leanness and greater muscularity of the animal. High shear values, indicating greater muscular rigidity seemed to accompany low muscle pH values. Eidelboom et al. (1973) showed a correlation of r = -.67 between subjective pork carcass leanness scores and the extent of rigor. Sybesma (1973) and Verdijh (1971) reported that the conformation of an animal influenced the rate of post-mortem glycolysis and subsequent progression of rigor more than did the actual size of the carcass.

Smith et al. (1976) in an attempt to determine the mechanism by which carcass fat covering affects meat tenderness, selected lambs with varying degrees of external finish. They showed that post-mortem contraction could be controlled by allowing rigor to proceed at slightly higher temperatures which minimized cold shortening. Marsh, Woodhams and Leet (1968) recognized that chilling rate was determined not only by the surrounding cooler temperature but also by the size of the carcass mass and the amount of insulation on the muscle tissue. Other writers had suggested that larger carcasses chill more slowly and are thus more tender (Wenham et al. 1973). Marsh and Leet (1966) postulate that only slight differences in thickness of the fat deposition acting as a protective covering from the cold temperature could bring about differences in the susceptability of the muscle fibers to cold shortening. Although it is well documented that fatter animals produce more tender meat than leaner animals, this has not been shown to be due to the greater quantities of marbling known to be present in the fatter animals. The work of Smith et al. (1976) suggested the role

of the carcass fat covering in determining the rate of carcass chilling might possibly be involved in the tenderness differences.

D. SUMMARY

One criterion by which most retail meat is judged is how well it meets the consumer's expectations. The literature cited here deals with possible ramifications of finishing slaughter cattle on forage as compared to grain diets on growth, sensory, histological, and histochemical characteristics, and the relationship of temperature, pH and rigor. To summarize, it can be said that cattle finished on forage (low energy) rations gain weight slower and are less efficient. They have little external finish which allows quick heat dissipation from the muscle and makes the muscle more susceptible to cold shortening, alters the rate of post-mortem muscle pH decline, and varies the development of rigor mortis. The extent of shortening and pattern of rigor development can cause greater sarcomere shortening and decreased tenderness of the cooked product thus reducing consumer acceptance of grass-fed beef.

CHAPTER III

MATERIALS AND METHODS

Thirty-nine steers, including 18 Angus, six Hereford, 12 Charolais and three Angus x Hereford crosses, weighing 460-680 pounds were grouped into 13 trios on the basis of breed, weight and body type. All steers were wintered together on a silage ration at the University of Tennessee Blount Farm. When pasture growth was sufficient to allow grazing, one steer of each trio was randomly assigned to one of three feeding treatments: pasture (orchard grass and clover); limit fed (fed grain in a dry lot to gain 1.4 to 1.5 pounds per day); full fed (fed grain ration Ad libitum in a dry lot). The steers were weighed initially and at 28-day intervals until terminated from the trail. The amount of feed received by the limit fed steers was adjusted as necessary after each weighing to produce the same rate of gain as the pasture steers (Appendix A). The steers remained on their respective feeding treatments until slaughtered; approximately 110 days. The steers were slaughtered in three groups over a ten day period at the University of Tennessee Meat Laboratory. All steers of a trio were slaughtered on the same day. The cattle were held off feed but allowed access to water for 24 hours prior to slaughter. Live weights were recorded immediately prior to exanguination. Weights of the head, shanks (hide on) edible offal (heart, tongue, and liver), inedible offal and hide were taken during the dressing process. Muscle pH was measured 0, 3, 6,

12, and 24 hours post-mortem. Zero time post-mortem was assumed to be immediately upon completion of slaughter and prior to chilling. A ten gram sample of the Gluteus medius muscle was removed from the left side of each carcass opposite the first sacral vertebra for pH determination. The sample was placed in a Waring blender with 100 milliliters of distilled water and blended for three minutes. The pH was determined on a Fisher Model 801 Ionalyzer by placing the electrode in an aliquot of the mixture and recording pH immediately. The decrease in post-mortem muscle temperature was determined using an eight inch meat thermometer inserted into the Gluteus medius muscle opposite the second sacral vertebra of the left side of each carcass. Temperature was recorded 0, 3, 6, 12 and 24 hours post-mortem. External fat thickness was measured at the point where the zero hour post-mortem pH sample was taken. A 50 gram sample of the Gluteus medius was removed opposite the third sacral vertebra on the left side immediately upon completion of slaughter for glycogen content determination. Immediately after excision from the carcass the samples were placed in whirl pack bags and frozen in a -30°F blast freezer to prevent further glycogen breakdown. Carcasses then were chilled at 34°F for 48 hours before fabrication. Prior to fabrication, the carcasses were weighed and the left side ribbed for yield and quality grading by University of Tennessee personnel. The left side of each carcass was fabricated into closely trimmed retail cuts in the meat laboratory. Retail yield was recorded and research samples for histological, sensory and chemical analysis collected. Histological analysis was performed on tissue samples taken

from the medial region of the Longissimus dorsi muscle at the 12th rib. Samples were fixed in 40 percent neutral formalin for storage until analyzed. Sarcomere length was measured by the method of Locker (1960) using a Wild phase contrast microscope at 1500X with an oil immersion objective and an eye piece micrometer. Fiber diameter was measured at 150X using an eye piece micrometer by the method of Tuma (1962). The third and fourth loin steaks were used for shear force determination and sensory evaluation, respectively. Steaks were removed from the freezer 24 hours before cooking and thawed at 34°F. Both steaks of each animal were broiled at the same time in a rotary oven at 350°F to an internal temperature of 150°F. Ten one-half inch diameter cores were removed from the third loin steak for shear force determination and the average obtained for statistical analysis. An eight member, untrained preference panel was used for sensory evaluation. Panelists were served a one-half inch diameter core sample from the fourth loin steak under red light. Panelists determined tenderness, juiciness, flavor and overall acceptability using a nine point hedonic scale (9 most desirable, 1 least desirable). Panelists were presented three samples at each sitting and two taste panels were held per day. The 9-10-11 rib section was removed and physically separated into fat, bone and lean by the method of Hankins and Howe (1946).

A completely randomized design with three treatments and 13 animals per treatment was used in this study.

ANALYSIS OF VARIANCE

Source	df
Treatment	2
Trio	12
Animal/Treatment	24

Orthogonal comparisons (as shown below) were used to determine where significant differences occurred between treatment means.

ORTHOGONAL CONTRASTS

	Pasture	Limit-Fed	Fed Ad Libitum
Comparison 1	-1	+1	0
Comparison 2	-1	-1	+2

Comparisons one and two compared source of feed (pasture versus limited-grain-fed) and level of energy intake (Ad libitum grain fed versus pasture and limited-grain-fed), respectively.

CHAPTER IV

RESULTS AND DISCUSSION

A. SLAUGHTER DATA

The analysis of variance, means and standard deviations are shown in Tables 1 and 2, respectively. Feed source (pasture versus grain), at approximately the same energy level, affected slaughter weight, hot carcass weight and percent edible and inedible offal. Steers from the pasture treatment were lighter ($P < .01$) at slaughter and had correspondingly lower hot carcass weights ($P < .05$) than the limit-fed steers. Edible offal, expressed as a percent of slaughter weight, was higher ($P < .05$) in the pasture-fed cattle. The difference in edible offal was attributable to variation in slaughter weight rather than variation in total weight of edible offal. Inedible offal weights were four percent higher ($P < .0001$) for the pasture cattle. This difference was possibly due to increased rumen content and intestinal development in the pasture steers. It is interesting to note these differences since all steers were held off feed for 24 hours prior to slaughter.

The level of energy influenced slaughter weight, hot carcass weight, and percentages of inedible offal, head and shank. Steers on the high energy diet were heavier ($P < .0001$) at slaughter and had heavier ($P < .0001$) hot carcass weights. This agrees with Guenther et al. (1965) who found increased slaughter weights in cattle fed at a high level of energy as compared to cattle on a moderate level of energy.

TABLE 1

MEAN SQUARES OF ANALYSIS OF VARIANCE AND COEFFICIENT OF REGRESSION FOR SLAUGHTER DATA

Source	Slaughter Weight	Dressing Percent	Hot Carcass Weight	Edible Offal Weight	Inedible Offal Weight	Head Weight	Shank Weight	Hide Weight
Comparison 1[a]	22273.8[d]	0.21	16728.47[c]	0.293[d]	105.85[f]	0.027	0.038	0.0072
Comparison 2[b]	252397.0[f]	0.38	133879.39[f]	0.079	69.89[f]	1.128[f]	0.769[e]	3.6900
Trio	28880.0[f]	3.53	14827.26[e]	0.047	4.83	0.121[c]	0.091	0.5814
Residual	2668.9	0.28	2679.12	0.031	2.79	0.049	0.056	0.9077
R^2	0.91[f]	0.42	0.83[f]	0.56[c]	0.78[e]	0.69[d]	0.59[c]	0.33

[a] Pasture versus limit-fed.

[b] Pasture, limit-fed versus fed Ad libitum.

[c] $P < .05$

[d] $P < .01$

[e] $P < .001$

[f] $P < .0001$

TABLE 2

TREATMENT MEANS AND STANDARD DEVIATIONS OF SLAUGHTER DATA

Treatment	Slaughter Weight (lbs)	Dressing Percent[a]	Hot Carcass Weight (lbs)	Expressed as Percent of Slaughter Weight: Edible Offal Weight	Inedible Offal Weight	Head Weight	Shank Weight	Hide Weight
Pasture $\bar{X}$	744.38	59.94	445.96	1.85	22.07	3.05	2.26	8.51
SD	±91.40	±9.14	±81.34	±0.26	±1.58	±0.27	±0.23	±0.92
Limit fed $\bar{X}$	802.92	61.74	496.69	1.64	18.04	2.98	2.18	8.47
SD	±95.40	±2.20	±69.21	±0.09	±2.47	±0.26	±0.31	±1.00
Ad libitum fed $\bar{X}$	944.31	62.94	595.62	1.84	17.21	2.65	1.92	7.84
SD	±129.50	±1.83	±93.70	±0.17	±1.35	±0.28	±0.23	±0.73

[a]Calculated on hot carcass basis.

Percent head and shank were lower ($P < .0001$ and $P < .001$, respectively) for the steers on the high level of energy. The means (Appendix B) for these weights were approximately the same for both groups. The difference in percent head and shank was due to the heavier slaughter weight of the steers on the high nutritional level. There was a significant trio effect on slaughter weight ($P < .00001$), hot carcass weight ($P < .001$), and head weight ($P < .05$). Although there was no statistical difference in dressing percent in the comparisons made, there was a definite trend for the fatter cattle in the limit-fed and Ad libitum fed treatments to have higher dressing percentages. Dressing percent is a vital factor in establishing the value of live cattle. Even though dressing percent was not statistically significant in these analyses, the three percent range (59.9 - 62.9) is of significant economic importance in evaluating results from future research of this nature. Hide weight expressed as a percent of live weight at slaughter was not affected by any treatment.

B. CARCASS TRAITS

The statistical analyses show that source of energy (pasture versus limit-fed) had a significant effect on marbling, quality grade, loin eye area, chilled carcass weight and fat thickness measured at the 12th rib (Tables 3 and 4). The limit-fed cattle had more marbling ($P < .001$) and higher quality grades ($P < .0001$) than the pasture steers. There was no difference in yield grades between the two treatments. However, the limit-fed steers had larger ($P < .05$) loin eyes and more

TABLE 3

MEAN SQUARES OF ANALYSIS OF VARIANCE AND COEFFICIENT OF REGRESSION FOR CARCASS TRAITS

Source	Marbling	Quality Grade	Yield Grade	Loin Eye Area	Percent Kidney Knob	Chilled Carcass Weight	Fat Thickness at 12th Rib
Comparison 1[a]	41.88[e]	30.15[f]	0.43	6.11[c]	0.346	33043.99[f]	0.111[f]
Comparison 2[b]	88.32[f]	37.38[f]	3.49[f]	12.32[d]	0.004	158157.07[f]	0.417[f]
Trio	59.90	25.59	0.15	2.62[c]	0.152	15134.84[f]	0.005
Residual	0.23	0.09	0.15	1.21	0.219	1245.62	0.004
R^2	0.74[e]	0.78[f]	0.61[c]	0.62[d]	0.29	0.93[f]	0.85[f]

[a] Pasture versus limit-fed.

[b] Pasture, limit-fed versus fed Ad libitum.

[c] $P < .05$

[d] $P < .01$

[e] $P < .001$

[f] $P < .001$

TABLE 4

TREATMENT MEANS AND STANDARD DEVIATIONS OF CARCASS TRAITS

Treatment		Marbling[a]	Quality[b] Grade	Yield Grade	Loin Eye Area (sq. in.)	Percent Kidney Knob	Chilled Carcass Weight (lbs)	Fat Thickness at 12th Rib (in.)
Pasture	$\bar{X}$	6.38	3.46	1.68	9.25	1.02	415.66	0.10
	SD	±0.96	±0.78	±0.34	±1.10	±0.35	±67.38	±0.05
Limit fed	$\bar{X}$	8.92	5.62	1.93	10.22	1.25	486.95	0.23
	SD	±1.98	±1.45	±0.44	±1.22	±0.38	±68.25	±0.08
Ad libitum fed	$\bar{X}$	10.85	6.62	2.44	10.93	1.11	586.39	0.38
	SD	±2.38	±1.26	±0.39	±1.53	±0.57	91.80	±0.07

[a] 6 = Traces plus, 7 = slight minus, 9 = slight plus, 10 = small minus, 11 = small average.

[b] 3 = High standard, 4 = low good, 6 = high good.

fat over the 12th rib ($P < .0001$). Because of lighter mean slaughter weights and lower dressing percent, the pasture steers had lighter ($P < .0001$) chilled carcass weights. The lack of significant difference in yield grades in Comparison 1 was attributable to the pasture cattle being significantly lighter and trimmer than the limit-fed cattle. The larger mean loin eye area of the limit-fed cattle did not offset these factors, thus yield grade was similar.

The level of nutrition affected all the carcass variables except percent kidney knob (Table 3). The results generally agree with those reported by Utley et al. (1975) who compared steers from a low energy pasture regime to steers fed a high energy grain diet. In the current study, steers on the high energy diet had more marbling ($P < .0001$) (Table 3) and higher quality grades ($P < .0001$) than the steers on the low energy diets. There was a thicker fat covering over the 12th rib ($P < .0001$) and higher yield grades ($P < .0001$) for the Ad libitum fed steers. Mean loin eye area was greater ($P < .01$) for steers fed on the high energy regime. Due to the heavier slaughter weight of the steers on the high energy diet, chilled carcass weights were correspondingly heavier ($P < .0001$).

C. TEMPERATURE, pH AND FAT THICKNESS AT THE FIRST SACRAL VERTEBRA

Source of feed influenced carcass fatness and post-mortem muscle temperature at 3, 6, 12 and 24 hours after exsanguination measured at the first sacral vertebra (Tables 5 and 6). Fat thickness at the first

TABLE 5

MEAN SQUARES OF ANALYSIS OF VARIANCE AND COEFFICIENT OF REGRESSION FOR FAT THICKNESS[a] AND POST-MORTEM MUSCLE TEMPERATURE[b]

Source	Fat Thickness	Time Post-Mortem (hours)[c]				
		0°F	3°F	6°F	12°F	24°F
Comparison 1[d]	0.146[f]	12.46	143.12[f]	240.04[g]	116.35[g]	64.65[h]
Comparison 2[e]	0.242[g]	5.13	152.32[f]	316.01[h]	269.55[i]	141.34[i]
Trio	0.028	2.64	24.62	24.53	14.70	8.94[f]
Residual	0.027	4.74	20.62	20.08	11.31	4.00
R^2	0.53	0.30	0.54	0.64	0.67[g]	0.77[h]

[a]Fat thickness measured at first sacral vertebra.

[b]Measured at third sacral vertebra in Gluteus medius.

[c]Zero time post-mortem was 30 minutes after exsanguination.

[d]Pasture versus limit-fed.

[e]Pasture, limit-fed versus fed Ad libitum.

[f]$P < .05$

[g]$P < .01$

[h]$P < .001$

[i]$P < .0001$

TABLE 6

TREATMENT MEANS AND STANDARD DEVIATIONS OF FAT THICKNESS,[a] POST-MORTEM MUSCLE TEMPERATURE[b] AND pH[c]

Treatment	Fat Thickness	Time Post-Mortem (hours)[d]									
		°F	pH	°F	pH	°F	pH	°F	pH	°F	pH
Pasture $\bar{X}$	0.21	100.69	6.46	83.0	6.23	68.08	5.91	53.53	5.70	40.46	5.19
SD	±0.10	±2.02	±0.13	±3.79	±0.15	±5.04	±0.25	±3.50	±0.29	±2.44	±0.11
Limit fed $\bar{X}$	0.36	102.08	6.37	87.69	6.06	74.15	5.84	57.77	5.59	43.62	5.19
SD	±0.25	±1.80	±0.21	±4.42	±0.32	±3.72	±0.27	±3.59	±0.22	±2.14	±0.13
Ad libitum $\bar{X}$	0.45	102.15	6.36	89.54	5.98	77.15	5.48	61.23	5.45	46.08	5.18
fed SD	±0.11	±2.19	±0.09	±5.68	±0.30	±5.05	±0.24	±3.49	±0.20	±2.53	±0.14

[a]Fat thickness measured at first sacral vertebra.

[b]Measured at third sacral vertebra in Gluteus medius.

[c]Measured at first sacral verteba in Gluteus medius.

[d]Zero time post-mortem was 30 minutes after exsanguination.

sacral vertebra was thicker ($P < .05$) in the limit-fed steers compared to pasture steers. This is consistent with the increased fat thickness over the 12th rib of limit-fed steers. Internal muscle temperature decreased from 3 to 24 hours at a significantly faster rate in the more thinly finished, pasture-fed cattle. The slower temperature decline in the fatter, limit-fed steers demonstrated the insulating ability of even slight increases in fat thickness. Source of feed did not statistically affect the pH (Table 7) at any time but there was a consistent trend in pH level and rate of change. The pasture cattle had higher pH values at each time except 24 hours post-mortem when pH values were the same for both groups (Table 6). This indicates that cooler mean carcass temperature and/or faster heat loss in these trimmer cattle slowed post-mortem glycolytic metabolism, reducing the build-up of lactic acid. The higher pH values suggest there were more stored energy reserves in the muscle. The greater energy reserve could, when stimulated by cold temperatures, be partially responsible for increased sarcomere shortening found in cold shortened meat as suggested by Parrish et al. (1969).

Difference in ration energy level caused an increase ($P < .01$) in fat thickness at the first sacral vertebra. The increased fat deposition in the Ad libitum fed steers caused a slower carcass chilling rate than found in the limit-fed steers. The pH was lower at six hours ($P < .0001$) and 12 hours ($P < .05$) post-mortem in the Ad libitum fed steers. Here, as in the limit-fed steers, the thicker fat covering caused the post-mortem muscle temperature to decrease slower, thus

TABLE 7

MEAN SQUARES OF ANALYSIS OF VARIANCE AND COEFFICIENT OF REGRESSION FOR POST-MORTEM pH[a]

Source	Time Post-Mortem (hours)[b] 0 pH	3 pH	6 pH	12 pH	24 pH
Comparison 1[c]	0.064	0.202	0.094	0.078	0.000038
Comparison 2[d]	0.032	0.232	1.532[h]	0.313[e]	0.00115
Trio	0.016	0.068	0.100[e]	0.056	0.0231
Residual	0.263	0.072	0.046	0.058	0.0136
R^2	0.31	0.42	0.72[g]	0.43	0.46

[a]Measured in Gluteus medius.

[b]Zero time post-mortem was 30 minutes after exsanguination.

[c]Pasture versus limit-fed.

[d]Pasture, limit-fed versus fed Ad libitum.

[e]$P < .05$

[f]$P < .01$

[g]$P < .001$

[h]$P < .0001$

permitting glycogen metabolism to continue at a faster rate, resulting in a lower pH reading. The pH values, while not statistically different, were also lower at zero and three hours post-mortem. The fat thickness, muscle temperature and pH relationship found in this study agrees with results reported by Smith et al. (1976).

D. HISTOLOGICAL AND HISTOCHEMICAL DATA

There was no statistical difference in sarcomere length, fiber diameter or glycogen content when comparing feed source or level of energy (Tables 8 and 9). Treatment means show that pasture steers had the shortest sarcomeres ($\bar{X}$ = 2.33μ) when compared to the limit-fed and Ad libitum fed steers ($\bar{X}$ = 2.42μ and $\bar{X}$ = 2.41μ, respectively). Fiber diameter did not follow the expected trend in that shorter sarcomeres are expected to be larger in diameter. The muscle glycogen content data was inconclusive and showed wide variation within the treatments. The effect of feed withdrawal and long and short-term stress on muscle glycogen content could possibly be the reason for the lack of variation.

E. RETAIL YIELD AND ESTIMATED CARCASS COMPOSITION

Source of feed significantly affected retail yield and the estimated percent separable fat and bone of the dressed carcass (Table 10). The limit-fed steers yielded more pounds of steak and roast meat ($P < .001$) and ground beef ($P < .0001$) (Table 11) than the pasture steers. Total yield accordingly was greater ($P < .0001$) for the limit-fed steers. This is easily explained as the limit-fed steers were heavier at slaughter and although slightly fatter very

TABLE 8

MEAN SQUARES OF ANALYSIS OF VARIANCE AND COEFFICIENT OF REGRESSION FOR HISTOLOGICAL AND HISTOCHEMICAL DATA

Source	Sarcomere Length	Fiber Diameter	Glycogen Content
Comparison 1[a]	0.048	76.87	209.90
Comparison 2[b]	0.009	4.34	95.62
Trio	0.096	136.61	165.81
Residual	0.046	102.07	169.81
R^2	0.52	0.41	0.36

[a]Pasture versus limit-fed.

[b]Pasture, limit-fed versus fed Ad libitum.

TABLE 9

TREATMENT MEANS AND STANDARD DEVIATIONS FOR HISTOLOGICAL AND HISTOCHEMICAL DATA

Treatment		Sarcomere Length (microns)	Fiber Diameter (microns)	Glycogen Content (mg/100 g)
Pasture	$\bar{X}$	2.33	60.08	28.06
	SD	0.17	9.62	10.67
Limit fed	$\bar{X}$	2.42	63.52	33.74
	SD	0.18	9.63	14.53
Ad libitum fed	$\bar{X}$	2.41	62.51	27.58
	SD	0.35	12.47	13.43

TABLE 10

MEAN SQUARES OF ANALYSIS OF VARIANCE AND COEFFICIENT OF REGRESSION FOR RETAIL YIELD AND ESTIMATED CARCASS COMPOSITION[a]

Source	Retail Yield			Percent of Dressed Carcass		
	Steak and Roast Meat	Ground Beef	Total Yield	Separable Fat	Separable Bone	Separable Lean
Comparison 1[b]	3235.51[f]	5322.46[g]	16857.58[g]	72.81[d]	40.24[d]	0.14
Comparison 2[c]	10619.47[g]	14810.19[g]	50511.63[g]	1019.51[g]	69.67[e]	408.65[f]
Trio	1949.67[g]	1714.53[g]	7163.14[g]	19.51	2.76	27.31
Residual	218.68	127.07	372.29	17.85	5.43	26.70
R^2	0.88[g]	0.93[g]	0.94[g]	0.82[g]	0.52	0.53

[a] 9-10-11 rib separation method, Hankins and Howe, 1946.

[b] Pasture versus limit-fed.

[c] Pasture, limit-fed versus fed Ad libitum.

[d] $P < .05$

[e] $P < .01$

[f] $P < .001$

[g] $P < .0001$

TABLE 11

TREATMENT MEANS AND STANDARD DEVIATIONS OF RETAIL YIELD AND ESTIMATED CARCASS COMPOSITION

Treatment	Retail Yield (lbs)			Percent of Dressed Carcass		
	Steak and Roast Meat	Ground Beef	Total	Separable Fat	Separable Lean	Separable Bone
Pasture $\bar{X}$	176.15	128.60	304.75	19.26	62.38	18.33
SD	±29.27	±23.30	±50.11	±4.11	±7.71	±3.31
Limit fed $\bar{X}$	198.46	157.22	355.68	22.61	62.53	15.84
SD	±25.00	±24.65	±47.51	±4.66	±4.21	±1.14
Ad libitum fed $\bar{X}$	222.31	184.25	406.56	31.78	55.59	14.25
SD	±30.09	±28.60	±56.03	±2.16	±1.87	±1.16

little fat had to be trimmed from the retail cuts. The estimated carcass composition based on the 9-10-11 rib section separation shows that pasture steers had less fat ($P < .05$) and correspondingly a higher percent bone ($P < .05$) than the limit-fed steers. The lower fat percentage agrees with the previously noted lower fat thickness measurement over the 12th rib, first sacral vertebra and lower marbling score. There was no difference in estimated percent lean.

Steers on the high nutritional plane produced more pounds ($P < .0001$) of steak and roast meat, ground beef and thus had greater total yield on a weight basis (Tables 8 and 9) than the steers on the low energy diet. This was due to the greater carcass weights of the Ad libitum steers. Estimated percent separable fat was higher ($P < .0001$) and estimated percent lean ($P < .001$) and bone ($P < .01$) was lower in the carcasses of the Ad libitum fed steers. Guenther et al. (1965) reported that calves fed on a high nutritional level yielded greater quantities of lean and fat when compared to calves on a moderate diet. However, Guenther et al. (1965) reported pounds of lean and fat and did not determine composition percentages.

F. ORGANOLEPTIC TRAITS AND WARNER-BRATZLER SHEAR

The source of feed significantly affected tenderness, flavor, overall acceptability and the Warner-Bratzler Shear values (Table 12). Steaks from the pasture steers scored lower for tenderness ($P < .001$), flavor ($P < .01$) and overall acceptability ($P < .001$) (Tables 12 and 13) than steaks from limit-fed steers. This generally agrees with the

TABLE 12

MEAN SQUARES OF ANALYSIS OF VARIANCE AND COEFFICIENT OF REGRESSION FOR ORGANOLEPTIC TRAITS AND WARNER-BRATZLER SHEAR VALUES

Source	Tenderness	Juiciness	Flavor	Overall Acceptability	Warner-Bratzler Shear
Comparison 1[a]	8.06[e]	0.529	4.04[d]	8.65[e]	61.89[f]
Comparison 2[b]	5.71[d]	1.460[c]	2.12[c]	4.25[e]	28.05[d]
Trio	0.45	0.611[c]	0.50	0.36	3.37
Residual	0.62	0.247	0.32	0.28	2.29
R^2	0.56[c]	0.61[c]	0.61[c]	0.72[e]	0.70[d]

[a] Pasture versus limit-fed.

[b] Pasture, limit-fed versus fed Ad libitum.

[c] $P < .05$

[d] $P < .01$

[e] $P < .001$

[f] $P < .001$

TABLE 13

TREATMENT MEANS AND STANDARD DEVIATIONS OF ORGANOLEPTIC TRAITS[a] AND WARNER-BRATZLER SHEAR VALUES[b]

Treatment		Tenderness	Juciness	Flavor	Overall Acceptability	Warner-Bratzler Shear
Pasture	$\bar{X}$	5.00	6.10	5.65	5.23	10.44
	SD	±0.89	±0.63	±0.62	±0.67	±2.08
Limit fed	$\bar{X}$	6.12	6.38	6.44	6.38	7.35
	SD	±0.52	±0.69	±0.73	±0.49	±1.14
Ad libitum fed	$\bar{X}$	6.37	6.65	6.54	6.51	7.10
	SD	±0.78	±0.49	±0.47	±0.48	±1.53

[a]Average of eight panelists evaluating the third loin steak using a 9 point hedonic scale (1=extremely undesirable, 5=acceptable, 9=extremely desirable).

[b]Average of 10 cores from fourth loin steak.

findings of Meyer et al. (1960). The objective tenderness measurement (Warner-Bratzler Shear) agreed with the taste panel scores for tenderness. Warner-Bratzler Shear values were higher ($P < .0001$) indicating less tender meat from the pasture steers compared to the limit-fed steers. Juiciness was not affected by source of feed although there were slightly higher juiciness scores for the limit-fed steers.

Level of nutrition affected all the sensory characteristics and the Warner-Bratzler Shear values (Tables 12 and 13). The steers fed Ad libitum scored higher for tenderness ($P < .01$), juiciness ($P < .05$) and overall acceptability ($P < .001$). Jacobson and Fenton (1956) reported superior flavor and increased tenderness in steers fed a high level of nutrition compared to medium and low levels of nutrition. Warner-Bratzler Shear values were lower ($P < .01$) for the steers on the high nutritional level indicating increased tenderness. This agrees with the taste panel scores and reports of other researchers.

CHAPTER V

SUMMARY

Thirty-nine steers were allotted to three feeding treatments (pasture, limit-grain-fed and grain fed Ad libitum) so the effect of feed source (pasture versus limit-fed) and level of energy intake (pasture and limit-fed versus fed Ad libitum) on certain carcass, cooked meat and histological characteristics could be evaluated.

The pasture steers had higher percentages, on a live weight basis of edible offal ($P < .01$) and inedible offal ($P < .0001$) than the limit-fed steers. Pasture steers had lighter slaughter weights ($P < .01$), lighter chilled carcass weights ($P < .0001$), less fat over the 12th rib ($P < .0001$), smaller loin eyes ($P < .05$) and produced less total pounds ($P < .0001$) of retail meat than the limit-fed steers. As expected, the pasture steers had lower estimated percent fat ($P < .05$) expressed as a percent of the dressed carcass. There was no difference in percent lean between pasture and limit-fed steers. Carcasses from the pasture steers had less finish over the first sacral vertebra ($P < .05$) and chilled at a significantly faster rate but there was no statistical difference in post-mortem muscle pH. Taste panelists rated steaks from the pasture steers lower for tenderness ($P < .0001$), flavor ($P < .01$) and overall acceptability ($P < .001$). Warner-Bratzler Shear values were higher ($P < .0001$) for the pasture steers.

The limit-fed steers had higher marbling scores ($P < .001$) and thus higher quality grades ($P < .0001$) than the pasture steers.

Steers on the high energy diet were heavier at slaughter ($P < .0001$), had heavier hot carcass ($P < .0001$) and chilled carcass weights ($P < .0001$) and yielded more pounds of retail meat ($P < .0001$) than either the pasture or limit-fed groups. The Ad libitum fed steers had larger ($P < .01$) loin eyes, more fat over the 12th rib ($P < .0001$) and higher yield grades ($P < .0001$). Steers on the high energy diet were more highly marbled ($P < .0001$) and had higher quality grades ($P < .0001$). Estimations of carcass composition, based on the 9-10-11 rib separation, showed a higher percentage of fat ($P < .0001$) and bone ($P < .01$) in the Ad libitum fed steers as compared to the low energy fed steers. Ad libitum fed steers had lower percentages of inedible offal ($P < .0001$), head ($P < .001$) and shank ($P < .0001$) on a live weight basis. Due to greater fat thickness ($P < .01$) (measured at the first sacral vertebra) carcasses of the Ad libitum fed steers chilled at a significantly slower rate. The pH was lower at six hours ($P < .0001$) and 12 hours ($P < .05$) post-mortem in the high energy fed steers but at 24 hours was the same as the low energy fed steers. An inverse relationship was found between temperature and pH. Carcasses with lower muscle temperatures had higher pH values, indicating the lower temperature inhibited enzymatic activity and glycogen breakdown. Taste panelists rated steaks from the Ad libitum fed steers higher on tenderness ($P < .01$), juiciness ($P < .05$) and overall acceptability ($P < .001$). Warner-Bratzler Shear values were lower ($P < .01$) for steaks from the high energy fed steers.

There were no statistical differences found in sarcomere lengths but there was a trend that agreed with both taste panel tenderness and Warner-Bratzler Shear scores. The pasture cattle had the shortest sarcomeres ($\bar{X}$ = 2.33μ) while there was no difference between the limit fed and Ad libitum fed steers ($\bar{X}$ = 2.42μ, $\bar{X}$ = 2.41μ, respectively).

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APPENDIXES

APPENDIX A

TABLE 14

PERFORMANCE DATA FOR STEERS DURING WINTERING AND THREE DIFFERENT FEEDING TREATMENTS

		Treatment		
		Pasture-fed	Limit-fed	Ad-libitum Fed
Pre-wintering weight, lbs	$\bar{X}$	553.8	548.1	541.3
	SD	±63.2	±58.5	±60.6
Pre-treatment weight, lbs	$\bar{X}$	656.2	656.9	630.8
	SD	±107.1	±86.2	±119.4
137 day gain (wintering phase), lbs	$\bar{X}$	146.3	131.5	115.0
	SD	±51.6	±52.5	±65.0
ADG (wintering phase), lbs	$\bar{X}$	1.05	0.96	0.93
	SD	±0.4	±0.4	±0.4
Slaughter weight, lbs	$\bar{X}$	744.4	802.9	944.3
	SD	±91.4	±95.4	±129.5
Weight gain during feeding treatment, lbs	$\bar{X}$	88.15	147.0	313.5
	SD	±37.1	±27.7	±52.9
Days on feed		110	110	110
ADG during trial, lbs		0.82	1.35	2.85
		±0.33	±0.25	±0.48
Fat thickness at slaighter, in.	$\bar{X}$	0.10	0.23	0.38
	SD	±0.05	±0.08	±0.07

APPENDIX B

TABLE 15

TREATMENT MEANS AND STANDARD DEVIATIONS OF RAW SLAUGHTER DATA

Treatment	Head Weight (lbs)	Shank Weight (lbs)	Edible Offal	Inedible Offal	Hide Weight
Pasture $\bar{X}$	22.64	16.85	13.80	163.27	63.02
SD	±3.13	±2.96	±2.62	±12.59	±7.71
Limit fed $\bar{X}$	23.79	17.36	13.15	144.17	67.99
SD	±2.22	±2.06	±1.66	±22.50	±11.18
Ad libitum $\bar{X}$	24.92	18.06	17.30	162.57	73.65
SD	±3.30	±2.70	±2.26	±26.07	±9.64

VITA

Joey Wayne Lusby was born January 9, 1953 to William I. and Catherine S. Lusby in Prescott, Arkansas. He graduated from Prescott High School in May 1971. In June 1971, he enrolled in Southern State College, Magnolia, Arkansas, majoring in General Agriculture. He transferred to Kansas State University, Manhattan, Kansas in June 1973 where he received a Bachelor of Science degree in Food Science and Industry in May 1975. He enrolled in the graduate school of the University of Tennessee at Knoxville in June 1975. While working towards a Master of Science Degree in Agriculture with a major in Food Technology and Science, he held the position of graduate research assistant in the Department of Food Technology and Science. He is a member of the American Meat Science Association and Gamma Sigma Delta.