SOME EFFECTS OF DIFFERENT PLANES OF NUTRITION ON CARCASS CHARACTERISTICS OF FATTENING STEER CALVES AND RELATIONSHIPS AMONG VARIOUS LIVE ANIMAL AND CARCASS MEASUREMENTS

By

ROBERT F. HENDRICKSON

Bachelor of Science
The University of Wisconsin
Madison, Wisconsin
June, 1956

Master of Science
Oklahoma State University
Stillwater, Oklahoma
May, 1961

Submitted to the Faculty of the Graduate School of
the Oklahoma State University of Agriculture and
Applied Science in partial fulfillment of the
requirements for the degree of
DOCTOR OF PHILOSOPHY
August, 1962

SOME EFFECTS OF DIFFERENT PLANES OF NUTRITION ON CARCASS CHARACTERISTICS OF FATTENING STEER CALVES AND RELATIONSHIPS AMONG VARIOUS LIVE ANIMAL AND CARCASS MEASUREMENTS

Thesis Approved:

L. L. Pope
Thesis Adviser

R. L. Henrickson

A. B. Nelson

L. M. Henderson

H. W. Reuber

Joe W. Whiteman

Robert MacVicar
Dean of the Graduate School

ACKNOWLEDGMENT

The author wishes to express his sincere appreciation to Dr. L. S. Pope, Professor of Animal Husbandry, for his valuable guidance during the course of this study and in the preparation of this thesis.

Grateful acknowledgment is also extended to Dr. R. L. Henrickson of the Animal Husbandry Department for his invaluable assistance in obtaining the necessary carcass information.

The author is deeply indebted to Dr. Wm. Granet of the Mathematics Department and to Mrs. Cassie Spencer, Supervisor of the Computing Center, for their advice and cooperation concerning computational problems. Appreciation is also extended to Dr. J. V. Whiteman of the Animal Husbandry Department for suggestions concerning the statistical aspects of this study.

The author is indeed grateful to George Odell of the Biochemistry Department for conducting the chemical analyses, to Dr. J. R. LeGendre for conducting the first trial of this experiment, and to Mrs. Grady Williams for obtaining much of the information involving cooked samples. Thanks are also extended to the members of the grading committee, which included Drs. L. S. Pope, R. L. Henrickson, J. V. Whiteman, J. C. Hillier, L. E. Walters, Robert Totusek and Doyle Chambers, and to the many students who cared for the cattle and assisted with slaughtering and collection of data.

Special thanks is due the author's wife, Norma, for her encouragement in the preparation of this thesis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

INTRODUCTION

> ... any excess fat beyond that which is required to make an attractive looking, juicy, and highly flavored meat is essentially waste ... this fat costs the producer a large sum of money for which the world gets no reasonable return ...

The above comments by Trowbridge et al. (1919) also apply to modern beef production. Recent consumer preference surveys indicate a desire for smaller, leaner cuts of beef, with less fat. The problem is to obtain maximum lean production at cheapest cost, yet retain the quality attributes - juiciness, tenderness and flavor - of well-finished beef.

To better meet consumer demands, many cattle are full-fed after weaning and marketed at an earlier age. However, surprisingly little information on efficiency of lean production has been published in recent years. In addition, knowledge concerning the performance and carcass desirability of weanling calves fed to gain at a moderate rate is extremely limited. Such a regime may promote maximum lean development without excessive fat deposition.

Thus, the effects of different nutritional planes on carcass composition of fattening cattle and on beef quality are yet to be determined. Data are also needed on the efficiency of conversion of ration constitutents to body components. Further, beef researchers are constantly confronted with the problem of developing reliable measures of animal performance and carcass desirability. Hence the relationships among various live animal and carcass measurements merit investigation.

In an attempt to provide this needed information, four feeding trials were conducted at the Oklahoma Agricultural Experiment Station. Individually-fed weanling steer calves were subjected to different planes of nutrition, and extensive feedlot and carcass data were collected. In three trials, the calves were fed for the same total feedlot gain (approximately 400 pounds) and, in one trial, for the same length of time. Results pertaining to feedlot performance have been reported previously (Henrickson, 1961). Carcass composition, quality, and efficiency data, together with certain relationships among live animal and carcass measurements, are presented herein.

REVIEW OF LITERATURE

This review is presented in three parts, consisting of (1) early body composition studies, (2) effect of plane of nutrition on carcass traits and (3) relationships among live animal and carcass traits.

Early Body Composition Studies

Many of the early investigations on carcass composition, as influenced by nutritional treatment, have been reviewed by Hammond (1955) and Hendrickson (1961). An inverse relationship between fat and water content of carcasses was observed as early as 1849 by Lawes and Gilbert (Haecker, 1920). In 1895, Jordan noted that, despite large differences in total gain, the relative weights of organs and body parts, and the proportions of water, fat, protein, and ash (on the basis of the entire body, the dressed carcass, or the edible portions only) were surprisingly similar for pairs of Shorthorn steer calves subjected to diets widely differing in nutritive ratios, when slaughtered at the same age (17 months or 27 months). The author concluded that the individual animal possesses a constitutional inertia which may not easily be overcome, and that severe measures are necessary if this growth pattern is to be disturbed. Consequently, more drastic treatments were imposed by many investigators in subsequent studies.

Several fundamental relationships were observed in these investigations. Waters (1908) was perhaps the first to show that skeletal growth continues, although lean and fat tissues are severely retarded, when young steers are fed rations which permit no gain in weight. Eckles and Swett (1918) and Hogan (1929) noted, as did Waters, that, despite a very strong tendency towards recovery when liberal feeding was resumed, both the severity and length of the underfeeding period affected the eventual mature size of cattle.

Further results of Water's experiments with yearling steers (reported by Trowbridge et al., 1918) indicated pronounced "savings" in nutrients, due to use of body fat, at maintenance and submaintenance feeding levels. The demand of body tissues for nutrients was, in order of increasing priority; subcutaneous fat, visceral and intermuscular fat, intramuscular fat, protein of the soft tissues, skeletal fat, and skeletal protein. Trowbridge et al. (1919) showed similar trends with older steers, and emphasized the large amount of waste fat and extreme inefficiency of full-feeding older cattle for long periods of time. The same effects were observed by Moulton et al. (1923). Most of the increase in fatty tissue in mature dairy cows was observed around the internal organs and only a relatively small part was found with the edible flesh.

Much of the early work cited is subject to criticism since rather general conclusions were often based on data from one or two animals. Later Missouri reports (Moulton et al., 1922a, 1922b), however, include observations on 30 steers and provide substantial support for many of the previous generalizations. Three groups of Hereford-Shorthorn steers were fed for maximum growth and fattening, maximum growth without fattening, and retarded growth, from birth until slaughter at intervals from a few weeks to four years of age. The proportions of skeleton and of total organs were greatest at birth, and of total fleshy parts, at four years. The rate of growth of most body components measured was at a maximum at 8.5 months of age, when the animal exhibited its most "juvenile" form. The main effect of age and plane of nutrition on composition of tissues and of the whole animal was an increase in percent fat and corresponding decreases in other constituent percentages, except where fattening was slight. The last weight gains made by older animals were calculated to be 90 percent fat.

Haecker (1920) conducted an extensive, well-designed study wherein 50 steers were slaughtered at various stages from 100 to 1,400 pounds live weight. The following figure, which is self-explanatory, not only summarizes part of his results but also illustrates the general pattern obtained in early investigations concerned with body composition. It is

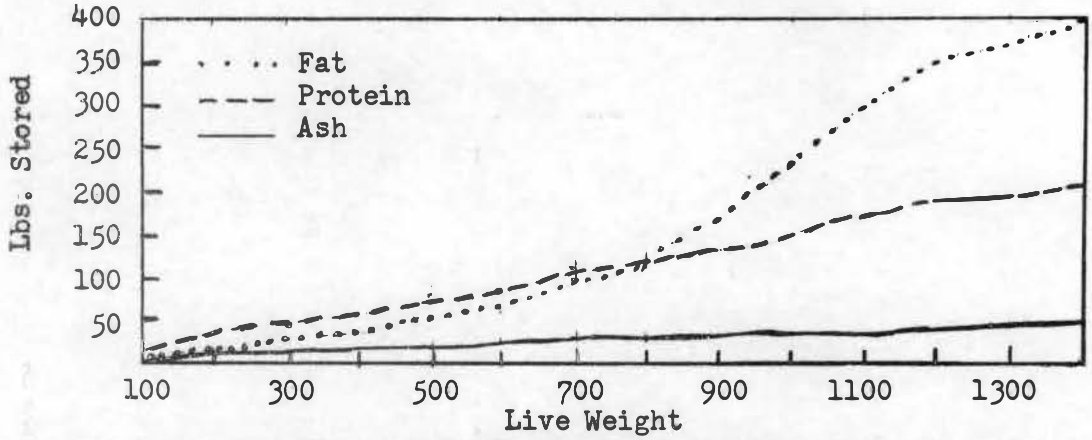

Figure 1. Amount of Fat, Protein and Ash Stored in the Body at Different Weights (Haecker, 1920)

readily seen that beyond 800 pounds live weight, fat accounts for an increasingly greater part of the weight gain than does protein. The lower efficiency of feed conversion obtained at the heavier weights substantiates the fact that fattening is an expensive process.

In general, these early investigations indicate effects of relatively severe treatments (particularly undernutrition) imposed for long periods of time. More recent experiments, while still not of a practical nature in most instances, provide information that is more readily applied to current feeding practices. The effect of plane of nutrition on rate of gain and feed efficiency has been reviewed by Hendrickson (1961). Therefore, the emphasis in the following discussion is placed on carcass studies involving different nutritional planes.

Effects of Plane of Nutrition on Carcass Traits

Because of the multiple effects due to treatment, and the large number of measurements taken in many experiments, this section is divided into three parts, involving effects on (1) carcass and tissue composition, (2) quality factors and (3) efficiency on a carcass basis.

Carcass and Tissue Composition

Since considerable time and expense is involved in detailed carcass analyses, more investigations have been conducted with swine and sheep than with cattle. In experiments with swine, Hogan _et al_. (1924) slaughtered pigs at 50 pound intervals from 100 to 300 pounds live weight and observed larger percentages of bacon and loin, and correspondingly smaller percentages of other cuts, as the animals gained in weight. McMeekan (1940a) postulated anterior to posterior gradients and centripetal gradients in skeletal, muscle and fat development of male pigs slaughtered at monthly intervals from birth to seven months of age. Extensive carcass measurements and quantitative and qualitative chemical data provided strong supporting evidence for these development patterns, and revealed the inadequacy of live weight as a measure of growth in the animal body. In subsequent studies, McMeekan (1940b) subjected pairs of closely inbred pigs to high and low planes of nutrition from birth to 16 weeks of age. Body length and the extremities in general were penalized less by inadequate nutrition than body depth, loin and hindquarters. Pigs on the higher plane contained 221, 291 and 1,007 percent as much skeletal, muscle and fat tissue, respectively, as low-plane pigs, which strikingly illustrates the differential effects of nutrition on body tissues. In every instance, early-developing parts and tissues were less markedly affected than those developing late.

Twenty similar pigs were fed to gain according to predetermined growth curves from birth to 200 pounds live weight (McMeekan, 1940c). The four treatments were High-High (HH), High-Low (HL), Low-High (LH) and Low-Low (LL), where "High" and "Low" refer to the nutritional plane imposed. HL and LH pigs were switched to the opposite plane at 16 weeks of age. Two distinct types of carcasses were produced; the HH and LH groups were similar, containing a greater proportion of the later-developing parts, while earlier-developing parts were proportionately greater in the case of HL and LL groups. The amount of skeleton and muscle increased, and fat decreased, in the order LH, HH, HL, and LL. Relative to LL, mean treatment differences ranged from six to 20 percent less bone, five to 25 percent less muscle and 26 to 64 percent more fat.

The above series of articles by McMeekan are classical in nature, and many investigators, including the author, have since conducted studies employing similar treatment arrangements.

In other research with swine, Brugman (1950) compared HH and LH feeding regimes using two cross-bred lines believed to be genetically similar. Limiting the feed intake to 70 percent of full-feed up to 150 pounds and then full-feeding to 220 pounds live weight (LH line) resulted in a higher percentage of trimmed primal cuts, less total lard and leaner carcasses. Winters et al. (1949) used HH, HL, LH and LL treatments and noted that the animals fed the restricted diet throughout (LL) produced the leanest carcasses. The results of these two studies do not necessarily conflict with McMeekan's work, however, since treatments were imposed at weaning, instead of at birth, and there were obviously differences in genetic material.

When two genetically dissimilar lines were used to compare effects of various nutritional planes on pork carcass traits, Lucas and Calder (1956) concluded from the results that genetic differences are likely to be of more importance in the production of desirable bacon than attempts to alter the growth curve by feeding - within the limits acceptable in practice. These limits are often much narrower than the range in treatments reported in studies of this nature.

Merkel et al. (1958) incorporated fibrous feeds (corn cobs and alfalfa hay) in swine rations to restrict energy intake. Pigs fed the restricted rations produced carcasses with less backfat and leaf fat, and higher percentages of skinned ham, ham muscle and lean cuts. Loin eye area and percent belly did not appear to be affected by treatment. Crampton et al. (1954) observed that not only the percent of lean in the bacon, but also the actual quantity of lean, increased when feed intake of swine was restricted during the finishing period.

Thus, the effects of plane of nutrition on carcass composition appear to be marked in swine, although dependent on the degree and time interval of feed restriction. As would be expected, fat tissue was affected most and skeletal tissue least, and carcass composition generally reflected the feeding regime imposed during the finishing phase.

All species may not respond according to the above pattern, however. Wilson (1954) used McMeekan's growth curves (HH, HL, LH and LL) with chickens and was unable to detect significant treatment differences in body composition when cockerels were sacrificed at intervals from birth to 24 weeks of age, compared on an equal weight basis. Since the chicken has relatively little fat tissue at this stage of development, compared to domestic mammals, this may explain the small differences obtained.

Palsson and Verges (1952a) used half-sib lambs to study body development on high and low planes of nutrition. The treatments were imposed from the third month of fetal life to 41 weeks of age. Carcasses were studied at birth, nine weeks and 41 weeks, and the extensive measurements taken provided strong support for the growth patterns and gradients proposed by McMeekan (1940a). Vital organs were not appreciably retarded by early restriction, and intermuscular fat was reduced less than subcutaneous fat by the low feeding regime.

In a subsequent study (Palsson and Verges, 1952b) HH, HL, LH and LL treatments were imposed on similar lambs from the third month of fetal life to 30 pounds carcass weight. Again results agreed remarkably well with McMeekan's, with two distinct types of carcasses being produced. HH and LH groups yielded very desirable carcasses, in contrast with the thin, poorly finished carcasses of the HL and LL treatments. Differences between the HL and LH groups furnish additional evidence for the premise that the tissues developing most rapidly at any given time are influenced most by nutritional treatment. In all cases, however, tissues in the later developing parts of the body were relatively more affected than those in the early developing regions. The same general pattern of results has been obtained by Wilson (1960), who reared goats on HH, HL, LH and LL planes of nutrition from birth to 16 and 30 pound weights.

Very little information is available on carcass composition on cattle, as influenced by nutritional plane, other than that discussed in the previous section. Callow (1961) reported significant differences in fat and lean content of carcasses from 24 steers subjected to High-High (HH), High-Moderate (HM), Moderate-High (MH) and Moderate-Moderate (MM) feeding regimes. These treatments were imposed during winter months only and all animals were grazed during the summer. Steers were slaughtered at an estimated yield of 57 percent. Percent of lean increased, and fat decreased, in the order HH, MH, MM and HM. This pattern may have been influenced by the fact that HH and MH groups were slaughtered off grass in late summer.

In 1955, Winchester and Howe used six pairs of identical twin steers to study the effects of continuous and interrupted growth. Control steers were fed a liberal ration, while the retarded animals received 50 percent (maintenance), 62 percent and 75 percent of a liberal ration from six to 12 months of age. The latter groups were then liberally fed and all steers were slaughtered at about 1,000 pounds live weight. Rather surprisingly, the quantity of lean meat in the carcass was not decreased by the growth interruption.

In a second investigation 10 pairs of identical twins were used with a wider range of treatments (Winchester and Ellis, 1957). The caloric retardation included sub-maintenance, maintenance, and super-maintenance levels from three to six or four to eight months of age. All steers were slaughtered at an estimated grade of Low Prime. No important differences in lean or fat content were observed. Significant increases in percent bone were noted for the maintenance and sub-maintenance groups over the controls, but this may have been due to age differences rather than nutritional regime.

Winchester et al. (1957) also reported no appreciable differences in carcass composition due to various levels of calorie and/or protein restriction with 12 pairs of identical twins restricted between six and 12 months of age and slaughtered at the same degree of fatness as their cotwins. In one extreme case (caloric maintenance and 2.5 percent digestible protein), one retarded twin possessed slightly less muscle and slightly more fat than its liberally fed cotwin.

The above series of experiments prominently illustrates the ability of steers to recover from a period of undernutrition. The preceding discussion strongly suggests that carcass composition of ruminants in general reflects the plane of nutrition imposed in the months just prior to slaughter. The growth and development patterns proposed by McMeekan appear to be applicable to cattle, sheep and goats as well as to swine. The literature also supports the contention of Jordan (1895) that rather severe nutritional regimes are needed to markedly affect carcass composition.

Quality Factors

Many of the articles concerned with the effects of plane of nutrition on live and carcass grades, yield and marbling scores have been reviewed by Hendrickson (1961). In general, when a reduction in fat content occurred due to a low nutritional plane, live and carcass grades were lowered (Merkel et al., 1958; Brugman, 1950; Guilbert et al., 1944; Weber et al., 1931; Palsson and Verges, 1952b). However, grades sometimes improved in the case of swine (Winters et al., 1949; Lucas and Calder, 1956; Lucas et al., 1960) while in other reports grades were not affected appreciably by treatment (Shorrock, 1940; Winchester et al., 1957). Trends in dressing percentage frequently paralleled carcass grades. In many instances where differences in grade or yield were not observed, the designs of the trials were such that variation in these measurements would be minimized.

The studies of McMeekan (1940b, 1940c) with swine and Palsson and Verges (1952b) with lambs indicate that marbling, as estimated by chemical analysis of the eye muscle, may be more closely associated with age than with nutritional treatment, since ether extract was least in samples from the HH group and greatest in samples from the LL carcasses. Moisture varied inversely with ether extract. Merkel et al. (1958) also noted that intramuscular fat did not appear to be associated with degree of feed restriction. However, Palsson and Verges (1952a) found significantly less marbling in lamb carcasses when a low plane of nutrition was compared to a high plane and animals were slaughtered at the same age.

Winchester and Howe (1955), Winchester and Ellis (1957), and Winchester et al. (1957) all concluded from investigations with identical twin steers that carcass quality was not adversely affected by retarding growth with a caloric maintenance ration for as long as six months. Measurements included carcass grade and yield, shear values, and organoleptic studies wherein tenderness and flavor of lean and fat were rated.

The literature available reveals a definite pattern for the effects of plane of nutrition on carcass quality factors only when experimental design is considered. In investigations where treatment groups were slaughtered at the same age, significant differences were often observed. Removal from test at approximately equal grade, yield or weight generally did not produce appreciable differences between treatments. Differences in organoleptic values appear difficult to obtain, except in extreme cases such as reported by Foster (1928) where roasts from aged steers were judged superior in aroma, flavor, color and juiciness to those from yearling steers. No tenderness differences were detected, however.

Efficiency on a Carcass Basis

Hendrickson (1961) has reviewed a number of articles concerning effects of plane of nutrition on feed efficiency, measured as feed or TDN required per pound of live weight gain. No clear-cut pattern was established in these reports, as feed efficiencies were often unchanged by treatment and occasionally favored the lower planes. With the widely used four treatment design, HM or HL groups often were more efficient than the other feeding regimes imposed.

However, the expression of feed efficiency on the basis of carcass composition has not been reported to any extent in plane of nutrition studies, although the basic concept is not new. The obvious advantage of such a procedure is that basing efficiency on the caloric content of the carcass provides a more realistic measure of the energetic efficiency of feeds than does weight gain, since gains are seldom isocaloric in nature (Reid et al., 1955). The major problem has been to obtain a reliable, yet inexpensive, estimate of carcass energy.

Reid et al. (1955) observed that fat-free body contained 21.64 $\pm$ 1.53 percent protein for beef and dairy carcasses of cattle varying from one to 4,860 days of age. Using the caloric values of fat (9,367 kcal./kg.) and of protein (5,233 kcal./kg.) reported by Blaxter and Rook (1953), these workers were able to calculate the energy value of the carcass. Data used included many of the early studies reported herein (Jordan, 1895; Haecker, 1920; Trowbridge et al., 1918, 1919; Moulton et al., 1922a, 1922b, 1923). Prediction equations were developed for estimation of energy value of the carcass from the percentage of body water and age of the animal. These caloric values compared favorably with those obtained from actual chemical composition data, but other workers (Garrett et al., 1959; Breidenstein et al., 1955) have not been able to satisfactorily measure body water.

Meyer et al. (1960) proposed the use of specific gravity to predict carcass composition. The percentages of fat and lean so obtained were converted to energy values by using 9,367 kcal./kg. fat (Blaxter and Rook, 1953) and 5,686 kcal./kg. protein (Garrett et al., 1959). The latter figure was determined on a dry fat- and ash-free basis, whereas the value used by Reid et al. (1955) was determined on a dry ash-free basis only, corresponding to a tissue containing 16 percent nitrogen. Using the calculated caloric carcass values, "corrected" carcass weights which were equivalent in caloric and protein content were obtained. These weights were adjusted for differences in initial weight by covariance analysis so that the resulting values incorporated the essential information commonly derived from live weight gains, dressing percentages and carcass grades, and permitted use of one over-all statistic (instead of three) for interpretation of experimental results.

Brody (1945) suggested that TDN may be converted to calories by multiplying pounds of TDN by 1,814. However, more recent data (Swift,

1957) suggests that 1,982 is a more appropriate conversion factor for cattle fed mixed rations. It appears that caloric efficiency may be calculated from TDN if the well known limitations of TDN as a measure of the value of feeds for ruminants are considered.

Although no plane of nutrition investigations appear to have employed the above methods, the author has used portions of these procedures to aid in evaluating efficiencies in the studies reported in this thesis.

Relationships Among Live Animal and Carcass Traits

No attempt has been made in this section to review the vast amount of literature pertaining to this subject. Rather, certain studies have been selected which illustrate the degrees of relationship most frequently observed. The emphasis in the following discussion will be on measurements and observations used to estimate carcass composition and quality, and will be limited to cattle.

A major problem in beef cattle evaluation has been the lack of an accurate method of measuring carcass traits in live cattle. Orme et al. (1959) studied the relationships among a large number of linear live animal and carcass measurements, using 31 long yearling beef steers. Repeatability estimates ranged from 0.50 to 0.90, 0.43 to 0.86, 0.73 to 0.96 and 0.70 to 0.98 for width, length, height and circumference measurements, respectively, taken on the live animal. Height at withers, circumference of fore flank and width of shoulder and round were among the most repeatable of these. All carcass measurements were highly repeatable.

Width measurements of the carcass were highly correlated with corresponding live animal measurements (r = 0.66 to 0.77). Both width and depth measurements of the carcass were more highly associated with objective on-foot measurements than with subjective grading scores. Ternan et al. (1959) obtained similar results with data from 98 yearling steers, although correlations were generally lower in magnitude. Subjective scores were usually only slightly correlated with objective measurements; however, this may reflect the true relationship more accurately than the high correlations found among linear measurements, since it is well established that the latter are highly associated with general size or weight. A number of investigators (Kidwell, 1955; Yao et al., 1953; Cook et al., 1951) have reported rather low correlations between live animal measurements or scores and production or carcass traits. Literature reviewed by Hendrickson (1961) indicates that, while heart girth has been closely related to nutritional plane imposed and certain width and depth measurements show some promise, these relationships are difficult to establish with treatments in the range acceptable to commercial practice. Heart girth has repeatedly been shown to be the best single estimate of body weight (Kidwell, 1955; Orme et al., 1959).

Orme et al. (1959) also correlated live animal measurements with wholesale cut percentages, holding live weight constant. Relationships were generally negative and non-significant, except for heart girth and percent primal cuts (r = -0.46). With carcass measurements, only width dimensions were highly correlated with primal cuts (-0.40 to -0.50).

Hearth girth accounted for 81 percent of the variation in loin eye area (live weight constant) but loin eye area showed a significant negative correlation with the major wholesale cuts (-0.51), which indicates that lower percentages of round, rump and loin may be expected as loin eye size increases. This is not in agreement with early reports by McMeekan (1941) and several others which indicate that the area of the Longissimus dorsi is a good index of muscling. Cole et al. (1960b) were able to account for only five to 30 percent of the variation in separable lean of either the entire carcass or of specific wholesale cuts using loin eye area. Since most of the studies supporting the value of this measurement as an indicator of lean have been conducted with sheep and swine, there may be an important species difference here.

Total carcass lean is of particular importance in carcass evaluation studies and investigators are continually searching for ways to obtain inexpensive and reliable estimates. The equations proposed by Hankins and Howe (1946) have been and are being used by many workers to estimate carcass composition from physical separation of the 9-10-11th rib cut. This is obviously more practical than complete physical separation of the carcass and appears to be among the best estimates available. Correlation coefficients between separable tissue components of the three-rib cut and corresponding separable carcass components were 0.90, 0.93, and 0.80 for lean, fat and bone, respectively, based on data from 84 steers. However, the extreme variation in experimental material used makes application of these results to certain uniform groups of cattle of somewhat questionable value.

Recently, Cole et al. (1960b) evaluated the separable lean of several wholesale cuts and various linear carcass measurements as to their usefulness in predicting carcass lean. Carcass weight was more highly associated with total lean ($r = 0.77$) than were linear measurements or loin eye area. Width and circumference measurements were correlated more highly with loin eye area than with lean, while the reverse was observed with length measurements. Correlation coefficients between separable lean in various wholesale cuts and carcass lean were 0.95 with round, 0.93 with chuck, 0.81 with foreshank, 0.80 with sirloin, 0.79 with rib, 0.75 with shortloin and 0.74 with the 9-10-11th rib. The authors suggested that separable lean in the round may be useful in estimating carcass lean, with negligible loss in economic value of the carcass.

Subsequently, the same group of workers (Orme et al., 1960) obtained the following standard partial regression coefficients between total carcass lean and weights of certain muscles or muscle groups: Biceps femoris, 0.97; sirloin tip muscles, 0.82; Longissimus dorsi, 0.79 and inside round muscles, 0.72. The data were collected from carcasses of 43 mature Hereford cows and slaughter weight was held constant in the calculations. Estimation of total carcass lean was not enhanced by use of multiple correlations. The relationships noted appear sufficiently high to be of predictive value, but the pattern for immature cattle is probably somewhat different, so this information may have only limited application.

There has been considerable interest in the use of specific gravity to estimate carcass composition. Kraybill et al. (1952) obtained correlation coefficients of -0.956 and 0.984 between specific gravity of the eviscerated body, and body fat and water contents, respectively. There was a close relationship between specific gravity of the carcass and of the whole animal (0.989). Specific gravity of the 9-10-11th rib was also highly correlated with that of the carcass (0.950) and the whole animal (0.954), indicating that this cut may be used nearly as effectively as the entire carcass for density determinations. Density values obtained for fat and lean, respectively, were 0.895 and 1.100. The high correlations observed in this study reflect the wide variation in body composition present in the 30 yearling Hereford steers used.

Meyer _et al._ (1960) noted a high relationship (r = -0.98) between specific gravity of the dressed carcass and percent carcass fat, as calculated from the data of Kraybill _et al._ (1952). Again, wide variation in the experimental material was evident.

Correlation coefficients of -0.57, 0.72, -0.77 and -0.60 were obtained between specific gravity and fat thickness, subjective marbling, chemical fat and drip loss, respectively, by Cole _et al._ (1960a). Measurements were obtained on 100 beef ribs grading from Prime to Standard and Commercial. Breidenstein _et al._ (1955) observed excellent agreement among several measures of carcass fatness with 24 steers which graded High Good to Low Prime. These measures were specific gravity, physical separation, and ether extract of the separable lean and fat, all determined on the wholesale rib. Little relationship was noted between specific gravity of the _Longissimus dorsi_ muscle and subjective marbling score, although the latter appeared to be directly related to ether extract of the rib eye.

Specific gravity has also been used to measure other quality attributes, which are generally considered to be far more elusive in nature than the composition of body tissues. Cole _et al._ (1960a) obtained highly significant correlation coefficients between specific gravity of the rib and palatability (-0.45), flavor of lean (-0.45), juiciness (-0.41), and tenderness scores (-0.31) but only 10 to 20 percent of the variation in beef eating quality was explained by specific gravity. In another study, correlation coefficients between specific gravity of the Longissimus dorsi muscle in the 9-10-11th rib and percent fat, water, protein and carcass grade (to the nearest one-third) were found to be -0.81, 0.74, 0.68 and -0.68, respectively (Orme *et al.*, 1958). The data included measurements of 51 wholesale beef ribs, primarily in the Choice grade. The authors suggest that specific gravity may be used to objectively measure marbling, which is not in agreement with the work of Breidenstein *et al.* reported above.

Other investigations concerned with carcass quality reveal that live animal measurements and scores are not significantly correlated with marbling (Good *et al.*, 1961). It seems obvious, then, that marbling, and therefore to a large extent carcass grade, cannot be accurately evaluated in the live animal. Wheat and Holland (1960) obtained average correlation coefficients of 0.07 to 0.39 between live slaughter grade and carcass grade after ribbing. Eighty-one percent of the 688 Herefords graded were in the Average Good to Average Choice range. Marbling and final carcass grade were highly correlated (0.89) within this range.

In summary, it appears that the degrees of relationship among numerous live animal and carcass traits are nearly as varied as the characteristics studied. Most investigators have found correlation coefficients among linear measurements of the live animal and carcass to be disappointingly low when the mutual influence of body size and live weight is removed. Similarly, subjective scores, whether on live animal or carcass traits, have not shown much promise for predictive purposes. In contrast, relatively accurate estimates of carcass composition have been obtained by use of separable lean in certain wholesale cuts, and with specific gravity and chemical analysis. Specific gravity is being studied extensively because it is very easily and quickly obtained and the saleability of the product is not altered. Carcass quality factors appear to remain elusive, and the predictive value of both objective and subjective measures of product acceptability has been relatively low.

It must be emphasized that none of the easily obtainable estimates and the traits which they estimate are sufficiently correlated to eliminate the need for refinement in techniques or for further exploratory investigations in any area of beef production research.

MATERIALS AND METHODS

Sixty-four weanling Hereford steer calves from the experiment station herd at Fort Reno were used in a series of three feeding trials initiated in December, 1956, at Stillwater, Oklahoma. A fourth trial was conducted in 1959-60 with 24 similar calves from the same herd. Average weight of the steers when placed on test was 482 pounds.

Trials I, II and III

The experimental design for the first three trials is shown in Table I, where "High" (H) represents full-feeding for rapid gain and "Moderate" (M) indicates restricted feeding for a limited rate of gain.

TABLE I

DESIGN OF EXPERIMENT (TRIALS I, II AND III)

Treatment Group	HH	HM	MH	MM
Plane of nutrition				
Phase I (200 lb. gain)	High	High	Moderate	Moderate
Phase II (200 lb. gain)	High	Moderate	High	Moderate
Number of steers				
Trial I (1956-57)	4	4	4	4
Trial II (1957-58)[a]	5	5	5	5
Trial III (1958-59)	6	6	6	4[b]
Total	15	15	15	13

[a]One steer was removed from each treatment group in Trial II: One steer died due to bloat; another was removed because of a throat injury; two were removed due to abnormally poor performance.

[b]Two steers were removed from the MM group in Trial III because of chronic bloat and poor performance.

Each steer remained on test until approximately 400 pounds total feedlot gain had been obtained, as estimated by shrunk weights (16 hours off feed and water).

Initial shrunk weight, feeder grade, sire, age of calf, and treatment and age of dam were considered in allotment of animals to the treatment groups. The steers were individually-fed in stanchioned stalls, twice daily, and had free access to water and a 2:1 salt:steamed bonemeal mixture between feedings. Stanchion time consisted of 1.5 to 2.0 hours per feeding. Feed refusals were weighed back and recorded.

To obtain different rates of gain, the calves were fed as indicated in Table II. The 2.0 pounds of milo per cwt. daily offered to the high plane groups is comparable to the amount consumed by self-fed steers on a fattening-type ration. Feed allowances were adjusted for each 50 pounds increase in body weight.

TABLE II

APPROXIMATE DAILY FEED OFFERED (TRIALS I, II AND III)

	Plane of Nutrition	
Ingredient (lb.)	High	Moderate
Rolled milo (per cwt.)	2.0	1.0
Cottonseed meal	1.5	1.5
Dehydrated alfalfa pellets	1.0	1.0
Cottonseed hulls (per cwt.)	0.75	1.5

It was hoped that these feed allowances would result in gains in excess of 2.0 pounds per day for the high plane groups and from 1.3 to 1.5 pounds per day for the moderately-fed groups. The average percents of feeds used, estimated chemical composition, and calculated TDN and net energy values are shown in Table III.

TABLE III

AVERAGE COMPOSITION OF RATIONS, AS FED (TRIALS I, II AND III)

Treatment Group	HH	HM	MH	MM
Ingredient (%)				
Rolled Milo	65.5	49.9	54.8	40.0
Cottonseed meal	6.8	8.1	7.8	8.7
Dehydrated alfalfa pellets	5.1	5.6	5.4	5.8
Cottonseed hulls	22.5	36.4	31.8	45.5
Molasses	0.1	----	0.2	----
Chemical composition (%)[a]				
Dry matter	89.7	90.0	89.9	90.2
Ash	2.9	3.0	3.0	3.1
Crude protein	11.7	11.2	11.4	10.7
Ether extract	2.7	2.5	2.6	2.3
Crude fiber	13.5	19.7	17.7	23.7
N-free extract	58.8	53.5	55.2	50.3
TDN (%)[b]	69.4	64.3	65.9	60.9
Net energy (therms/cwt.)[b]	64.7	57.7	60.0	53.2

[a]Composition was estimated by chemical analysis of feedstuff samples.

[b]Values were calculated using TDN and net energy data of Morrison (1956).

The following body measurements were taken at the beginning, mid-point and end of each trial: Height at withers, length of body, width of shoulder, width of loin, width of quarter and heart girth. Other data collected during the feedlot phase included individual feed records, average daily gains and length of time required to reach slaughter weight. Information on feedlot performance and reference points for the above body measurements have been presented and discussed by Hendrickson (1961).

As the steers were individually removed for slaughter at the Meats Laboratory, a grading panel of three to seven members of the Animal Husbandry Department staff scored each animal subjectively in terms of compactness, width of body, crops, loin, rump, quarter, muscling, thickness of fat, smoothness, refinement and live slaughter grade. A similar committee appraised the carcass with respect to compactness, thickness, rib eye lean, loin, round, thickness of external fat, distribution of fat, kidney knob, marbling, texture of lean, firmness of lean, color of fat and carcass grade.

At time of slaughter, the contents of four compartments of the ruminant stomach were weighed to obtain an estimate of "fill". Weights of the hide, large and small intestines (full), internal fat (Trials II and III only), pluck, liver, heart and hanging tenderloin were also recorded. Dressing percentages were obtained, based on 48-hour chilled carcass weight.

Carcass measurements taken after 24 hours chill included carcass length, length of leg, circumference of round (Trials I and II only), length of loin, depth of body, thickness of chuck and thickness of round. Reference points for these measurements have been presented by Hendrickson (1961).

From a tracing at the twelfth rib, rib eye area was determined with a compensating planimeter. Width and length of the rib eye cross section and thickness of external fat over the rib eye were measured from the same tracing as shown in Figure 2.

Carcass cutout values were obtained after 48 hours chill by cutting each side "Chicago-style" into 10 wholesale cuts (round, rump, loin, flank, kidney knob, chuck, rib, plate, brisket and shank) in the conventional manner. Specific gravity readings of the major wholesale cuts (round, rump, loin, chuck and rib) were also obtained at this time.

An attempt to estimate gross composition of the carcass was made by a physical separation of the 9-10-11th rib cut. In addition, samples of the Longissimus dorsi and Semimembranosus muscles were analyzed chemically for percentages of moisture, protein, fat and ash. Left side Semimembranosus muscles were not samples in Trial II, and only the right side of the carcass was analyzed in Trial III.

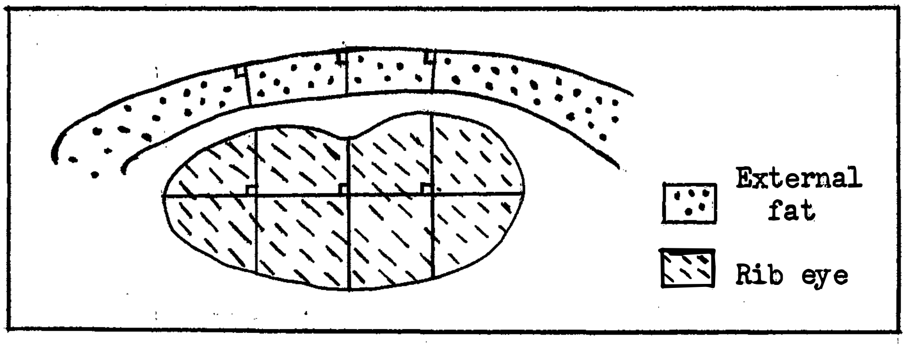

Figure 2. Reference Points for Measurements from Rib Eye Tracing

Tenderness of well-broiled, two-inch steaks was estimated with the Warner-Bratzler shearing device. The steaks were put in the broiler at $46^{\circ} - 48^{\circ}$ F., turned at 95° and removed at 155° internal temperatures, as determined with meat thermometers. Two shears (Trial I) or three shears (Trials II and III) were obtained from each of three one-inch diameter cores from twelfth rib steaks in all trials and from top round steaks in Trials I and II.

Similar one-inch steaks from the eighth rib and top round were used for more subjective organoleptic studies. A panel of six to eight students and staff members recorded the number of chews required per sample (one-half-inch diameter core), and rated each sample from "one" to "nine" with respect to tenderness and juiciness; the larger numerals denoting the more desirable ratings. Round steaks were not evaluated in

Trial III.

Except where otherwise indicated, both sides of the carcass were utilized in obtaining the above data.

Trial IV

Trial IV differed from the previous tests in that only three treatments were imposed (eight steers per treatment), as follows:

High--Full-fed to gain rapidly for 350 pounds total feedlot gain.

Moderate I--Fed to gain moderately and removed from test at the same time as the "High" group.

Moderate II--Fed to gain moderately for 350 pounds total feedlot gain.

Allotment and handling of cattle, and collection of data, were essentially as described for previous trials. The rations, however, were changed by adding sorghum silage and decreasing the cottonseed hull content in an attempt to improve palatability and thereby increase feed intake of the full-fed calves. The average composition of the rations used is presented in Table IV. As in previous trials, the different rates of gain were achieved by offering a full feed of milo to the "High" group and approximately one-half this amount, or 1.0 pound of milo per cwt. daily, to the "Moderate" groups. The latter steers also received additional roughage.

Data obtained were similar to those collected in earlier trials, with the following exceptions. Only two sets of live animal measurements were taken (initial and final), and weights of the rumen, liver, heart, hanging tender and pluck were not determined. However, length and width measurements of the right front cannon bone were recorded. Shear values were obtained on rib steak only (three shears per core) and only

Longissimus dorsi muscles from the right side were utilized for chemical analysis. In addition, no organoleptic tests were conducted in the fourth trial.

TABLE IV

AVERAGE COMPOSITION OF RATIONS, AS FED (TRIAL IV)

Treatment	High	Moderate I	Moderate II
Ingredient (%)			
Rolled milo	52.3	26.7	29.3
Cottonseed meal	6.2	6.0	6.2
Dehyd. alfalfa pellets	4.2	4.0	4.9
Cottonseed hulls	8.5	16.0	18.1
Sorghum silage	28.8	47.2	41.5
Chemical composition (%)[a]			
Dry matter	71.0	59.5	63.2
Ash[b]	3.2	3.8	3.5
Crude protein[b]	12.4	11.3	11.4
Ether extract[b]	2.9	2.7	2.6
Crude fiber[b]	10.9	19.0	19.0
N-free extract[b]	60.4	52.8	52.8
TDN (%)[a,b]	71.4	63.1	63.2
Net energy (therms/cwt.)[a,b]	67.3	56.3	56.5

[a]Values were calculated using data of Morrison (1956).

[b]Values were adjusted to 90 percent dry matter equivalent.

Analysis of the Data

The data obtained in all four trials were punched on cards and the IBM 650 electronic computer was utilized for the statistical analyses. Fortran and Fortransit IIS interpretive schemes were employed to write the programs needed for compilation of the data. The results were analyzed according to methods described by Snedecor (1956). The program used for analysis of variance, designed for one or two-way cross classification, was written in Fortran by the author and is presented in Table XXIV, Appendix A. The Beaton Correlation Routine was used to obtain means, standard deviations, and simple correlations. Orthogonal comparisons were made to compare differences among treatment groups.

Subjective evaluation scores were adjusted by use of Fortransit IIS programs to reduce the effects due to individual graders. This procedure is described in Appendix A.

Efficiency of conversion of feed constituents to carcass components was calculated by assuming equal initial carcass composition among treatments of 63 percent lean and 20 percent fat. Equal initial yields of 56 percent were also assumed. Total carcass lean and fat were calculated from 9-10-11th rib physical separation data by employing the equations of Hankins and Howe (1946):

$Y = 16.08 + 0.80\ X$; Y = percent lean in carcass, X = percent separable lean in 9-10-11th rib.

$Y = 3.54 + 0.80\ X$; Y = percent fat in carcass, X = percent separable fat in 9-10-11th rib.

Caloric value of the carcass was calculated using 9,367 kcal./kg. in fat (Blaxter and Rook, 1953) and 5,686 kcal./kg. in protein (Garrett et al., 1959). Carcass protein was calculated from 21.64 percent protein in the fat-free body (Reid et al., 1955). Caloric value of the ration was calculated using 1,982 kcal./lb. in TDN (Swift, 1957).

RESULTS AND DISCUSSION

Results of the feedlot performance of calves in the four trials reported herein have been presented by Hendrickson (1961) and are briefly summarized in Table V. The following comments serve merely to orientate the reader with respect to the variability and nutritional history of the cattle used in this study.

Initial shrunk weight of the steers ranged from 330 to 585 pounds. The wide variation in weight within treatment groups is indicated by large standard deviations.

Although average daily gains decreased markedly in successive years for the first three trials (1.95 vs. 1.68 vs. 1.52 pounds per steer per day), a consistent pattern was noted among treatments within each trial. This trend is indicated in the three-year average shown in Table V. Note that the HH and MH groups gained over 0.29 pound per day more than HM and MM groups. The pronounced effect of plane of nutrition during the second half of the feedlot period (HM and MH groups) on overall performance has been observed by several other investigators (Hammond, 1955; Guilbert <u>et al</u>., 1944; Weber <u>et al</u>., 1931; Wilson, 1960).

In the first three trials, calves full-fed in Phase II (HH and MH) consumed more feed and TDN per day, but required less feed per pound of gain, than steers in the other two groups. An average of 40 less days was needed, by HH and MH groups, to obtain the desired total gain. However, when nutritive value of the rations was considered, expressed as

TABLE V

FEEDLOT PERFORMANCE[a]

Treatment Group	Trials I, II and III (Av.)				Trial IV		
	HH	HM	MH	MM	High (H)	Moderate I (MI)	Moderate II (MII)
Days on feed	211[b]	251	221[b]	261	206	206[c]	271
Initial weight (lb.)	485	476	473	492	484	485	483
Std. deviation	±48	±59	±55	±59	±56	±34	±50
Av. daily gain (lb.)	1.88[d]	1.54	1.79[d]	1.54	1.73[e]	1.32	1.29
Feed/day (lb.)	19.0[f]	17.2	17.8[f]	17.0	23.6	24.4[g]	23.4
TDN/day (lb.)	13.2[h,i]	11.1[i]	11.8[h]	10.3	13.2[e]	10.2	10.4
Feed/lb. gain (lb.)	10.2[f]	11.2	10.0[f]	11.2	13.7[e]	18.7	18.1
TDN/lb. gain (lb.)	7.1[j]	7.2[j]	6.6	6.8	7.7	7.8	8.1

[a]Summary table compiled from data reported by Hendrickson (1961).

[b](HH + MH) significantly different from (HM + MM) at $P < 0.025$.

[c]MI significantly different from MII at $P \ll 0.001$.

[d](HH + MH) significantly different from (HM + MM) at $P < 0.01$.

[e]H significantly different from (MI + MII) at $P < 0.001$.

[f](HH + MH) significantly different from (HM + MM) at $P < 0.05$.

[g]MI significantly different from MII at $P < 0.05$.

[h](HH + MH) significantly different from (HM + MM) at $P \ll 0.001$.

[i](HH + HM) significantly different from (MH + MM) at $P < 0.01$.

[j](HH + HM) significantly different from (MH + MM) at $P \simeq 0.10$.

TDN, the cattle fed to gain moderately in Phase I were slightly more efficient. The MH group, in particular, required less TDN per pound of gain than steers on the opposite (HM) regime, which probably reflects the greater maintenance needs of the latter steers during Phase II.

In Trial IV, no important differences were noted in feedlot performance between the two moderate groups. The full-fed calves (H) gained more rapidly, consumed more TDN per day and required less feed per pound of gain, but were not significantly more efficient than moderately-fed steers in terms of TDN required per pound of gain. The MI group gained about 80 pounds less than the other two groups during the feedlot test. Much of the following discussion involves presentation of carcass data for the steers in these four trials.

The results reported herein are divided into two parts: Effects of Plane of Nutrition on Carcass Traits, and Relationships Among Live Animal and Carcass Traits. The first part includes discussion of subjective grading scores, slaughter floor data, yield of wholesale cuts, specific gravity determinations, rib eye measurements, physical separation data, chemical analysis of lean tissue, shear values and organoleptic data, and efficiency on a carcass basis. Relationships involving linear live animal and carcass measurements, specific gravity determinations, other indicators of carcass composition, and subjective scores and carcass quality data, are discussed in the second part.

Effect of Plane of Nutrition on Carcass Traits

Subjective Grading Scores

In all trials, a grading committee of three to seven men evaluated each steer at the end of the feeding test (live animal scores) and after slaughter (carcass scores). Both sets of grades are included in the following discussion. The actual scores were adjusted, because of a large number of missing values, as described in Appendix A. However, only the actual values were subjected to an analysis of variance.

Live animal evaluation scores. -- The average live animal scores, actual and adjusted, for the first three trials are shown in Table VI. Tables XXVI, XXVII and XXVIII, Appendix B, show the corresponding values obtained in each trial. Smoothness of finish and live slaughter grade were the only variables approaching statistical significance for the three-year average. The steers full-fed in Phase II (HH and MH) were given more favorable scores for finish, refinement and grade than the other two treatment groups, but the only trend noticeable among the seven conformation scores is that the HH group appeared slightly more desirable than the MM group. Adjustment of the data was of no benefit in establishing a pattern, which may indicate that one of the assumptions made prior to this adjustment, namely that each grader was consistent in his own standard, was not valid. Several of the graders commented that consistency was difficult when observing only one or two animals at a time, particularly within the relatively narrow grade range of these cattle.

A number of significant differences in favor of the HH and MH treatments were obtained in Trial I, but there were no highly significant differences in Trials II and III. In Trial III, the HM regime resulted in generally more favorable scores than the MH treatment. After adjustment, the two groups appeared more nearly equal in terms of the variables used. The discrepancies between trials may serve to illustrate the sampling error and natural variation common to biological material, and

TABLE VI

LIVE ANIMAL EVALUATION SCORES
(AV. OF TRIALS I, II AND III)[a,b]

Treatment Group	HH Actual	HH Adj.[c]	HM Actual	HM Adj.[c]	MH Actual	MH Adj.[c]	MM Actual	MM Adj.[c]
Conformation								
Compactness	17.8	18.3	18.5	19.0	19.1	19.1	19.4	19.1
Width of body	17.4	18.6	18.1	19.6	18.0	17.9	18.6	18.4
Crops	17.8	18.9	18.9	20.8	18.1	19.4	19.0	18.9
Loin	17.3	18.2	17.5	19.5	16.9	16.9	18.0	17.7
Rump	18.3	18.5	17.6	19.6	18.3	18.1	18.7	18.9
Quarter	18.9	20.2	18.8	20.4	18.8	19.2	19.2	19.6
Muscling	17.4	18.4	18.0	18.9	17.6	18.0	17.9	17.9
Finish								
Thickness of fat	17.0	17.9	18.2	18.8	17.3	17.8	18.0	17.1
Smoothness	15.3[d]	16.4	17.1	15.8	14.1[d]	14.7	17.3	17.1
Quality								
Refinement	16.3	17.0	17.9	17.1	16.1	16.5	17.7	18.4
Live slaughter grade	14.8[e]	15.5	16.3	17.0	15.2[e]	15.2	16.2	15.8

[a]Corresponding values for individual trials are presented in Tables XXVI through XXVIII, Appendix B.

[b]14 = High Good; 16 = Av. Good; 18 = Low Good; 20 = High Standard.

[c]Actual scores were adjusted as indicated in Appendix A.

[d](HH + MH) significantly different from (HM + MM) at $P \simeq 0.10$.

[e](HH + MH) significantly different from (HM + MM) at $P \simeq 0.12$.

particularly to the small groups of cattle used.

The subjective live animal scores for the fourth trial are presented in Table VII. The full-fed steers (H) recieved the most desirable ratings for the majority of the variables shown, and the MI group was rated as inferior to the MII cattle for all scores except "refinement." The latter score may reflect age differences, as the MII steers were approximately two months older. The adjusted values, although higher, do not alter the above trends.

The literature on subjective live animal scores appears rather limited. Ternan et al. (1959) concluded that the use of one overall score provided as adequate an evaluation of conformation as did consideration of all the individual items on the grading card. Orme et al. (1959) reported that linear carcass measurements could be predicted more accurately from live animal measurements than from subjective scores. Since Hendrickson (1961) obtained few significant differences among treatments using objective live animal measurements, it is not surprising that subjective scores (which may be even less reliable) generally did not reveal marked treatment differences in these trials.

Carcass evaluation scores. -- The average carcass evaluation scores, actual and adjusted, for the first three trials are presented in Table VIII. Corresponding values obtained in each trial are shown in Tables XXIX, XXX and XXXI, Appendix B. The data indicate a tendency to rate the HH and HM treatments as more desirable than the other two groups. This is a somewhat different trend than observed for on-foot scores, where HH and MH treatments tended to grade higher. The adjusted values do not appear to alter this pattern appreciably.

Of particular interest are the marbling scores, which are highly

TABLE VII

LIVE ANIMAL EVALUATION SCORES (TRIAL IV)[a]

Treatment Group	High (H)		Moderate I (MI)		Moderate II (MII)	
	Actual	Adj.[b]	Actual	Adj.[b]	Actual	Adj.[b]
Conformation						
Compactness	17.9	19.6	20.1	21.9	17.8	19.8
Width of body	17.8[c]	19.4	21.9[d]	24.1	19.0	20.4
Crops	17.0[e]	18.5	21.9	23.9	20.3	20.9
Loin	17.0[e]	18.5	21.7	24.2	19.0	21.1
Rump	17.7[e]	19.9	22.1	25.2	19.8	21.5
Quarter	18.6[f]	21.0	23.1[g]	26.2	20.1	22.5
Muscling	17.9[f]	20.2	21.8[h]	24.6	18.8	20.4
Finish						
Thickness of fat	17.6[i]	19.5	22.5	25.3	20.1	22.5
Smoothness	14.4	15.4	16.3	16.8	14.8	16.6
Quality						
Refinement	15.9	16.9	15.8	16.2	17.1	17.6
Live slaughter grade	16.4[j]	16.5	20.7[k]	21.0	17.9	18.3

[a]14 = High Good; 16 = Av. Good; 18 = Low Good; ... ; 26 = High Utility.

[b]Actual scores were adjusted as indicated in Appendix A.

[c]H significantly different from (MI + MII) at $P \simeq 0.06$.

[d]MI significantly different from MII at $P \simeq 0.08$.

[e]H significantly different from (MI + MII) at $P < 0.05$.

[f]H significantly different from (MI + MII) at $P \simeq 0.08$.

[g]MI significantly different from MII at $P \simeq 0.10$.

[h]MI significantly different from MII at $P \simeq 0.07$.

[i]H significantly different from (MI + MII) at $P \simeq 0.025$.

[j]H significantly different from (MI + MII) at $P \simeq 0.01$.

[k]MI significantly different from MII at $P < 0.025$.

TABLE VIII

CARCASS EVALUATION SCORES[a,b]
(AV. OF TRIALS I, II AND III)

Treatment Group	HH		HM		MH		MM	
	Actual	Adj.[c]	Actual	Adj.[c]	Actual	Adj.[c]	Actual	Adj.[c]
Conformation								
Compactness	16.5[d]	16.7	16.6[d]	16.2	17.5	17.3	18.7	18.1
Thickness	16.0	16.3	16.7	16.6	16.6	17.4	17.8	17.4
Rib eye (lean)	16.2	17.2	15.1	15.2	16.6	17.0	16.9	16.8
Loin	16.0	16.6	16.1	16.1	17.0	18.1	17.3	17.4
Round	17.2	17.0	16.2	15.8	17.1	17.9	17.5	16.1
Finish								
Fat thickness	16.5[d]	16.7	17.2[d]	18.3	17.9	18.5	18.1	17.5
Distribution (external)	16.0	15.9	16.3	16.7	15.9	16.5	17.5	17.1
Kidney knob	17.2	17.8	17.8	19.2	18.0	18.4	18.3	19.8
Marbling (rib eye)	16.8[e]	17.6	16.7[e]	18.7	20.2	20.9	21.0	20.5
Quality								
Grain of lean	14.8[f]	15.7	14.4[f]	15.4	15.9	16.6	17.0	17.1
Firmness of lean	13.8[g]	13.1	14.2[g]	15.3	15.1	15.6	15.8	15.3
Color of lean	15.5[h]	15.8	14.6[h]	16.5	17.4	18.0	17.9	16.9
Color of fat	12.2[g]	12.3	12.4[g]	14.1	13.5	14.2	12.5	14.7
Carcass grade	14.2[f,i]	14.9	15.2[f]	15.6	15.6[i]	16.0	17.3	16.7

[a]Corresponding values for individual trials are presented in Tables XXIX through XXXI, Appendix B.

[b]12 = Low Choice; 14 = High Good; 16 = Av. Good; ··· ; 22 = Av. Standard.

[c]Actual scores were adjusted as indicated in Appendix A.

[d](HH + HM) significantly different from (MH + MM) at $P \simeq 0.06$.

[e](HH + HM) significantly different from (MH + MM) at $P \ll 0.001$.

[f](HH + HM) significantly different from (MH + MM) at $P < 0.025$.

[g](HH + HM) significantly different from (MH + MM) at $P \simeq 0.10$.

[h](HH + HM) significantly different from (MH + MM) at $P < 0.01$.

[i](HH + MH) significantly different from (HM + MM) at $P \simeq 0.08$.

correlated with carcass grade (Wheat and Holland, 1960). These favor the HH and HM regimes and represent the most significant differences obtained in each trial. However, the adjusted marbling scores and carcass grades in Trial I suggest that the actual values may not be realistic. These results lend further support to the evidence presented by McMeekan (1940b, 1940c), Palsson and Verges (1952b) and Merkel et al. (1958) which indicates that age, as well as plane of nutrition, may influence the amount of intramuscular fat. Age differences were considerably less in Trial I than in Trials II and III.

Carcass scores should be more effective than live animal scores in detecting treatment differences, since the former were established under much more uniform conditions. This is borne out by the greater number of significant differences obtained among the variables studied; however, none of these differences were large. Carcass grade ranged from High Good (HH group) to Low to Average Good (MM group), representing only one-half of a grade difference between the treatment extremes.

The subjective carcass scores for Trial IV are presented in Table IX. Carcasses from full-fed steers (H) appeared to have superior conformation, as indicated by all five conformation scores, and more external fat than the moderate groups. The lighter weight steers (MI) were generally inferior to the MII cattle. Carcass grades were significantly different and reflected the pattern evident with most of the other variables. In this trial, subjective scores on the live animal and carcass showed essentially the same trends, which merely indicates the ability of graders to detect larger differences than existed in the earlier tests.

The effect of age on marbling, discussed previously, is especially

TABLE IX

CARCASS EVALUATION SCORES (TRIAL IV)[a]

Treatment Group	High (H)		Moderate I (MI)		Moderate II (MII)	
	Actual	Adj.[b]	Actual	Adj.[b]	Actual	Adj.[b]
Conformation						
Compactness	17.4[c]	17.8	19.9	20.1	18.3	19.3
Thickness	16.6[d]	17.0	21.1[e]	21.6	18.6	18.9
Rib eye (lean)	14.9[d]	15.1	19.7	19.9	17.8	16.2
Loin	16.2[d]	16.4	20.6[e]	21.2	18.1	18.0
Round	16.8[f]	17.2	21.0	22.1	18.8	18.8
Finish						
Fat thickness	17.6[d]	18.2	23.9[g]	25.0	19.4	22.1
Distribution (external)	15.5	16.5	16.1	16.7	15.9	15.6
Kidney knob	18.5[f]	19.5	22.5[g]	24.1	19.1	22.0
Marbling (rib eye)	19.0	20.2	24.4[h]	26.4	19.3	19.3
Quality						
Grain of lean	15.7	16.1	17.9[g]	18.3	14.5	16.3
Firmness of lean	15.7	16.0	18.6	18.4	16.1	15.6
Color of lean	16.1[c]	16.3	20.7[h]	21.0	16.6	19.0
Color of fat	14.4	14.7	16.1	16.6	14.6	17.6
Carcass grade	16.7[d]	16.7	21.0[h]	21.1	18.2	17.4

[a]14 = High Good; 16 = Av. Good; 18 = Low Good; ••• ; 26 = High Utility.

[b]Actual scores were adjusted as indicated in Appendix A.

[c]H significantly different from (MI + MII) at $P \simeq 0.10$.

[d]H significantly different from (MI + MII) at $P < 0.025$.

[e]MI significantly different from MII at $P \simeq 0.06$.

[f]H significantly different from (MI + MII) at $P < 0.05$.

[g]MI significantly different from MII at $P < 0.025$.

[h]MI significantly different from MII at $P < 0.05$.

evident in Trial IV, where it appears that the increased marbling resulting from full-feeding could also be obtained by moderately-fed cattle permitted to remain on feed 65 days longer, or until total feedlot gains equaled those of steers on the High regime.

Slaughter Floor Data

The average values for Trials I, II and III for hide, "fill," internal fat, and yield, all expressed as a percentage of live weight, are presented in Table X. Corresponding values for individual trials may be found in Table XXXII, Appendix B. Data for the fourth trial are also included in Table X.

Cattle full-fed in Phase II yielded a significantly lower percentage of hide than did steers subjected to HM and MM treatments. The same trend was evident in Trial IV, and probably reflects the relative finish or condition of the steers. Callow (1961) observed this pattern with older steers, using similar treatment comparisons.

Percent "fill," as estimated by the contents of the ruminant stomach, was significantly less for the HH and MH groups in Trial I, but varied from year to year, and the three-year average does not reveal significant differences among treatments. For this reason, "fill" was not estimated in Trial IV.

An estimate of internal fat was included in the data collected after the first trial, in an attempt to obtain some indication of the amount of fat produced having little practical value. Moulton _et al._ (1923) and Trowbridge _et al._ (1919) reported that much of the increase in fat in older cattle was deposited around the internal organs. As expected, steers full-fed in Phase II had larger amounts of internal fat in the second trial. In Trial II, however, smaller but statistically significant differences, were obtained for another set of comparisons (HH + HM > MH + MM). The large treatment by year interaction prevented significant differences among the averages shown in Table X, although the values reflect the expected trend, as do the percentages observed in Trial IV.

Yield or dressing percentage, based on 48-hour chilled carcass weights, was similar for all treatments in the three-year average, although HH and MH regimes resulted in higher yields in Trial I. The average yield of steers in the MI group was lower than for steers allowed to gain approximately 80 pounds more (H and MII regimes). These effects were expected, since many other investigators (Brugman, 1950; Lucas et al., 1960; Guilbert et al., 1944; Winchester et al., 1957) were unable to detect differences in yield with swine and cattle. Lower dressing percentages were obtained with sheep, however, by Weber et al. (1931) and Palsson and Verges (1952a, 1952b) on restricted or low planes of nutrition. In general, use of extreme nutritional regimes produces marked differences in yield, whereas little or no effect may be observed when more practical treatments are employed.

In Trial IV, the right front cannon bone was measured to determine if differences in bone development could be detected. The treatment means were found to be nearly identical. This should be expected, since Waters (1908) demonstrated the priority for skeletal growth, which continued even when steers were subjected to submaintenance rations.

Other data collected at time of slaughter included weights of the heart, pluck, liver and hanging tender. It is believed that trimming errors on these items exceeded any probable treatment differences, and

TABLE X

SLAUGHTER FLOOR DATA

Treatment Group	Trials I, II and III (Av.)[a]				Trial IV		
	HH	HM	MH	MM	High (H)	Moderate I (MI)	Moderate II (MII)
Percent							
Hide	8.6[b]	8.9	8.5[b]	9.1	8.6[c]	9.4	9.1
"Fill"[d]	6.0	6.0	6.6	6.7	----	---	---
Internal fat[e]	2.3	1.8	2.1	1.5	1.6	1.3	1.4
Yield	61.0	60.7	60.3	60.7	58.8	56.6[f]	59.0
Cannon bone meas. (in.)							
Width	----	----	----	----	1.58	1.55	1.58
Length	----	----	----	----	7.86	7.82	7.84

[a]Corresponding values for individual trials are presented in Table XXXII, Appendix B.

[b](HH + MH) significantly different from (HM + MM) at $P < 0.05$.

[c]H significantly different from (MI + MII) at $P \simeq 0.07$.

[d]Estimated by weighing contents of the ruminant stomach.

[e]Includes easily removable fat from the stomach and pelvic cavity. No estimate was obtained in Trial I.

[f]MI significantly different from MII at $P < 0.05$.

therefore they are not reported.

Yield of Wholesale Cuts

Average percentages of wholesale cuts obtained in the first three trials and in Trial IV are presented in Table XI. Corresponding values for Trials I, II and III are shown in Tables XXXIII, XXXIV and XXXV, respectively, Appendix B. The three-year average (Table XI) reveals that carcasses from steers full-fed in Phase II (HH and MH) yielded lower percentages of round, shank and major cuts and higher percentages of flank, plate, cheap cuts and wasty cuts. A slightly higher percentage of kidney knob was also observed for these groups, while brisket values were higher for cattle from the HH and HM regimes. No appreciable treatment differences were noted among the remaining cuts. The smaller cuts, such as brisket and shank, were probably subject to more cutting error.

Fewer significant differences were obtained in the separate trials, although the percentage of round reflected the three-year average in each test, as did the percentages of major cuts, cheap cuts and wasty cuts in Trials I and II. There were no important discrepancies between trials.

In the fourth trial, carcasses of full-fed steers yielded higher percentages of flank, plate and wasty cuts and lower percentages of round, shank and major cuts than the two moderate groups. The younger, lighter weight cattle (MI) tended to have lower percentages of fat cuts and higher percentages of lean cuts than the other moderate group (MII), but the only significant increase was in percentage of round.

It is readily seen that steers fed to gain rapidly in the finishing phase produced small but consistent increases in the cheaper and fatter

TABLE XI

YIELD OF WHOLESALE CUTS (%)

	Trials I, II and III (Av.)[a]				Trial IV		
Treatment Group	HH	HM	MH	MM	High (H)	Moderate I (MI)	Moderate II (MII)
Wholesale cuts							
Round	17.7[b]	18.5	17.8[b]	18.8	18.5[c]	19.8[d]	19.0
Rump	5.7	5.7	5.9	5.6	6.1[e]	5.9	5.8
Loin	14.4	14.4	14.6	14.4	13.5	14.0	13.9
Flank	6.9[f]	6.6	6.9[f]	6.4	7.0[g]	6.0	6.5
Kidney knob	3.2	2.8	3.0	2.9	2.8	2.4	2.6
Chuck	25.8	25.4	25.7	26.1	25.2	25.3	25.7
Rib	8.0	8.1	8.0	8.0	8.1	8.0	8.0
Plate	8.8[h]	8.3	8.4[h]	8.1	8.7[g]	8.2	8.1
Brisket	5.1[i]	5.3[i]	5.0	4.9	5.3	5.3	5.4
Shank	4.4[h]	4.6	4.5[h]	4.6	4.7[j]	5.3	5.1
Hind quarter	47.9	48.0	48.1	48.1	47.9	48.1	47.8
Fore quarter	52.1	51.7	51.6	51.7	52.0	52.1	52.3
Major cuts[k]	71.6[h]	72.1	72.0[h]	72.9	71.4[e]	73.0	72.4
Cheap cuts[l]	28.4[f]	27.6	27.8[f]	26.9	28.5	27.2	27.7
Wasty cuts[m]	24.0[n]	23.0	23.3[n]	22.3	23.8[g]	21.9	22.6

[a] Corresponding values for individual trials are presented in Tables XXXIII through XXXV, Appendix B.

[b] (HH + MH) significantly different from (HM + MM) at $P < 0.001$.

[c] H significantly different from (MI + MII) at $P < 0.025$.

[d] MI significantly different from MII at $P < 0.05$.

[e] H significantly different from (MI + MII) at $P \simeq 0.10$.

[f] (MH + MH) significantly different from (HM + MM) at $P \simeq 0.07$.

TABLE XI (Continued)

[g]H is significantly different from (MI + MII) at $P < 0.05$.

[h](HH + MH) significantly different from (HM + MM) at $P \simeq 0.10$.

[i](HH + HM) significantly different from (MH + MM) at $P \simeq 0.08$.

[j]H is significantly different from (MI + MII) at $P \simeq 0.08$.

[k]Includes round, rump, loin, chuck and rib.

[l]Includes flank, kidney knob, plate, brisket and shank.

[m]Includes flank, kidney knob, plate and brisket.

[n](HH + MH) significantly different from (HM + MM) at $P < 0.05$.

cuts, compared with moderately-fed cattle. This trend was more pronounced when high and moderate groups were fed for the same length of time (MI) than when fed for the same total feedlot gain (MII). These results are in agreement with studies by Goll et al. (1961) which indicate that percentage of round tends to be influenced more by differences in carcass grade than the other wholesale cuts. The percentage of major cuts was also markedly affected. Butler (1957) noted only small differences in wholesale cutout despite wide variation in experimental material. Considering the relatively narrow range in carcass grades reported in a previous section, it is not surprising that large differences in yields of wholesale cuts were not obtained. Insofar as percentages of major and wasty cuts reflect carcass composition, the results parallel those observed by McMeekan (1940b, 1940c) and Palsson and Verges (1952b), who reported that the major differences among treatments could be attributed to the nutritional plane imposed in the second half of the fattening period.

Specific Gravity Determinations

Specific gravity readings are presented as averages of the first three trials in Table XII, which also contains the readings obtained in Trial IV. Corresponding values for Trials I, II and III may be found in Table XXXVI, Appendix B. Density readings recorded for the five major wholesale cuts were lowest for the HH group and highest for the MM group, without exception, in each of the three trials. Significantly lower relative densities were obtained on cuts from steers full-fed in Phase II (HH and MH) for all comparisons, except round and rump in Trial III, at $P < 0.10$. In addition, lower values were observed for HH and HM

TABLE XII

SPECIFIC GRAVITY DETERMINATIONS

Treatment Group	Trials I, II and III (Av.)[a]				Trial IV		
	HH	HM	MH	MM	High (H)	Moderate I (MI)	Moderate II (MII)
Wholesale cuts							
Round	1.079[b,c]	1.082[b]	1.082[c]	1.087	1.084[d]	1.090	1.091
Rump	1.057[e,f]	1.063[e]	1.062[f]	1.071	1.064[d]	1.072	1.076
Loin	1.047[g,h]	1.055[g]	1.051[h]	1.062	1.058[d]	1.065	1.065
Chuck	1.061[g,i]	1.068[g]	1.066[i]	1.073	1.067[j]	1.075	1.077
Rib	1.058[g,h]	1.068[g]	1.063[h]	1.074	1.065[d]	1.078	1.076
Average (5 cuts)	1.062[g,f]	1.068[g]	1.066[f]	1.074	1.069[k]	1.078	1.078

[a] Corresponding values for individual trials are presented in Table XXXVI, Appendix B.
[b] (HH + HM) significantly different from (MH + MM) at $P \simeq 0.06$.
[c] (HH + MH) significantly different from (HM + MM) at $P \simeq 0.08$.
[d] H significantly different from (MI + MII) at $P < 0.025$.
[e] (HH + HM) significantly different from (MH + MM) at $P < 0.025$.
[f] (HH + MH) significantly different from (HM + MM) at $P < 0.01$.
[g] (HH + HM) significantly different from (MH + MM) at $P < 0.05$.
[h] (HH + MH) significantly different from (HM + MM) at $P < 0.005$.
[i] (HH + MH) significantly different from (HM + MM) at $P < 0.025$.
[j] H significantly different from (MI + MII) at $P < 0.001$.
[k] H significantly different from (MI + MII) at $P < 0.005$.

treatments for all cuts in Trial III and in the three-year average, and for rib in Trial II ($P < 0.10$). As indicated in the tables, most of the above differences were highly significant.

In Trial IV, cuts from high plane steers had lower relative densities than those from the moderately-fed cattle ($P < 0.025$), as expected, but the differences between the two moderate groups were negligible.

It is obvious that specific gravity determinations were of much greater value in detecting treatment differences than were the measurements reported in previous sections. Of the cuts studied, the wholesale rib appeared to be more useful than the round or rump in this regard. Kraybill _et al._ (1952) suggested that the 9-10-11th rib cut could be used to estimate specific gravity of the entire carcass, and Meyer _et al._ (1960) proposed that specific gravity determinations could be used to obtain economical and reliable estimates of percent carcass fat.

The trends observed among treatments in relative densities are similar to, but more pronounced than, those noted for wholesale cut yields, and provide additional support for the contention that carcass differences are due more to the plane of nutrition imposed in Phase II than in Phase I.

Rib Eye Measurements

Average rib eye measurements obtained in the first three trials are presented in Table XIII. Corresponding values for the individual trials are shown in Table XXXVII, Appendix B. Few significant differences were observed, although cross-sectional length and rib eye area tended to be least for the HH group and greatest in the case of the MM regime. The opposite tendency was noted for width of external fat, with

TABLE XIII

RIB EYE MEASUREMENTS (12th RIB)

Treatment Group	Trials I, II and III (Av.)[a]				Trial IV		
	HH	HM	MH	MM	High (H)	Moderate I (MI)	Moderate II (MII)
Rib eye							
Av. width (cm.)	5.5	5.3	5.3	5.6	5.5	5.0[b]	5.4
Length (cm.)	12.8[c,d]	13.0[c]	13.0[d]	13.6	13.6	13.4	13.3
Width x length ($cm.^2$)	69.8	69.7	69.0	76.1	75.8	66.7	72.4
Area ($in.^2$)	9.39	9.47	9.20	10.01	10.13	8.99	9.66
Av. width external fat (cm.)	1.07	0.97	0.96	0.85	0.76[e]	0.48[f]	0.65

[a]Corresponding values for individual trials are presented in Table XXXVII, Appendix B.

[b]MI significantly different from MII at $P \simeq 0.08$.

[c](HH + HM) significantly different from (MH + MM) at $P < 0.05$.

[d](HH + MH) significantly different from (MH + MM) at $P < 0.025$.

[e]H significantly different from (MI + MII) at $P = 0.025$.

[f]MI significantly different from MII at $P \simeq 0.07$.

HM and MH treatments resulting in intermediate values. No consistent trend was evident for width measurements, or for width x length dimensions.

HH and MH groups had significantly more external fat in Trial I, and significantly smaller rib eyes in Trial III, as estimated by width, length, width x length, or area measurements. However, all other comparisons within each trial were nonsignificant. Variation in response from year to year was evident, and the reasons for discrepancies such as the extremely low value for width of external fat observed for the MH group in Trial III are not apparent. Errors in measurement or a poor sample of experimental material may have been responsible.

In Trial IV (Table XIII), the MI treatment tended to produce smaller rib eyes and less external fat than the MII regime. This might be expected since the former steers weighed approximately 80 pounds less at time of slaughter. High and Moderate II treatments were more nearly comparable in measures obtained for size of rib eye, although the full-fed steers tended to have more external fat.

Insofar as rib eye measurements are indicators of carcass lean, these results suggest that moderately different nutritional planes do not appreciably influence lean development when steers are allowed to attain equal feedlot gains, but that steers gaining at moderate rates may not produce as much lean tissue as full-fed steers when removed from test at the same time and slaughtered at the same age. However, Cole and associates (1960b) reported that only 18 percent of the variation in total carcass lean could be accounted for by rib eye area determinations.

Physical Separation Data

The results of physical separation of the 9-10-11th rib cut, expressed as the average of three trials, are shown in Table XIV. Corresponding values for the individual trials are presented in Table XXXVIII, Appendix B. HH and MH regimes produced carcasses containing a calculated average of 2.8 percent less lean, 4.0 percent more fat and 0.8 percent less bone than those from HM and MM treatments. Differences in lean and fat were significant at $P < 0.01$, and differences in bone at $P < 0.05$, whether actual or calculated percentages were used.

These trends agree well with those obtained from wholesale cutout and specific gravity data, and are further substantiated by the studies of McMeekan (1940b, 1940c) and Palsson and Verges (1952a, 1952b). As mentioned previously, the plane of nutrition imposed in the latter part of the feeding period appears to dictate the major differences observed in carcass composition, although this effect was not obtained in Trial III in this study. Percent fat was influenced the most, and percent bone the least, by nutritional plane, which serves to illustrate the different priorities of body tissues for nutrients first reported by Waters (1908).

In Trial IV (Table XIV), full-fed steers produced carcasses containing more fat and less bone, but only slightly less lean, than those from the two moderate treatments. Carcasses from the MI group were lower in percent fat, and higher in percent lean and bone, than those from the MII group, although the differences were small and not statistically significant. Wholesale cutout and relative density determinations discussed previously show the same general trends. However, percentages do not reveal differences in actual weight of the carcass or its components.

TABLE XIV

PHYSICAL SEPARATION DATA (9-10-11th RIB)

Treatment Group	Trials I, II and III (Av.)[a]				Trial IV		
	HH	HM	MH	MM	High (H)	Moderate I (MI)	Moderate II (MII)
9-10-11th rib composition (%)							
Lean	49.7[b,c]	53.0[b]	51.5[c]	55.2	55.3	57.8	56.3
Fat	35.1[c]	29.9	32.5[c]	28.0	28.8[d]	23.8	25.8
Bone	14.5[e]	16.4	15.4[e]	16.1	15.7[d]	17.9	17.3
Carcass composition (%)[f]							
Lean	55.8[b,c]	58.4[b]	57.3[c]	60.3	60.3	62.3	61.1
Fat	31.9[c]	27.4	29.5[c]	25.9	26.6[d]	22.6	24.2
Bone	13.8[e]	14.9	14.3[e]	14.7	14.5[d]	15.7	15.4

[a]Corresponding values for individual trials are presented in Table XXXVIII, Appendix B.

[b](HH + HM) significantly different from (MH + MM) at $P \simeq 0.06$.

[c](HH + MH) significantly different from (HM + MM) at $P < 0.01$.

[d]H significantly different from (MI + MII) at $P < 0.05$.

[e](HH + MH) significantly different from (HM + MM) at $P < 0.05$.

[f]Calculated from 9-10-11th rib data using equations of Hankins and Howe (1946).

While the MI group had the highest percentage of lean, total carcass lean was actually least for this group due to differences in feedlot gains and slaughter weight, as will be discussed later.

Chemical Analysis of Lean Tissue

Samples of Longissimus dorsi and Semimembranosus muscles were subjected to proximate chemical analysis and the averages obtained for the series of three trials are presented in Table XV. Corresponding values for each trial are shown in Table XXXIX, Appendix B. Differences among treatments were quite variable; however, significantly more ether extract was observed for the HH and HM groups. The marbling scores reported earlier revealed a similar pattern. Percent moisture tended to vary inversely with ether extract, while no definite trends were established for ash and protein. The reason for significantly more ash in L. dorsi samples from HH and MH groups in the three-year average is not apparent.

Only L. dorsi samples were analyzed in Trial IV (Table XV). Samples from the carcasses of full-fed cattle contained more ether extract ($P < 0.05$) and slightly less moisture than those from the other groups. Protein and ash appeared to be relatively unaffected by treatment.

A major problem in obtaining reliable chemical analysis data is in getting representative samples. It seems logical that sampling error could easily mask or distort small treatment differences. This should be particularly true where relatively low-grading cattle are involved, since differences in intramuscular fat would likely be minimal in such instances.

Palsson and Verges (1952b) found that age had more influence than plane of nutrition on marbling of the eye muscle. This could explain

TABLE XV

CHEMICAL ANALYSIS OF LEAN TISSUE

Treatment Group	Trials I, II and III (Av.)[a]				Trial IV		
	HH	HM	MH	MM	High (H)	Moderate I (MI)	Moderate II (MII)
Longissimus dorsi (%)							
Moisture	71.04[b,c]	71.38[b]	71.69[c]	72.53	73.49	74.01	74.11
Protein[d]	21.91	21.42	21.80	21.91	21.42	21.49	21.14
Ether extract	4.46[e]	4.71[e]	4.16	3.35	3.74[f]	2.28	2.84
Ash	1.12[c]	1.08	1.11[c]	1.10	1.12	1.13	1.16
Semimembranosus (%)							
Moisture	70.72[g]	71.30[g]	71.87	71.24	-----	-----	
Protein[d]	22.01	21.68	22.16	22.07			-----
Ether extract	3.94[e]	3.80[e]	3.32	3.33	-----		
Ash	1.10	1.07	1.10	1.10			-----

[a]Corresponding values for individual trials are presented in Table XXXIX, Appendix B.

[b](HH + HM) significantly different from (MH + MM) at $P < 0.05$.

[c](HH + MH) significantly different from (HM + MM) at $P < 0.05$.

[d](HH + HM) vs. (MH + MM), (HH + MH) vs. (HM + MM) and (HH + MM) vs. (HM + MH) all significantly different at $P < 0.10$.

[e](HH + HM) significantly different from (MH + MM) at $P < 0.025$.

[f]H significantly different from (MI + MII) at $P < 0.05$.

[g](HH + HM) significantly different from (MH + MM) at $P \simeq 0.10$.

the higher ether extract values observed for the HM group than for the opposite (MH) regime.

Shear Values and Organoleptic Data

Shear values and organoleptic scores are summarized in Table XVI. Corresponding data for Trials I, II and III are presented in Table XL, Appendix B. Except for slightly lower shear values for cooked rib steak in Trial II, none of the comparisons approached statistical significance. Apparently, errors inherent in the techniques used produced far more variation than resulted from any treatment differences, since "F" values obtained in the variance analyses were often less than 1.00. Christians (1962) reported that the cooking procedure introduced considerable variation. Cole _et al_. (1960a) observed significant differences in shear values and taste panel data, as have many other investigators, but only when steaks used represented a fairly wide range in carcass grade; even so, differences were often small.

The shear values obtained in Trial IV (Table XVI) reveal a logical trend; as carcass grade decreased, tenderness also decreased. However, differences in shear value did not approach significance.

Efficiency on a Carcass Basis

Average efficiency values, expressed on the basis of carcass composition, were calculated from data obtained during the first three trials and are presented in Table XVII. Corresponding data for individual trials are presented in Tables XLI, XLII and XLIII, Appendix B.

Total carcass lean and fat were calculated by multiplying carcass weight by the estimated carcass percentages of lean and fat shown in Tables XIV and XXXVIII. Steers full-fed in Phase II (HH and MH regimes)

TABLE XVI

SHEAR VALUES AND ORGANOLEPTIC DATA

Treatment Group	Trials I, II and III (Av.)[a]				Trial IV		
	HH	HM	MH	MM	High (H)	Moderate I (MI)	Moderate II (MII)
Av. shear values (lb.)							
12th rib steak	16.79	15.82	16.53	16.82	13.88	18.22	15.75
Top round steak	15.19	15.43	16.02	15.07	-----	-----	-----
Organoleptic scores							
Tenderness	6.54	6.11	6.55	6.43	-----	-----	-----
No. of chews	21.7	23.5	21.8	22.7			
Juiciness	6.52	6.09	6.45	6.45	-----	-----	-----

[a]Corresponding values for individual trials are presented in Table XI, Appendix B.

TABLE XVII

EFFICIENCY ON A CARCASS BASIS

Treatment Group	Trials I, II and III (Av.)[a]				Trial IV		
	HH	HM	MH	MM	High (H)	Moderate I (MI)	Moderate II (MII)
Total carcass lean (lb.)[b]	295.1[c,d]	300.2[c]	296.0[d]	317.6	297.1	266.5[e]	299.8
Total carcass fat (lb.)	168.7[f]	141.4	153.6[f]	137.3	131.9[g]	96.4[e]	119.0
Lb. TDN/lb. of gain[h]							
Carcass	10.8	11.2	10.3	10.6	12.2	13.3	12.7
Fat and lean	11.7	12.6	11.3	11.8	13.4[g]	15.1	14.9
Lean	22.4[i,d]	21.0[i]	20.1[d]	18.5	21.2	21.1	21.8
Therms NE/lb. of gain[h]							
Carcass	10.0[j]	10.0[j]	9.4	9.3	11.5	11.8	11.3
Fat and lean	10.9[j]	11.3[j]	10.3	10.4	12.6	13.5	13.3
Lean	20.8[k,d]	18.9[k]	18.3[d]	16.2	19.9	19.7	19.6
Cal. feed/cal. fat and lean[h]	12.3[f]	14.4	12.6[f]	14.1	15.8[l]	19.6	18.6
Lb. crude protein/lb. Carcass protein[h]	17.2[i]	17.0[i]	15.8	14.9	17.2[g]	18.5	18.5

[a]Corresponding values for individual trials are presented in Tables XLI through XLIII, Appendix B.

[b]Calculated from 9-10-11th rib physical separation data (Hankins and Howe, 1946).

[c](HH + HM) significantly different from (MH + MM) at $P \simeq 0.10$.

[d](HH + MH) significantly different from (HM + MM) at $P < 0.05$.

[e]MI significantly different from MII at $P < 0.05$.

[f](HH + MH) significantly different from (HM + MM) at $P < 0.025$.

[g]H significantly different from (MI + MII) at $P < 0.025$.

TABLE XVII (Continued)

[h]Calculated using 9,367 kcal./kg. fat (Blaxter and Rook, 1953), 5.686 kcal./kg. protein, 21.64 percent protein on fat-free basis (Reid *et al*., 1955) and 1,982 kcal./lb. TDN (Swift, 1957). Theoretical initial yield (56%), lean (63%) and fat (20%) were used.

[i](HH + HM) significantly different from (MH + MM) at $P < 0.025$.

[j](HH + HM) significantly different from (MH + MM) at $P < 0.05$.

[k](HH + HM) significantly different from (MH + MM) at $P < 0.005$.

[l]H significantly different from (MI + MII) at $P < 0.01$.

yielded carcasses containing significantly more total fat and less lean. This effect was pronounced in Trials I and II, but not in Trial III.

Since none of the cattle were slaughtered at the beginning of the feedlot tests, estimates of initial carcass composition were not available. Carcass composition was assumed to be similar for all groups at this time. Theoretical initial values for pounds of carcass lean and fat were calculated by assuming an average yield of 56 percent and average carcass composition of 63 percent lean and 20 percent fat for each treatment group. These values approximate those obtained in subsequent studies and should be satisfactory for comparative purposes. Efficiencies obtained by their use should also be more realistic than using total carcass fat and lean, with no correction for initial compositions.

The three-year average for Trials I, II and III (Table XVII) showed that efficiencies were generally improved according to the treatment order HM, HH, MM and MH when measured as pounds of TDN, or therms of net energy, required per pound increase in carcass weight, or in weight of fat and lean tissue. Since TDN is known to over-estimate the value of roughages for productive purposes, the net energy values may be more reliable. In the latter comparisons, MM and MH regimes resulted in significantly more efficient feed conversion ($P < 0.05$).

By converting both ration and carcass components to calories, efficiency ratios expressed in the same units can be obtained. The conversion factors used (Table XVII) permit determination of the calories of "digestible energy" in the ration required per calorie of edible meat (fat and lean) produced. This procedure gives additional credit to rations which result in production of carcasses higher in fat content. However, this credit may not be justified in studies where the amount of fat deposited is in excess of that required for a product of acceptable quality. In the present study, steers full-fed in Phase II (HH and MH) needed 12.6 percent less feed calories per calorie of fat and lean, than cattle subjected to HM and MM regimes ($P < 0.025$).

One of the objectives of this study was to determine the feeding regimes which would result in the conversion of feed nutrients to lean meat most efficiently. Expressed as either pounds of TDN or therms of net energy required per pound of increase in lean tissue, the efficiency of conversion increased in the treatment order HH, HM, MH and MM. The same trend was noted for pounds of crude protein needed to produce a pound of carcass protein; MH and MM groups were more efficient than steers subjected to HH and HM regimes ($P < 0.025$).

The preceding discussion illustrates how efficiency rankings of the four treatments vary, depending on the method of measurement. However, regardless of the criteria used, the values obtained for the average of three trials (Table XVII) indicate an interesting overall trend. The HM regime always ranked as one of the two least efficient treatments, while the opposite regime (MH) ranked first or second in efficiency of feed conversion in every comparison. Most of the carcass data reported earlier indicate that carcass composition and quality were similar for these two treatments. In view of these findings, the MH feeding regime appears decidedly superior to the HM treatment. Increased maintenance requirements in Phase II may have contributed to the relatively poor performance of the latter group. Other treatment comparisons may not be valid because of greater differences in carcass characteristics.

No literature has been found to support or contradict these efficiency patterns since, in most studies, efficiency comparisons have been based on live weight gains. Species differences may exist, since McMeekan (1940c) reported that the HL regime was most efficient, followed in sequence by HH, LH and LL treatments. Many researchers have observed little or no difference in feed efficiency between various nutritional regimes (Merkel et al., 1958; Lucas et al., 1960; Winchester and Howe, 1955; Winchester and Ellis, 1957; Winchester et al., 1957).

In Trial IV (Table XVII) the moderate plane of nutrition failed to promote maximum lean development. This is indicated by the relatively small quantity of lean produced by the MI treatment, and illustrates the need for feeding steers on high and moderate nutritional planes for equal gains (MII), rather than for an equal length of time (MI), if comparable quantities of lean are desired.

The full-fed steers were generally more efficient than either Moderate group in Trial IV. There were essentially no differences in efficiency between the MI and MII treatments, except when expressed on a caloric basis. In the latter comparison, the MII regime resulted in a small improvement in efficiency.

Relationships Among Live Animal and Carcass Traits

The data reported herein involve numerous measurements and scores individually obtained from 82 steers. These measures have been discussed in the preceding section, and by Hendrickson (1961), with respect to the effects of nutritional plane. The experimental material was selected primarily for this nutrition study, and therefore contains less variation than is usually desired in investigations designed to study interrelationships among various measurements.

However, the large number of different measurements available permit a wide range of comparisons on the same cattle. The correlation coefficients presented in the following tables represent a survey of these comparisons and serve primarily to establish general relationship patterns for the type of steers used. All values are simple overall correlations, unadjusted for treatment or year effect, or for the influence of any other variables.

Relationships Involving Linear Live Animal and Carcass Measurements

Correlation coefficients obtained between live animal measurements and other selected variables are shown in Table XVIII. Skeletal measurements (X_4 and X_5), and particularly heart girth, were highly associated with live weight. Width of shoulder and quarter were related (0.78), but neither was appreciably associated with width of loin. Difficulty in measuring loin width was evident in these studies. Heart girth was positively correlated with the other live animal measurements. Width and length measurements were negatively associated when correlations involving width of loin were not considered.

In general, width of shoulder and quarter, height at withers, and heart girth were positively related to linear carcass measurements. Results of other investigations (Orme et al., 1959; Ternan et al., 1959) support the above trends; however, higher correlation coefficients were obtained for most comparisons, which reflects wider variation in experimental material. It should be emphasized that linear measurements reflect body size and, because of this, are positively correlated with live weight. This relationship is strikingly illustrated in Table XIX. Note the highly significant positive correlation (0.39 to 0.64) between slaughter weight and various linear carcass measurements. Many of the

TABLE XVIII

CORRELATIONS BETWEEN LIVE ANIMAL MEASUREMENTS AND OTHER SELECTED VARIABLES[a,b]

Variable	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Slaughter wt. (lb.)	0.38	0.07	0.27	0.55	0.43	0.82	-0.25	0.59
Av. daily gain (lb.)	-0.25	-0.02	-0.31	0.28	0.40	0.19	-0.45	0.32
Live body meas. (in.)								
Width of shoulder (X_1)		0.22	0.78	0.25	-0.37	0.42	0.05	-0.17
Width of loin (X_2)			0.01	0.25	0.19	-0.03	0.11	0.41
Width of quarter (X_3)				0.23	-0.40	0.30	0.17	-0.20
Height at withers (X_4)					0.27	0.59	0.08	0.67
Length of body (X_5)						0.31	-0.11	0.90
Heart girth (X_6)							-0.08	0.51
Av. of width meas. (X_7)								-0.05
Av. of length meas. (X_8)								
Carcass meas. (in.)								
Carcass length	0.42	0.39	0.46	0.54	0.31	0.51	0.23	0.49
Length of leg	0.45	0.08	0.48	0.57	0.14	0.49	0.17	0.37
Depth of body	0.37	0.16	0.53	0.34	-0.10	0.32	0.06	0.08
Length of loin	0.19	0.01	0.23	0.48	0.44	0.40	0.18	0.56
Width of shoulder	0.52	-0.06	0.48	0.12	-0.16	0.35	-0.26	-0.07
Width of round	0.32	-0.06	0.20	0.39	0.13	0.47	0.24	0.28
Carcass composition (%)								
Lean	0.35	-0.13	0.42	0.04	-0.37	-0.26	0.50	-0.27
Fat	-0.17	0.12	-0.24	0.03	0.29	0.42	-0.51	0.23
Bone	-0.34	-0.11	-0.28	-0.19	-0.04	-0.63	0.24	-0.13

[a]Correlations between live animal measurements and subjective grading scores are presented in Table XLIV, Appendix B.

[b]$r = 0.217$ at $P = 0.05$ and 0.283 at $P = 0.01$.

TABLE XIX

CORRELATIONS BETWEEN CARCASS MEASUREMENTS AND OTHER SELECTED VARIABLES[a,b]

Variable	X_1	X_2	X_3	X_4	X_5	X_6
Slaughter wt. (lb.)	0.64	0.56	0.41	0.55	0.48	0.39
Av. daily gain (lb.)	-0.20	-0.32	-0.31	-0.14	-0.12	0.05
Carcass meas. (in.)						
Carcass length (X_1)		0.81	0.49	0.88	0.25	0.43
Length of leg (X_2)			0.60	0.73	0.34	0.32
Depth of body (X_3)				0.39	0.40	0.16
Length of loin (X_4)					0.81	0.31
Width of shoulder (X_5)						-0.16
Width of round (X_6)						
Carcass composition (%)						
Lean	0.21	0.32	0.20	0.19	-0.04	0.11
Fat	-0.13	-0.24	-0.13	-0.16	0.15	-0.02
Bone	-0.16	-0.10	-0.15	-0.04	-0.35	-0.22

[a]Correlations between carcass measurements and subjective grading scores are presented in Table XLV, Appendix B.

[b]$r = 0.217$ at $P = 0.05$ and 0.283 at $P = 0.01$.

high correlations among the latter variables, and most of the positive relationships mentioned previously (Table XVIII) can be attributed in part to the mutual influence of live weight. It is obvious that some of the correlations among carcass measurements in Table XIX are spurious because of part-to-whole relationships between the variables.

Correlation coefficients observed between live animal measurements and subjective scores are presented in Table XLIV, Appendix B. Comparisons were also made between subjective scores and linear carcass measurements and are shown in Table XLV, Appendix B. Although a few high correlations were observed, most relationships were quite low. Negative values actually indicate positive correlations due to the method of scoring used. Heart girth (Table XLIV) and width of shoulder (Table XLV) were significantly associated with most subjective scores. Ternan _et al_. (1959) observed low or insignificant correlations between body measurements and conformation scores, and Orme _et al_. (1959) found subjective scores to be of less predictive value than objective live animal measurements for estimating carcass dimensions.

Christians (1962) reported that live animal measurements had little value for predicting carcass components. The correlations between live animal measurements and carcass composition (Table XVIII) and between linear carcass measurements and carcass composition (Table XIX) reveal no consistent trends.

The amount of variation accounted for in any one comparison may be expressed as r^2. None of the comparisons discussed account for sufficient variation to be of much predictive value.

Relationships Involving Specific Gravity Determinations

The correlation coefficients obtained between specific gravity readings and other selected variables are presented in Table XX. These values were essentially the same magnitude, regardless of which wholesale cut was used. Likewise, the five-cut average did not appreciably alter the size of the correlations. Rib and loin readings were in closest agreement (0.91) of the five cuts measured.

The use of specific gravity as an estimate of carcass fat has been advocated by Kraybill et al. (1952) and Meyer et al. (1960). Correlations between specific gravity of the wholesale rib cut and the calculated carcass composition were -0.90, 0.80 and 0.70 for percent fat, lean and bone, respectively. Thus, despite limited variation in these cattle, specific gravity of the rib accounted for 81 percent of the variation in percent carcass fat. Up to 96 percent has been accounted for in other studies (Meyer et al., 1960).

Significant relationships were generally observed between specific gravity and percentages of wholesale cuts, except for chuck, rib and brisket. Percent round, flank, plate, shank, major cuts and wasty cuts all showed relatively high correlation coefficients. Calculating correlations from percentage data removes most of the effect of live weight, but may introduce artificial interrelationships since all values must add to 100 percent.

Specific gravity readings were also highly associated with width of external fat at the 12th rib, percent moisture and ether extract in the rib eye, live and carcass grade and other selected scores. Correlations involving estimates of fat were generally higher than those estimating lean. Measures of rib eye size were not appreciably associated

TABLE XX

CORRELATIONS BETWEEN SPECIFIC GRAVITY DETERMINATIONS AND OTHER SELECTED VARIABLES[a]

Variable	X_1	X_2	X_3	X_4	X_5	X_6
Specific gravity						
Round (X_1)		0.85	0.87	0.89	0.84	0.94
Rump (X_2)			0.88	0.87	0.84	0.92
Loin (X_3)				0.88	0.91	0.96
Chuck (X_4)					0.88	0.96
Rib (X_5)						0.94
Av. of 5 cuts (X_6)						
Carcass composition (%)						
Lean	0.71	0.72	0.81	0.74	0.80	0.80
Fat	-0.76	-0.79	-0.87	-0.82	-0.90	-0.88
Bone	0.55	0.58	0.62	0.63	0.70	0.65
Wholesale cuts (%)						
Round	0.45	0.60	0.67	0.53	0.68	0.62
Rump	0.46	0.27	0.43	0.42	0.45	0.44
Loin	-0.19	-0.15	-0.37	-0.18	-0.27	-0.27
Flank	-0.58	-0.62	-0.63	-0.59	-0.70	-0.65
Kidney knob	-0.39	-0.45	-0.52	-0.41	-0.53	-0.48
Chuck	0.18	0.23	0.17	0.10	0.22	0.17
Rib	0.02	0.02	0.02	0.05	-0.06	0.02
Plate	-0.51	-0.60	-0.52	-0.57	-0.59	-0.57
Brisket	-0.06	-0.05	0.05	0.01	0.00	0.00
Shank	0.49	0.50	0.57	0.51	0.55	0.56
Major cuts[b]	0.53	0.60	0.57	0.53	0.65	0.59
Cheap cuts[c]	-0.49	-0.56	-0.51	-0.49	-0.60	-0.54
Wasty cuts[d]	-0.61	-0.68	-0.66	-0.63	-0.74	-0.69

[a]$r = 0.217$ at $P = 0.05$ and 0.283 at $P = 0.01$.

[b]Includes round, rump, loin, chuck and rib.

[c]Includes flank, kidney knob, plate, brisket and shank.

[d]Includes flank, kidney knob, plate and brisket.

TABLE XX (Continued)

Variable	X_1	X_2	X_3	X_4	X_5	X_6
Rib eye data (in.)						
Area	0.05	0.14	0.13	0.05	-0.01	0.06
Length	0.24	0.32	0.34	0.27	0.19	0.28
Av. fat cover	-0.70	-0.63	-0.79	-0.67	-0.77	-0.76
Av. width	-0.09	0.02	-0.03	-0.09	-0.15	-0.09
Width x length	0.04	0.16	0.12	0.05	-0.03	-0.06
Chemical analysis (%)						
Moisture	0.55	0.59	0.61	0.61	0.52	0.62
Ether extract	-0.67	-0.64	-0.66	-0.71	-0.66	-0.71
Ash	0.14	0.14	0.13	0.18	0.18	0.16
Protein	-0.14	-0.20	-0.25	-0.16	-0.20	-0.20
Subjective scores (live)						
Width of body	0.40	0.45	0.39	0.42	0.39	0.43
Muscling	0.37	0.37	0.31	0.35	0.29	0.36
Fat thickness	0.51	0.53	0.52	0.53	0.51	0.55
Live slaughter grade	0.65	0.61	0.67	0.68	0.67	0.70
Subjective scores (carcass)						
Thickness	0.51	0.46	0.51	0.48	0.54	0.54
Fat thickness	0.67	0.58	0.66	0.61	0.68	0.68
Kidney knob	0.50	0.51	0.56	0.48	0.61	0.55
Marbling	0.58	0.52	0.57	0.58	0.60	0.60
Firmness of lean	0.51	0.48	0.50	0.52	0.52	0.54
Carcass grade	0.77	0.72	0.78	0.77	0.79	0.82

[a] r = 0.217 at P = 0.05 and 0.283 at P = 0.01.

[b] Includes round, rump, loin, chuck and rib.

[c] Includes flank, kidney knob, plate, brisket and shank.

[d] Includes flank, kidney knob, plate and brisket.

with specific gravity determinations. Cole et al. (1960b) reported that the rib eye was a relatively poor index of total lean development.

The above discussion indicates that specific gravity determinations may be of considerable predictive value, particularly for estimating percent carcass fat. In this study, as much as 81 percent of the variation in this trait could be accounted for by one specific gravity measurement.

Relationships Involving Other Indicators of Carcass Composition

Correlations between the wholesale cuts most highly associated with specific gravity and other selected variables are presented in Table XXI. The relationships among wholesale cuts are undoubtedly too high, due to part-to-whole relationships and the limitations of percentage data. Correlations between rib eye area and wholesale cuts were negligible. In every remaining comparison, highly significant relationships were observed. Values were generally slightly higher for variables estimating fat content, but prediction of percent carcass fat from percent wasty cuts accounted for only 55 percent of the variation.

Correlations between percent wholesale cuts and estimated carcass composition reported in the literature have generally been low. However, Cole et al. (1960b) recently obtained a correlation of 0.95 between separable lean in the wholesale round and total carcass lean.

Relationships between estimated carcass composition data, thickness of external fat, and chemical analysis values for lean tissue are presented in Table XXII. Correlations of -0.70, 0.79 and -0.63 were obtained between thickness of external fat and percent lean, fat and bone, respectively. Percent moisture and ether extract were also highly associated with percent fat and lean, and with fat thickness. Most other

TABLE XXI

CORRELATIONS BETWEEN CERTAIN WHOLESALE CUTS AND OTHER SELECTED VARIABLES[a]

Variable	X_1	X_2	X_3	X_4	X_5	X_6
Wholesale cuts (%)						
Round (X_1)		-0.63	-0.46	0.46	0.64	-0.69
Flank (X_2)			0.37	-0.44	-0.69	0.75
Plate (X_3)				-0.24	-0.70	0.74
Shank (X_4)					0.18	-0.38
Major cuts[b] (X_5)						0.96
Wasty cuts[c] (X_6)						
Carcass composition (%)						
Lean	0.63	-0.61	-0.55	0.57	0.62	-0.71
Fat	-0.70	0.68	0.57	-0.58	-0.66	0.74
Bone	0.52	-0.50	-0.35	0.33	0.44	-0.46
Rib eye						
Area	-0.04	-0.02	-0.07	-0.07	0.05	-0.04
Fat cover	-0.60	0.63	0.31	-0.54	-0.48	0.55
Chemical analysis (%)						
Moisture	0.52	-0.33	-0.29	0.46	0.29	-0.37
Ether extract	-0.44	0.47	0.45	-0.48	-0.43	0.54
Live slaughter grade	0.48	-0.46	-0.35	0.58	0.43	-0.52
Carcass grade	0.59	-0.49	-0.46	0.61	0.56	-0.66

[a]$r = 0.217$ at $P = 0.05$ and 0.283 at $P = 0.01$.

[b]Includes round, rump, loin, chuck and rib.

[c]Includes flank, kidney knob, flank and brisket.

TABLE XXII

CORRELATIONS BETWEEN CARCASS COMPOSITION AND CHEMICAL ANALYSIS DATA[a]

Variable	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Carcass composition (%)							
Lean (X_1)	-0.94	0.36	-0.70	0.59	-0.69	0.15	-0.36
Fat (X_2)		-0.63	0.79	-0.61	0.65	-0.17	0.31
Bone (X_3)			-0.63	0.39	-0.30	0.19	0.00
Fat cover (rib eye) (X_4)				-0.52	-0.54	-0.14	0.26
Chemical analysis							
Moisture (X_5)					-0.64	0.21	-0.46
Ether extract (X_6)						-0.24	0.04
Ash (X_7)							0.08
Protein (X_8)							

[a] $r = 0.217$ at $P = 0.05$ and 0.283 at $P = 0.01$.

comparisons are insignificant or unrealistic when expressed as percentages.

The general trend observed in Tables XXI and XXII is that most of the variables studied, which were believed to provide some indication of carcass composition, were significantly correlated with calculated percentages of carcass lean and fat. These correlations were usually in the range of 0.50 to 0.70.

Relationships Involving Carcass Quality Data

Correlations among certain subjective scores, organoleptic data and shear values are presented in Table XXIII. Refinement score, observed on the live animal, was not significantly correlated with any of the other variables. No important relationships were noted for any comparisons which included shear readings or organoleptic scores. However, correlations from 0.65 to 0.82 were obtained between carcass grade and live slaughter grade, marbling, and other carcass scores (texture and firmness of lean, and color of lean and fat). All other comparisons among these scores were also highly significant.

It is apparent that organoleptic tests and shear values, determined on the cooked product, were of no importance in this study. Christians (1962) noted that cooking introduced considerable variation, which could easily mask small differences in the raw product.

TABLE XXIII

CORRELATIONS BETWEEN CERTAIN SUBJECTIVE SCORES AND CARCASS QUALITY DATA[a]

Variable	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
Subjective score											
Refinement (X_1)	0.14	0.09	0.11	-0.07	-0.05	0.05	0.11	-0.08	0.03	0.01	0.16
Live grade (X_2)		0.51	0.42	0.43	0.45	0.53	0.79	-0.13	0.17	-0.11	0.10
Marbling (X_3)			0.61	0.57	0.72	0.46	0.82	-0.20	0.14	-0.16	0.18
Texture of lean (X_4)				0.64	0.68	0.57	0.65	-0.06	0.05	0.08	0.06
Firmness of lean (X_5)					0.60	0.62	0.69	0.07	0.04	-0.10	-0.07
Color of lean (X_6)						0.49	0.70	-0.18	0.09	-0.02	0.12
Color of fat (X_7)							0.68	0.04	-0.07	0.11	-0.13
Carcass grade (X_8)								-0.19	0.09	-0.12	0.12
Organoleptic data											
Tenderness (X_9)									-0.15	0.24	0.10
No. of chews (X_{10})										-0.09	0.05
Juiciness (X_{11})											-0.16
Shear value (X_{12})											

[a] $r = 0.217$ at $P = 0.05$ and 0.283 at $P = 0.01$.

SUMMARY

Three trials, involving 64 weanling steer calves, were conducted to study the effects of different nutritional planes on carcass composition, quality, and efficiency of nutrient conversion. The planes of nutrition imposed were: Full-feeding for 360-400 pounds feedlot gain (HH); full-feeding for approximately half the total gain, followed by a moderate level of feeding (HM); moderate feeding, followed by full-feeding (MH); and a moderate level of feeding throughout (MM). The different nutritional planes were achieved by varying the amounts of rolled milo and cottonseed hulls in the ration, which also contained cottonseed meal and dehydrated alfalfa pellets. The steers were individually-fed, and slaughtered after 360-400 pounds gain. A fourth trial, using 24 calves, was conducted to compare the effects of high (H) vs. moderate nutritional regimes imposed for equal length of time (MI) or equal feedlot gain of 350 pounds (MII). In each trial, individual records were maintained on weight gains and feed consumption. Data collected included linear live animal and carcass measurements, subjective live animal and carcass evaluation scores, hide weight, dressing percent and estimates of "fill" and internal fat. Other carcass information included rib eye tracings, yield of wholesale cuts, specific gravity of wholesale cuts, physical separation of the 9-10-11th rib cut, and proximate chemical analysis of lean tissue. Desirability of the cooked product was estimated by shear tests and organoleptic studies. Simple overall correlations were calcu-

lated on the data from 82 steers to establish general [illegible] patterns among these variables.

In Trials I, II and III, steers full-fed for rapid gain (HH) produced higher grading carcasses which contained more fat and less lean and bone, as indicated by physical separation data, than those from steers fed to gain at a moderate rate (MM). When the plane of nutrition was reversed in Phase II (HM and MH treatments), the carcasses produced were intermediate to the HH and MM regimes in composition and grade. However, carcass composition reflected the influence of the plane of nutrition imposed in the second phase, as evidenced by an increased percentage of fat and decreased percentages of lean and bone for the MH group, relative to the HM regime. Yield and specific gravity of the wholesale cut and physical separation of the 9-10-11th rib all revealed small but consistent differences among treatment groups in support of the above conclusions. Treatment differences with rib eye area, internal fat and subjective conformation scores were generally not significant.

No differences in desirability of the cooked product were detected among the four treatment groups. The range in carcass grade, High Good to Low-to-Average Good, suggests small differences in quality. Subjective carcass quality scores paralleled those for carcass grade.

The distribution of treatment means with respect to relative efficiency of meat production varied, depending on the criteria used. When expressed on the basis of carcass lean or protein, efficiencies increased in the treatment order HH, HM, MH and MM. In every comparison, the MH regime was more efficient than the HM regime.

In Trial IV, all composition measurements and subjective scores indicated a lower percentage of lean and more fat in carcasses of the full-fed group. When the moderate plane of nutrition was imposed for the same length of time (MI), rather than for the same total feedlot gain (MII), lighter-weight carcasses were obtained which were inferior in grade and yield. Carcass grades ranged from Average Good (High group) to Average-to-High Standard (MI group). Although the percentage of carcass lean increased, total lean production for the MI regime was approximately 30 pounds less than for the High treatment. The latter group was also more efficient in conversion of calories and protein.

A large number of simple correlation coefficients were calculated using the various measurements and scores available in these four trials. In general, the relationships were in agreement with those reported in the literature. However, the coefficients were frequently lower in magnitude, due to the relative uniformity of the experimental material, and most of the variables, therefore, appeared to be of low predictive value.

LITERATURE CITED

Blaxter, K. L. and J. A. F. Rook. 1953. The heat of combustion of the tissues of cattle in relation to their chemical composition. British J. Nutr. 7:83.

Breidenstein, B. C., Sleeter Bull, R. M. Forbes and J. R. Stouffer. 1955. Comparative evaluation of techniques used in estimating beef carcass quality. J. Animal Sci. 14:1227 (Abstract).

Brody, S. 1945. Bioenergetics and growth. Reinhold Publishing Corporation, New York.

Brugman, H. H. 1950. The effect of the plane of nutrition on the carcass quality of a line of swine based on a Chester White and Danish Landrace cross. J. Animal Sci. 9:602.

Butler, O. D. 1957. The relation of conformation to carcass traits. J. Animal Sci. 16:227.

Callow, E. H. 1961. Comparative studies of meat. VII. A comparison between Hereford, Dairy Shorthorn and Freisian steers on four levels of nutrition. J. Agr. Sci. 56:265.

Christians, Charles J. 1962. Factors affecting beef carcass traits. Ph. D. Thesis. Oklahoma State University.

Cole, J. W., W. R. Backus and L. E. Orme. 1960a. Specific gravity as an objective measure of beef eating quality. J. Animal Sci. 19:167.

______, L. E. Orme and C. M. Kincaid. 1960b. Relationship of loin eye area, separable lean of various beef cuts and carcass measurements to total carcass lean in beef. J. Animal Sci. 19:89.

Cook, A. C., M. L. Kohli and W. M. Dawson. 1951. Relationships of five body measurements to slaughter grade, carcass grade, and dressing percentage in Milking Shorthorn steers. J. Animal Sci. 10:386.

Crampton, E. W., G. C. Ashton and L. E. Lloyd. 1954. The effect of restricting feed intake of market hogs during the finishing period on the quality of the bacon carcass. J. Animal Sci. 13:321.

Eckles, C. H. and W. W. Swett. 1918. Some factors influencing the rate of growth and the size of dairy heifers at maturity. Mo. Agr. Exp. Sta. Res. Bul. 31.

Federer, Walter T. 1955. Experimental design. The Macmillan Company, New York.

Foster, M. T. 1928. Carcass compositions of mature and immature steers. Mo. Agr. Exp. Sta. Res. Bul. 117.

Garrett, W. N., J. H. Meyer and G. P. Lofgreen. 1959. The comparative energy requirements of sheep and cattle for maintenance and gain. J. Animal Sci. 18:528.

Goll, D. E., E. A. Kline and L. N. Hazel. 1961. Influence of beef carcass grade and weight on yield of wholesale cuts and carcass measurements. J. Animal Sci. 20:260.

Good, D. L., G. M. Dahl, S. Wearden and D. J. Weseli. 1961. Relationships among live and carcass characteristics of selected slaughter steers. J. Animal Sci. 20:698.

Guilbert, H. R., G. H. Hart, K. A. Wagnon and H. Goss. 1944. The importance of continuous growth in beef cattle. Calif. Agr. Exp. Sta. Bul. 688.

Haecker, T. L. 1920. Investigations in beef production. Minn. Agr. Exp. Sta. Bul. 193.

Hammond, John. 1955. Progress in the physiology of farm animals. Volume 2. Butterworth's Scientific Publications, London.

Hankins, O. G. and P. E. Howe. 1946. Estimation of the composition of beef carcasses and cuts. U.S.D.A. Tech. Bul. 926.

Hendrickson, R. F. 1961. Effect of different planes of nutrition on feedlot performance and body size of fattening steer calves. M. S. Thesis. Oklahoma State University.

Hogan, A. G. 1929. Retarded growth and mature size of beef steers. Mo. Agr. Exp. Sta. Res. Bul. 123.

_______, L. A. Weaver, A. T. Edinger and E. A. Trowbridge. 1924. The relation of feed consumed to protein and energy retention. Mo. Agr. Exp. Sta. Res. Bul. 73.

Jordan, Whiteman H. 1895. The relation of food to the growth and composition of the bodies of steers. Me. State Col. Agr. Exp. Sta. Rpt. p. 36.

Kidwell, J. F. 1955. A study of the relation between body conformation and carcass quality in fat calves. J. Animal Sci. 14:233.

Kraybill, H. F., H. L. Bitter and O. G. Hankins. 1952. Body composition of cattle. II. Determination of fat and water content from measurement of body specific gravity. J. Applied Physiol. 4:575.

Lucas, I. A. M. and A. F. C. Calder. 1956. The response of different types of pigs to varying levels of feeding from weaning to bacon weight, with particular reference to carcass quality. J. Agr. Sci. 47:287.

______, I. McDonald and A. F. C. Calder. 1960. Some further observations upon the effects of varying the plane of feeding for pigs between weaning and bacon weight. J. Agr. Sci. 54:81.

McMeekan, C. P. 1940a. Growth and development in the pig, with special reference to carcass quality characters. I. J. Agr. Sci. 30:276.

1940b. Growth and development in the pig, with special reference to carcass quality characters. Part II. The influence of the plane of nutrition on growth and development. J. Agr. Sci. 30:387.

______ 1940c. Growth and development in the pig, with special reference to carcass quality characters. Part III. Effect of the plane of nutrition on the form and composition of the bacon pig. J. Agr. Sci. 30:511.

______. 1941. Growth and development in the pig, with special reference to carcass quality characters. Part IV. The use of sample joints and of carcass measurements as indices of the composition of the bacon pig. Part V. The bearing of the main principles emerging upon the many problems of animal production and human development. J. Agr. Sci. 31:1.

Merkel, R. A., R. W. Bray, R. H. Grummer, P. H. Phillips and G. Bohstedt. 1958. The influence of limited feeding, using high fiber rations, upon growth and carcass characteristics of swine. II. Effects upon carcass characteristics. J. Animal Sci. 17:13.

Meyer, J. H., G. P. Lofgreen and W. N. Garrett. 1960. A proposed method for removing sources of error in beef cattle feeding experiments. J. Animal Sci. 19:1123.

Morrison, F. B. 1956. Feeds and feeding. 22nd Ed. Morrison Publishing Company, Ithaca, New York.

Moulton, C. Robert, P. F. Trowbridge and L. D. Haigh. 1922a. Studies in animal nutrition. II. Changes of proportions of carcass and offal on different planes of nutrition. Mo. Agr. Exp. Sta. Res. Bul. 54.

______, P. F. Trowbridge and L. D. Haigh. 1922b. Studies in animal nutrition. III. Changes in chemical composition on different planes of nutrition. Mo. Agr. Exp. Sta. Res. Bul. 55.

______, P. F. Trowbridge and L. D. Haigh. 1923. Studies in animal nutrition. V. Changes in the composition of the mature dairy cow during fattening. Mo. Agr. Exp. Sta. Res. Bul. 61.

Orme, L. E., J. W. Cole, C. M. Kincaid and R. J. Cooper. 1960. Predicting total carcass lean in mature beef from weights of certain entire muscles. J. Animal Sci. 19:726.

______, A. M. Pearson, L. J. Bratzler and W. T. Magee. 1958. Specific gravity as an objective measure of marbling. J. Animal Sci. 17:693.

______, A. M. Pearson, W. T. Magee and L. J. Bratzler. 1959. Relationships of live animal measurements to various carcass measurements in beef. J. Animal Sci. 18:991.

Palsson, H. and Juan B. Verges. 1952a. Effects of the plane of nutrition on growth and development of carcass quality in lambs. Part I. The effects of high and low planes of nutrition at different ages. J. Agr. Sci. 42:1.

______ and Juan B. Verges. 1952b. Effects of the plane of nutrition on growth and the development of carcass quality in lambs. Part II. Effects on lambs of 30 lb. carcass weight. J. Agr. Sci. 42:93.

Reid, J. T., G. H. Wellington and H. O. Dunn. 1955. Some relationships among the major chemical components of the bovine body and their application to nutritional investigation. J. Dairy Sci. 37:1344.

Shorrock, R. W. 1940. The "restricted" feeding of bacon pigs. J. Agr. Sci. 30:598.

Snedecor, G. W. 1956. Statistical methods. 5th Ed. The Iowa State College Press, Ames, Iowa.

Swift, R. W. 1957. The caloric value of TDN. J. Animal Sci. 16:753.

Ternan, P. R., J. F. Kidwell, J. E. Hunter, C. E. Shelby and R. T. Clark. 1959. Associations among conformation scores, among body measurements and the relations between scores and measurements in yearling steers. J. Animal Sci. 18:880.

Trowbridge, P. F., C. R. Moulton and L. D. Haigh. 1918. Effect of limited foods on growth of beef animal. Mo. Agr. Exp. Sta. Res. Bul. 28.

______, C. R. Moulton and L. D. Haigh. 1919. Composition of the beef animal and energy cost of fattening. Mo. Agr. Exp. Sta. Res. Bul. 30.

Waters, H. J. 1908. The capacity of animals to grow under adverse condition. Soc. Prom. Agr. Sci. Proc. 29th Assoc. Meeting. p. 71.

Weber, A. D., Wm. J. Loeffel and Matilda Peters. 1931. Length of feeding period and plane of nutrition as factors in lamb fattening. Neb. Agr. Exp. Sta. Bul. 262.

Wheat, J. D. and L. A. Holland. 1960. Relationship between slaughter and carcass grades in beef cattle. J. Animal Sci. 19:722.

Wilson, P. H. 1954. Growth analysis of the domestic fowl. II. Effect of plane of nutrition on carcass composition. J. Agr. Sci. 44:67.

______. 1960. The effect of plane of nutrition on the growth and development of the East African Dwarf goat. III. The effect of plane of nutrition and sex on the carcass composition of the kid at two stages of growth, 16 lb. weight and 30 lb. weight. J. Agr. Sci. 60:105.

Winchester, C. F. and N. R. Ellis. 1957. Delayed growth of beef cattle. U.S.D.A. Tech. Bul. 1159.

______, R. L. Hiner and V. C. Scarborough. 1957. Some effects on beef cattle of protein and energy restriction. J. Animal Sci. 16:426.

______ and Paul E. Howe. 1955. Relative effects of continuous and interrupted growth on beef steers. U.S.D.A. Tech. Bul. 1108.

Winters, L. M., C. F. Sierk and J. N. Cummings. 1949. The effect of plane of nutrition on the economy of production and carcass quality of swine. J. Animal Sci. 8:132.

Yao, T. S., W. M. Dawson and A. C. Cook. 1953. Relationships between meat production characters and body measurements in beef and in Milking Shorthorn steers. J. Animal Sci. 12:775.

A P P E N D I X A

ANALYSIS OF THE DATA AND ADJUSTMENT OF SUBJECTIVE GRADING SCORES

Analysis of Variance

The analysis of variance program used was written in Fortran for use on the IBM 650 computer, and is presented in Table XXIV. As written, the program will perform either one- or two-way cross classification analysis of a maximum of 24 variables. Any number of treatment and/or block groups may be used and unequal subgroup numbers are permitted; however, one effect (treatment or block) is limited to 12 unequal subgroups.

All input cards are in fixed point form and have a 12 punch in column 73. Data may be either positive or negative. The first header card has the following format:

Word 1 -- 000000000X, X=1 (one-way AOV) or X=2 (two-way AOV).

Word 2 -- No. of groups for Effect I (usually treatment).

Word 3 -- No. of groups for Effect II (usually block).

Word 4 -- No. of data cards (six variables per card).

Word 5 -- No. of variables (up to 24).

This header is followed by a subgroup header card for each set of subgroups (all treatment subgroups in one block = one set). Two subgroup headers are needed when there are more than five unequal subgroups in a set. All unused columns must contain zeros. The first subgroup header card has the following format:

Word 1 -- No. of subgroup headers (1 or 2).

Word 2 -- No. of experimental units in Subgroup 1 (N).

Word 3 -- XX000000YY, where XX = no. of first subgroup with different N than the preceding subgroup, and YY = change in N. For example, 050000001$\bar{0}$ indicates that Subgroup 5 has 10 less

TABLE XXIV

ANALYSIS OF VARIANCE PROGRAM

Fortran Statements

```
1 0000 0   ONE OR TWO WAY CROSS AOV
    42 0   DIMENSION MA(24), A(24),
    42 1   B(24), C(24), D(24), E(24),
    42 2   G(24), N(11), ZNC(12), P(24),
    42 3   R(24), T(24,12), S(24),
    42 4   NFT (24,3)
     1 0   READ 1, KT, K, L, KD, KV
           DO 2 I=1,11
     2 0   N(I)=0
           ZNT=0.0
           NO=0
           DO 3 I=1,24
           D(I)=0.0
           G(I)=0.0
           P(I)=0.0
           R(I)=0.0
           DO 3 J=1,12
           ZNC(J)=0.0
     3 0   T(I,J)=0.0
           MM=1
     4 0   READ 1, KH, NA, N(1), N(2),
     4 1   N(3), N(4), N(5)
           ZNA=NA
           GO TO (6,5), KH
     5 0   READ 1, N(6), N(7), N(8),
     5 1   N(9), N(10), N(11)
     6 0   DO 7 I=1,24
           B(I)=0.0
     7 0   C(I)=0.0
           ZNB=0.0
           IJ=10
           M=1
     8 0   DO 9 I=1,24
     9 0   E(I)=B(I)
           DO 15 J=1,NA
    10 0   READ 1, MD1, (MA(J),J=1,6)
           GO TO (14,13,12,11), KD
    11 0   READ 1, MD1, (MA(J),J=19,24)
    12 0   READ 1, MD1, (MA(J),J=13,18)
    13 0   READ 1, MD1, (MA(J),J=7,12)
    14 0   DO 15 I=1,KV
           A(I)=MA(I)
           B(I)=B(I)+A(I)
           C(I)=C(I)+A(I)**2
```

TABLE XXIV (Continued)

Fortran Statements

```
15 0    CONTINUE
        DO 16 J=M,M
        ZNC(J)=ZNC(J)+ZNA
        DO 16 I=1,KV
        E(I)=B(I)-E(I)
        D(I)=D(I)+E(I)**2/ZNA
        T(I,J)=T(I,J)+E(I)
16 0    CONTINUE
        ZNB=ZNB+ZNA
        M=M+1
        IF (K-M) 18,20,20
18 0    DO 19 I=1,KV
        G(I)=G(I)+B(I)
        P(I)=P(I)+C(I)
        R(I)=R(I)+B(I)**2/ZNB
19 0    CONTINUE
        ZNT=ZNT+ZNB
        MM=MM+1
        IF (L-MM) 31,4,4
20 0    LL=300000000
21 0    IF (N(1)) 23,8,22
22 0    IF (N(1)-LL) 25,8,24
23 0    IF (N(1)+LL) 24,8,25
24 0    LL=LL+100000000
        GO TO 21
25 0    LL=LL-100000000
        IF (M-LL/100000000) 8,26,8
26 0    IF (N(1)) 27,8,28
27 0    NA=NA+(N(1)+LL)
        GO TO 29
28 0    NA=NA+(N(1)-LL)
29 0    ZNA=NA
        DO 30 I=1,IJ
30 0    N(I)=N(I+1)
        IJ=IJ-1
        GO TO 8
31 0    DO 33 I=1,KV
        A(I)=G(I)**2/ZNT
        B(I)=P(I)-A(I)
        C(I)=0.0
        DO 32 J=1,K
32 0    C(I)=C(I)+T(I,J)**2/ZNC(J)
        C(I)=C(I)-A(I)
        E(I)=R(I)-A(I)
        G(I)=D(I)-A(I)-C(I)-E(I)
```

TABLE XXIV (Continued)

Fortran Statements

```
33 0   R(I)=B(I)-C(I)-E(I)-G(I)
       JA=ZNT-1.0
       JB=K-1
       ZJB=JB
       JC=L-1
       ZJC=JC
       JD=JB*JC
       ZJD=JD
       JE=JA-JB-JC-JD
       ZJE=JE
       KEY=1111
       KK=K-1
       DO 41 I=1,KV
       IF (A(I)) 43,41,43
43 0   A(I)=C(I)/ZJB
       S(I)=R(I)/ZJE
       GO TO (35,34), KT
34 0   D(I)=E(I)/ZJC
       P(I)=G(I)/ZJD
       NFT(I,3)=(P(I)/S(I))*100.0+0.5
       NFT(I,1)=(A(I)/P(I))*100.0+0.5
       NFT(I,2)=(D(I)/P(I))*100.0+0.5
       GO TO 36
35 0   NFT(I,1)=(A(I)/S(I))*100.0+0.5
36 0   NO=NO+1
45 0   PUNCH 1, MD1, NO, KT
37 0   PUNCH 1, MD1, JA, B(I)
38 0   PUNCH 1,MD1, JB, C(I), A(I),
38 1   NFT(I,1)
       GO TO (44,39), KT
39 0   PUNCH 1,MD1, JC, E(I), D(I),
39 1   NFT(I,2)
40 0   PUNCH 1,MD1, JD, G(I), P(I),
40 1   NFT(I,3)
44 0   PUNCH 1,MD1, JE, R(I), S(I)
       DO 46 J=1,KK
46 0   PUNCH 1, MD1, ZNC(J), T(I,J)
       J=K
47 0   PUNCH 1, MD1, ZNC(J), T(I,J),
47 1   KEY
41 0   CONTINUE
       GO TO 1
       END
```

experimental units than Subgroup 4.

Words 4 through 7 -- Same as Word 3. If there are no unequal subgroups, these words contain zeros.

If a second subgroup header is needed, all words are punched in the same manner as words three through seven of the first subgroup header.

Data cards contain identification in word one and data in words two through seven. The first data card contains the first six variables. Card two (if present) is read as the last six variables, card three (if present) as the six variables preceding those in card two, and card four (if present) as variables seven through twelve.

Program output is in standard AOV format. Two examples are given in Table XXV. These examples are from data collected in the studies reported in this thesis and illustrate the types of analysis used. Main effects were assumed to be fixed in calculating "F" values. If this is true, the statistical model for example I is

$X_{ijh} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \epsilon_{ijh}$, $i = 1 \ldots a$, $j = 1 \ldots b$, $h = 1 \ldots n$, ϵ_{ijh} is $N(0,\sigma)$,

and the model for example II is

$X_{ij} = \mu + \alpha_i + \beta_j + \epsilon_{ij}$, $i = 1 \ldots a$, $j = 1 \ldots b$, ϵ_{ij} is $N(0,\sigma)$,

where "X" is the observation, "μ" is the overall mean, "α" is the treatment effect, "β" is the block effect, "ϵ" is a random effect, "a" is the number of treatments, "b" is the number of blocks and "n" is the number of observations per treatment within each block (Snedecor, 1956; Federer, 1955).

Individual treatment sums of squares were also punched in order to use AOV output for input of a program designed to test orthogonal comparisons among treatment groups. Since the latter program is specific in

TABLE XXV

EXAMPLES OF OUTPUT FORMAT OF ANALYSIS OF VARIANCE PROGRAM

Identification	df	SS	MS	F
Example I				
943342132+	12+[a]	2+[b]		
943342132+	57+	2110800054+		
943342132+	3+	1807000053+	6023333352+	417+
943342132+	2+	3983000053+	1991500053+	1378+
943342132+	6+	8670000052+	1445000052+	46+
943342132+	46+	1445100054+	3141521752+	
943342132+	1500000052+[c]	2359000054+[d]		
943342132+	1500000052+[c]	2313000054+[d]		
943342132+	1500000052+[c]	2319000054+[d]		
943342132+	1300000052+[c]	2060000054+[d]	1111+[e]	
Example II				
954532132+	18+[a]	1+[b]		
954532132+	23+	5522170057+	1115730057+	712+
954532132+	2+	2231460057+	1567004856+	
954532132+	21+	3290710057+		
954532132+	800000051+[c]	3962000055+[d]		
954532132+	800000051+[c]	3944500055+[d]		
954532132+	800000051+[c]	3436000055+[d]	1111+[e]	

[a]Sequential number of variable.

[b]Type of analysis (one-way or two-way).

[c]Number of animals in each treatment.

[d]SS for each treatment.

[e]Signifies last card in each analysis.

design and evaluates only the comparisons of importance in this study, it is not presented here.

Adjustment of Subjective Grading Scores

The subjective grading scores reported in this thesis are averages of the evaluations of three to seven men. Many of the graders did not observe all of the animals and consequently the data are far from complete. While it must be assumed that each grader was consistent in the use of his own "standard," it is highly probable that different graders had different standards in the case of many variables. If this is true, then certain of the averages are biased due to differences in the "average" standards used for different animals which are caused by absences of one or more graders.

For this reason, an attempt was made to adjust the averages to reduce this bias. The usual procedures for supplying missing data were not considered because of the large numbers of missing values. The equation that was used to create values for missing information is

$$X_{ijk} = \left(\frac{\Sigma A_{ij}}{N_a}\right) \cdot \left[\frac{(\Sigma B_i/N_c)k}{\Sigma A_i/(N_a \cdot N_c)}\right],$$

where "X" is the created value. "A" represents the actual values given by the number of men (N_a) who graded all the animals within a group, "B" represents the actual values given by each man (k) who graded one or more, but not all, animals within a group, and N_c is the number of animals in a group. The variable number is "i" and the animal number is "j". This equation merely multiplies the average values for the complete portion of the data (no missing values) by the ratio of values given by men grading all animals to those given by each man not grading all animals in a group.

The values were calculated on a within treatment basis first and the resulting data (containing actual and created values) were used to repeat the process on a within year basis. The new treatment means subsequently obtained included many created values.

This procedure is not statistically valid, since it results in adjusted means but not in adjusted variances. In all instances experimental error is drastically reduced and analyses of variance are not appropriate. However, analyses of variance were conducted on the actual averages and the adjusted means were used only as a further aid in evaluating the results. It is the author's opinion that this type of adjustment, while not recommended in most analyses, is of some benefit in evaluating data with a large number of missing values, in which case the usual methods become extremely complex.

A P P E N D I X B

TABLE XXVI

LIVE ANIMAL EVALUATION SCORES (TRIAL I)[a]

Treatment Group	HH		HM		MH		MM	
	Actual	Adj.	Actual	Adj.	Actual	Adj.	Actual	Adj.
Conformation								
Compactness	18.6[b]	16.7	22.0	20.9	18.8[b]	18.8	20.4	18.6
Width of body	16.7[c]	16.3	18.7	19.8	18.4[c]	17.8	20.1	18.9
Crops	16.3[d]	17.5	19.5	20.7	17.4[d]	18.7	20.0	18.9
Loin	15.9[d]	15.8	18.7	21.7	17.6[d]	17.4	19.4	18.1
Rump	18.4	16.3	17.9	18.8	18.4	17.5	19.8	18.4
Quarter	18.1[b]	17.3	20.2	17.5	19.0[b]	17.5	20.9	18.5
Muscling	16.1[e]	15.0	18.4	17.4	18.0[e]	16.5	18.7	17.3
Finish								
Thickness of fat	15.7[e]	13.7	20.0	17.9	16.6[e]	14.8	18.6	16.5
Smoothness	14.9[e,f]	15.0	19.0[f]	16.4	12.2[e]	12.2	17.3	15.8
Quality								
Refinement	17.4	17.0	18.8	15.1	14.0	14.3	17.1	15.6
Live slaughter grade	12.7[g]	12.8	15.8	17.3	12.6[g]	12.5	14.7	14.8

[a] 12 = Low Choice, 14 = High Good, 16 = Av. Good, ... , 22 = Av. Standard.

[b] (HH + MH) significantly different from (HM + MM) at $P \simeq 0.10$.

[c] (HH + MH) significantly different from (HM + MM) at $P \simeq 0.07$.

[d] (HH + MH) significantly different from (HM + MM) at $P < 0.01$.

[e] (HH + MH) significantly different from (HM + MM) at $P < 0.025$.

[f] (HH + HM) significantly different from (MH + MM) at $P \simeq 0.08$.

[g] (HH + MH) significantly different from (HM + MM) at $P \ll 0.001$.

TABLE XXVII

LIVE ANIMAL EVALUATION SCORES (TRIAL II)[a]

Treatment Group	HH		HM		MH		MM	
	Actual	Adj.	Actual	Adj.	Actual	Adj.	Actual	Adj.
Conformation								
Compactness	17.9	18.1	18.5	20.7	20.1	19.9	17.5	18.9
Width of body	16.9	16.9	18.3	19.9	18.0	17.5	16.7	17.3
Crops	17.5	17.5	19.3	20.3	18.5	17.9	17.1	18.4
Loin	17.3	17.3	17.3	18.4	16.6	16.4	16.0	16.4
Rump	18.5	18.4	17.9	20.6	17.9	17.8	15.9	17.4
Quarter	18.8	19.0	19.1	21.6	19.8	20.0	16.0	17.7
Muscling	17.5	17.7	18.3	19.7	18.0	17.6	16.1	17.2
Finish								
Thickness of fat	16.8	16.8	18.2	18.9	16.9	16.8	15.9	16.2
Smoothness	15.8[b]	15.8	16.3[b]	15.7	13.4	13.7	15.2	16.0
Quality								
Refinement	15.7	15.6	16.3	17.9	15.2	15.6	16.5	18.6
Live slaughter grade	14.8	14.9	17.0	17.0	15.4	15.3	15.2	15.1

[a]14 = High Good, 16 = Av. Good, 18 = Low Good, ... , 22 = Av. Standard.

[b](HH + HM) significantly different from (MH + MM) at $P \simeq 0.09$.

TABLE XXVIII

LIVE ANIMAL EVALUATION SCORES (TRIAL III)[a]

Treatment Group	HH		HM		MH		MM	
	Actual	Adj.	Actual	Adj.	Actual	Adj.	Actual	Adj.
Conformation								
Compactness	18.0[b]	19.6	16.3[b]	16.4	18.4	18.7	20.3	20.0
Width of body	18.5	21.4	17.1	19.2	18.1	18.4	19.2	19.5
Crops	19.2	21.0	18.3	21.2	18.9	21.0	20.3	19.5
Loin	18.8	20.6	16.9	18.9	17.3	17.0	18.8	18.8
Rump	18.8[c]	19.9	17.2[c]	19.4	18.5	18.7	20.6	21.3
Quarter	19.9	23.2	17.1	21.4	18.0	19.6	20.8	23.0
Muscling	18.6	21.2	17.2	19.2	17.3	19.3	18.8	19.6
Finish								
Thickness of fat	18.8	21.6	16.6	19.3	18.5	20.6	19.7	18.9
Smoothness	15.6[c,d]	17.7	15.6[c]	15.5	15.2[d]	17.3	20.2	19.9
Quality								
Refinement	16.7	18.1	17.9	17.6	17.0	18.7	20.8	21.2
Live slaughter grade	16.8[b]	17.9	16.0[b]	16.7	17.0	16.9	18.6	17.7

[a]16 = Av. Good, 18 = Low Good, 20 = High Standard, 22 = Av. Standard.

[b](HH + HM) significantly different from (MH + MM) at $P \simeq 0.09$.

[c](HH + HM) significantly different from (MH + MM) at $P \simeq 0.06$.

[d](HH + MH) significantly different from (HM + MM) at $P \simeq 0.10$.

TABLE XXIX

CARCASS EVALUATION SCORES (TRIAL I)[a]

Treatment Group	HH		HM		MH		MM	
	Actual	Adj.	Actual	Adj.	Actual	Adj.	Actual	Adj.
Conformation								
Compactness	16.0	15.4	14.8	15.9	15.7	15.2	17.4	15.0
Thickness	15.4[b]	15.3	16.8	16.4	16.3[b]	16.8	17.1	14.9
Rib eye (lean)	16.0	18.1	14.8	14.4	15.7	15.4	15.6	15.1
Loin	15.4	15.4	16.8	14.7	17.3	16.9	16.8	14.6
Round	16.6	15.1	14.4	13.6	17.3	15.5	16.5	12.9
Finish								
Fat thickness	15.1	13.8	16.0	17.3	16.3	15.8	16.6	13.2
Distribution (external)	15.3[c]	13.6	18.4	16.3	14.7[c]	14.8	16.0	12.6
Kidney knob	17.4	16.0	16.0	16.9	15.0	13.4	16.8	14.0
Marbling (rib eye)	17.1[d]	16.8	15.6[d]	21.0	18.0	17.1	20.1	19.8
Quality								
Grain of lean	14.0	15.1	12.0	14.9	12.7	13.0	14.3	14.1
Firmness of lean	10.3[d]	8.6	11.2[d]	16.8	14.0	15.4	13.6	13.0
Color of lean	15.1	15.0	14.8	17.8	15.0	15.4	16.6	15.4
Color of fat	9.7	8.4	11.2	13.9	10.7	11.1	10.0	10.8
Carcass grade	12.3[e]	13.0	14.4	15.3	13.0[e]	12.9	14.8	14.9

[a]8 = High Choice, 10 = Av. Choice, 12 = Low Choice, ... , 20 = High Standard.

[b](HH + MH) significantly different from (HM + MM) at $P \simeq 0.09$.

[c](HH + MH) significantly different from (HM + MM) at $P \simeq 0.10$.

[d](HH + HM) significantly different from (MH + MM) at $P < 0.05$.

[e](HH + MH) significantly different from (HM + MM) at $P < 0.05$.

TABLE XXX

CARCASS EVALUATION SCORES (TRIAL II)[a]

Treatment Group	HH		HM		MH		MM	
	Actual	Adj.	Actual	Adj.	Actual	Adj.	Actual	Adj.
Conformation								
Compactness	17.1	16.7	18.2	17.5	19.3	18.1	18.0	19.5
Thickness	16.3	16.1	17.5	17.1	17.2	16.6	16.6	18.0
Rib eye (lean)	16.7	16.1	17.8	17.2	16.5	15.6	15.4	15.8
Loin	16.0	16.0	16.8	16.8	16.5	16.5	16.9	17.8
Round	17.4	17.0	18.2	17.4	17.6	16.8	16.9	17.2
Finish								
Fat thickness	16.9	17.0	17.2	16.8	17.5	17.5	17.2	17.9
Distribution (external)	17.0	17.0	15.5	15.6	16.1	16.3	16.5	18.4
Kidney knob	17.0	17.0	18.4	18.6	19.2	18.7	18.1	19.6
Marbling (rib eye)	17.1[b]	17.0	17.2[b]	16.5	20.6	19.7	19.8	19.6
Quality								
Grain of lean	15.0	14.7	15.5	14.8	16.3	16.0	17.3	17.9
Firmness of lean	14.9	14.3	15.5	14.6	14.1	13.4	17.4	16.8
Color of lean	16.2	16.5	14.7	14.6	16.6	16.9	18.3	17.6
Color of fat	12.7	12.7	12.5	13.8	14.1	14.5	13.6	14.3
Carcass grade	14.7	14.7	15.7	15.6	15.7	15.7	16.9	16.7

[a]12 = Low Choice, 14 = High Good, 16 = Av. Good, ··· , 20 = High Standard.

[b](HH + HM) significantly different from (MH + MM) at $P \simeq 0.11$.

TABLE XXXI

CARCASS EVALUATION SCORES (TRIAL III)[a]

Treatment Group	HH Actual	HH Adj.	HM Actual	HM Adj.	MH Actual	MH Adj.	MM Actual	MM Adj.
Conformation								
Compactness	17.0[b]	17.7	16.5[b]	15.3	17.6	18.1	20.8	19.6
Thickness	16.7[c]	17.2	15.7[c]	16.2	17.0	18.5	19.7	19.1
Rib eye (lean)	16.4[b]	17.5	12.9[b]	13.9	17.7	19.1	19.5	19.8
Loin	17.2	17.9	14.9	16.4	17.5	20.1	18.2	19.6
Round	18.1	18.2	15.0	15.8	17.3	20.3	19.2	18.0
Finish								
Fat thickness	17.8	18.5	18.5	20.3	20.2	21.1	19.8	21.2
Distribution (external)	15.9[c]	16.6	15.8[c]	17.9	17.0	17.9	18.8	19.8
Kidney knob	18.4	19.8	18.7	21.3	19.5	21.5	19.3	25.9
Marbling (rib eye)	17.6[d]	18.7	17.6[d]	18.9	21.7	24.4	23.7	22.2
Quality								
Grain of lean	16.2[b]	17.0	15.6[b]	16.1	18.2	19.5	19.2	19.0
Firmness of lean	15.4	15.0	15.6	14.9	17.2	17.6	15.8	15.5
Color of lean	15.5[e]	15.9	15.3[e]	17.1	19.9	20.6	18.2	17.7
Color of fat	13.8	14.6	13.4	14.5	15.2	16.0	13.8	19.1
Carcass grade	15.9[d]	16.2	15.6[d]	15.9	17.7	18.3	19.8	18.5

[a] 12 = Low Choice, 14 = High Good, 16 = Av. Good, ..., 24 = Low Standard.

[b] (HH + HM) significantly different from (MH + MM) at $P < 0.05$.

[c] (HH + HM) significantly different from (MH + MM) at $P \simeq 0.06$.

[d] (HH + HM) significantly different from (MH + MM) at $P < 0.01$.

[e] (HH + HM) significantly different from (MH + MM) at $P < 0.025$.

TABLE XXXII

SLAUGHTER FLOOR DATA (%)
(TRIALS I, II AND III)

Treatment Group	HH	HM	MH	MM
Trial I				
Hide	8.5	8.5	8.4	8.9
"Fill"[a]	5.5[b]	7.0	6.5[b]	7.2
Internal fat[c]	----	----	----	----
Yield	63.6[d]	61.3	62.4[d]	61.2
Trial II				
Hide	8.2	8.7	8.1	8.6
"Fill"[a]	6.3	7.0	7.2	7.1
Internal fat[c]	2.9[e]	1.9	2.8[e]	1.8
Yield	60.9	60.3	60.7	60.8
Trial III				
Hide	9.0[f]	9.3	8.9[f]	10.0
"Fill"[a]	6.1[g]	4.6	6.1[g]	5.7
Internal fat[c]	1.8[h]	1.8[h]	1.6	1.1
Yield	59.3	60.5	58.5	60.0

[a]Estimated by weighing contents of the ruminant stomach.

[b](HH + MH) significantly different from (HM + MM) at $P < 0.025$.

[c]Includes easily removable fat from the stomach and pelvic cavity. No estimate was obtained in Trial I.

[d](HH + MH) significantly different from (HM + MM) at $P < 0.05$.

[e](HH + MH) significantly different from (MH + MM) at $P \ll 0.001$.

[f](HH + MH) significantly different from (HM + MM) at $P \simeq 0.07$.

[g](HH + MH) significantly different from (HM + MM) at $P \simeq 0.09$.

[h](HH + HM) significantly different from (MH + MM) at $P < 0.05$.

TABLE XXXIII

PERCENT WHOLESALE CUTS (TRIAL I)

Treatment Group	HH	HM	MH	MM
Wholesale cuts				
Round	17.9[a]	18.6	17.4[a]	18.7
Rump	4.8	5.0	4.9	4.8
Loin	14.9	14.8	14.7	14.8
Flank	7.3[b]	6.5	7.6[b]	6.7
Kidney knob	3.7	3.1	3.9	3.4
Chuck	25.3[c]	26.1	25.5[c]	26.1
Rib	8.0	8.2	8.1	7.9
Plate	8.9	8.7	8.6	8.4
Brisket	4.9	4.8	5.0	4.5
Shank	3.9[c]	4.2	3.9[c]	4.3
Hind quarter	48.5	48.0	48.5	48.4
Fore quarter	51.0[d]	52.0	51.1[d]	51.2
Major cuts[e]	70.9[f]	72.7	70.6[f]	72.3
Cheap cuts[g]	28.6[b]	27.3	29.0[b]	27.3
Wasty cuts[h]	24.7[b]	23.1	25.1[b]	23.0

[a](HH + MH) significantly different from (HM + MM) at $P \simeq 0.10$.

[b](HH + MH) significantly different from (HM + MM) at $P \simeq 0.06$.

[c](HH + MH) significantly different from (HM + MM) at $P < 0.05$.

[d](HH + MH) significantly different from (HM + MM) at $P \simeq 0.09$.

[e]Includes round, rump, loin, chuck and rib.

[f](HH + MH) significantly different from (HM + MM) at $P \simeq 0.08$.

[g]Includes flank, kidney knob, plate, brisket and shank.

[h]Includes flank, kidney knob, plate and brisket.

TABLE XXXIV

PERCENT WHOLESALE CUTS (TRIAL II)

Treatment Group	HH	HM	MH	MM
Wholesale cuts				
Round	17.3[a]	18.1	17.7[a]	18.8
Rump	5.7	5.7	5.7	5.7
Loin	15.1	15.0	14.9	14.5
Flank	6.8	6.8	7.1	6.4
Kidney knob	3.2	2.7	2.6	2.8
Chuck	25.9	25.1	25.6	26.3
Rib	7.7[a]	8.4	7.8[a]	8.3
Plate	8.6[b]	7.9	8.7[b]	7.7
Brisket	5.0[c]	5.6[c]	4.9	4.8
Shank	4.6	4.6	4.7	4.6
Hind quarter	48.1	48.3	48.0	48.2
Fore quarter	51.8	51.6	51.7	51.7
Major cuts[d]	71.7[a]	72.3	71.7[a]	73.6
Cheap cuts[e]	28.2[f]	27.6	28.0[f]	26.3
Wasty cuts[g]	23.6[h]	23.0	23.3[h]	21.7

[a](HH + MH) significantly different from (HM + MM) at $P < 0.025$.

[b](HH + MH) significantly different from (HM + MM) at $P < 0.01$.

[c](HH + HM) significantly different from (MH + MM) at $P \simeq 0.07$.

[d]Includes round, rump, loin, chuck and rib.

[e]Includes flank, kidney knob, plate, brisket and shank.

[f](HH + MH) significantly different from (HM + MM) at $P < 0.05$.

[g]Includes flank, kidney knob, plate and brisket.

[h](HH + MH) significantly different from (HM + MM) at $P \simeq 0.06$.

TABLE XXXV

PERCENT WHOLESALE CUTS (TRIAL III)

Treatment Group	HH	HM	MH	MM
Wholesale cuts				
Round	17.8[a]	18.7	17.9[a]	18.9
Rump	6.2	6.2	6.8	6.1
Loin	13.5	13.7	14.3	13.9
Flank	6.8[b]	6.4[b]	6.3	6.1
Kidney knob	2.9	2.8	2.7	2.6
Chuck	26.0	25.2	25.8	25.9
Rib	8.1	7.9	8.0	7.8
Plate	8.7	8.5	8.0	8.3
Brisket	5.3	5.4	5.2	5.3
Shank	4.5[c]	4.9	4.7[c]	5.0
Hind quarter	47.2	47.8	48.0	47.6
Fore quarter	52.6	51.9	51.7	52.3
Major cuts[d]	71.6	71.7	72.8	72.6
Cheap cuts[e]	28.2	28.0	26.9	27.3
Wasty cuts[f]	23.7	23.1	22.2	22.3

[a](HH + MH) significantly different from (HM + MM) at $P \simeq 0.09$.

[b](HH + HM) significantly different from (MH + MM) at $P \simeq 0.06$.

[c](HH + MH) significantly different from (HM + MM) at $P \simeq 0.07$.

[d]Includes round, rump, loin, chuck and rib.

[e]Includes flank, kidney knob, plate, brisket and shank.

[f]Includes flank, kidney knob, plate and brisket.

TABLE XXXVI

SPECIFIC GRAVITY READINGS
(TRIALS I, II AND III)

Treatment Group	HH	HM	MH	MM
Trial I				
Round	1.072[a]	1.080	1.077[a]	1.084
Rump	1.049[b]	1.062	1.056[b]	1.067
Loin	1.039[c]	1.035	1.044[c]	1.057
Chuck	1.055[d]	1.065	1.060[d]	1.069
Rib	1.052[c]	1.063	1.054[c]	1.068
Average (5 cuts)	1.055[e]	1.066	1.060[e]	1.070
Trial II				
Round	1.079[a]	1.080	1.078[a]	1.085
Rump	1.058[a]	1.063	1.059[a]	1.071
Loin	1.045[d]	1.050	1.045[d]	1.059
Chuck	1.062[b]	1.068	1.062[b]	1.071
Rib	1.055[c,f]	1.065[f]	1.059[c]	1.072
Average (5 cuts)	1.061[b]	1.066	1.062[b]	1.072
Trial III				
Round	1.084[g]	1.085[g]	1.090	1.095
Rump	1.061[h]	1.065[h]	1.068	1.075
Loin	1.052[b,g]	1.060[g]	1.060[b]	1.071
Chuck	1.065[g,i]	1.069[g]	1.073[i]	1.079
Rib	1.064[a,h]	1.073[h]	1.074[a]	1.081
Average (5 cuts)	1.067[a,j]	1.072[j]	1.074[a]	1.082

[a](HH + MH) significantly different from (HM + MM) at $P < 0.05$.

[b](HH + MH) significantly different from (HM + MM) at $P < 0.01$.

[c](HH + MH) significantly different from (HM + MM) at $P < 0.001$.

[d](HH + MH) significantly different from (HM + MM) at $P < 0.025$.

[e](HH + MH) significantly different from (HM + MM) at $P < 0.005$.

[f](HH + HM) significantly different from (MH + MM) at $P \simeq 0.06$.

[g](HH + HM) significantly different from (MH + MM) at $P < 0.025$.

[h](HH + HM) significantly different from (MH + MM) at $P < 0.05$.

[i](HH + MH) significantly different from (HM + MM) at $P \simeq 0.07$.

[j](HH + HM) significantly different from (MH + MM) at $P < 0.01$.

TABLE XXXVII

RIB EYE MEASUREMENTS
(TRIALS I, II AND III)

Treatment Group	HH	HM	MH	MM
Trial I				
Av. rib eye width (cm.)	5.4	5.0	5.5	5.8
Rib eye length (cm.)	12.2	12.4	12.6	13.0
Width x length (cm.^{2})	66.3	62.2	69.2	75.5
Rib eye area (in.^{2})	8.87	8.55	9.02	9.43
Av. width external fat (cm.)	1.24[a]	0.95	1.27[a]	0.58
Trial II				
Av. rib eye width (cm.)	5.8	5.3	5.5	5.5
Rib eye length (cm.)	13.2	13.1	13.1	13.7
Width x length (cm.^{2})	77.1	69.2	72.2	75.1
Rib eye area (in.^{2})	10.16	9.28	9.67	10.31
Av. width external fat (cm.)	1.22	1.20	1.16	0.96
Trial III				
Av. rib eye width (cm.)	5.2[b]	5.6	5.0[b]	5.6
Rib eye length (cm.)	12.8[c]	13.4	13.1[c]	14.0
Width x length (cm.^{2})	66.0[b]	75.0	66.1[b]	78.0
Rib eye area (in.^{2})	9.07[d]	10.25	8.94[d]	10.23
Av. width external fat (cm.)	0.83	0.80	0.59	0.73

[a](HH + MH) significantly different from (HM + MM) at $P < 0.01$.

[b](HH + MH) significantly different from (HM + MM) at $P < 0.025$.

[c](HH + MH) significantly different from (HM + MM) at $P \simeq 0.06$.

[d](HH + MH) significantly different from (HM + MM) at $P < 0.05$.

TABLE XXXVIII

PHYSICAL SEPARATION DATA (%)
(TRIALS I, II AND III)

Treatment Group	HH	HM	MH	MM
Trial I				
Lean (9-10-11th rib)	43.9[a]	49.1	45.4[a]	51.4
Fat (9-10-11th rib)	39.8[b]	32.5	38.7[b]	30.1
Bone (9-10-11th rib)	15.1[b]	17.2	14.8[b]	18.0
Lean (carcass)[c]	51.2[a]	55.3	52.4[a]	57.2
Fat (carcass)[c]	35.4[b]	29.5	34.5[b]	27.6
Bone (carcass)[c]	14.1[b]	15.3	14.0[b]	15.8
Trial II				
Lean (9-10-11th rib)	50.0[d,e]	52.9[d]	51.7[e]	56.4
Fat (9-10-11th rib)	35.8[e]	30.0	33.5[e]	28.1
Bone (9-10-11th rib)	13.6[f]	16.2	14.2[f]	14.6
Lean (carcass)[c]	56.1[d,e]	58.4[d]	57.4[e]	61.2
Fat (carcass)[c]	32.2[e]	27.6	30.3[e]	26.0
Bone (carcass)[c]	13.3[f]	14.7	13.6[f]	13.8
Trial III				
Lean (9-10-11th rib)	53.3	55.6	55.5	57.6
Fat (9-10-11th rib)	31.5	28.0	27.5	25.9
Bone (9-10-11th rib)	14.9	16.1	16.7	16.2
Lean (carcass)[c]	58.7	60.5	60.5	62.2
Fat (carcass)[c]	28.7	25.9	25.5	24.2
Bone (carcass)[c]	14.0	14.7	15.0	14.8

[a](HH + MH) significantly different from (HM + MM) at $P < 0.005$.

[b](HH + MH) significantly different from (HM + MM) at $P < 0.001$.

[c]Calculated from 9-10-11th rib data using equations of Hankins and Howe (1946).

[d](HH + HM) significantly different from (MH + MM) at $P \simeq 0.08$.

[e](HH + MH) significantly different from (HM + MM) at $P < 0.025$.

[f](HH + MH) significantly different from (HM + MM) at $P < 0.05$.

TABLE XXXIX

CHEMICAL ANALYSIS OF LEAN TISSUE
(TRIALS I, II AND III)

Treatment Group	HH	HM	MH	MM
Trial I				
Moisture (rib)	69.83[a]	69.97	69.79[a]	71.30
Protein (rib)	22.28	21.94	22.46	22.55
Ether extract (rib)	6.82	6.82	6.41	5.77
Ash (rib)	1.08	1.02	1.10	1.06
Moisture (round)	71.53	72.27	71.97	71.92
Protein (round)	21.65	21.96	21.79	22.17
Ether extract (round)	4.77	3.79	3.83	3.51
Ash (round)	1.16	1.10	1.16	1.16
Trial II				
Moisture (rib)	71.32[b]	72.20	71.57[b]	72.77
Protein (rib)	21.94	21.45	21.87	21.70
Ether extract (rib)	4.19	4.01	3.99	2.77
Ash (rib)	1.13	1.08	1.12	1.12
Moisture (round)	70.23	70.24	70.50	71.23
Protein (round)	22.01[b]	21.53	22.17[b]	21.73
Ether extract (round)	3.81	4.55	3.49	3.19
Ash (round)	1.09	1.07	1.10	1.07
Trial III				
Moisture (rib)	71.62[c]	71.64[c]	73.05	73.45
Protein (rib)	21.63	21.06	21.30	21.54
Ether extract (rib)	3.10[d]	3.88[d]	2.80	1.64
Ash (rib)	1.14	1.13	1.12	1.12
Moisture (round)	70.59	71.54	71.11	70.56
Protein (round)	22.25	21.62	22.40	22.39
Ether extract (round)	3.49	3.18	2.85	3.34
Ash (round)	1.08	1.05	1.07	1.07

[a](HH + MH) significantly different from (HM + MM) at $P \simeq 0.09$.

[b](HH + MH) significantly different from (HM + MM) at $P < 0.05$.

[c](HH + HM) significantly different from (MH + MM) at $P \simeq 0.08$.

[d](HH + HM) significantly different from (MH + MM) at $P < 0.01$.

TABLE XL

SHEAR VALUES AND ORGANOLEPTIC DATA
(TRIALS I, II AND III)

Treatment Group	HH	HM	MH	MM
Trial I				
Av. shear (rib steak)	20.90	19.33	16.97	20.23
Av. shear (round steak)	15.89	14.07	16.48	15.21
Organoleptic scores				
Tenderness	6.55	5.98	6.24	6.67
No. of chews	29.0	30.4	28.1	26.7
Juiciness	7.00	6.31	6.77	6.84
Trial II				
Av. shear (rib steak)	14.30[a]	13.56[a]	16.09	16.20
Av. shear (round steak)	12.65	14.50	14.49	15.81
Organoleptic scores				
Tenderness	6.42	6.18	6.69	6.41
No. of chews	21.6	24.9	23.2	24.0
Juiciness	6.42	6.28	6.53	6.69
Trial III				
Av. shear (rib steak)	16.12	15.37	16.61	14.19
Av. shear (round steak)	16.83	17.12	17.00	14.02
Organoleptic scores				
Tenderness	6.53	6.17	6.69	6.16
No. of chews	16.4	17.3	15.8	17.0
Juiciness	6.25	5.80	6.15	5.63

[a](HH + HM) significantly different from (MH + MM) at $P \simeq 0.08$.

TABLE XLI

EFFICIENCY ON A CARCASS BASIS
(TRIAL I)

Treatment Group	HH	HM	MH	MM
Total lean (lb.)[a]	280.8	288.8	278.8	298.2
Total fat (lb.)[a]	194.3[b]	154.2	183.6[b]	143.5
Lb. TDN/lb. of				
Carcass[c]	9.7[d]	10.6[d]	9.4	9.3
Fat and lean[c]	10.7[d]	12.2[d]	10.3	10.6
Lean[c]	25.7[e]	23.3	24.2[e]	18.6
Therms NE/lb. of				
Carcass[c]	9.0[f]	9.4[f]	8.6	8.0
Fat and lean[c]	9.9[f]	10.8[f]	9.4	9.1
Lean[c]	23.9[d,e]	20.7[d]	22.0[e]	16.0
Cal. feed/cal. fat and lean[c]	10.2[e]	13.1	10.1[e]	11.8
Lb. crude protein/lb. carcass protein[c]	18.8[e]	17.6	18.2[e]	14.1

[a]Calculated from 9-10-11th rib physical separation data (Hankins and Howe, 1946).

[b](HH + MH) significantly different from (HM + MM) at $P < 0.001$.

[c]Calculated using 9,367 kcal./kg. fat (Blaxter and Rook, 1953), 5,686 kcal./kg. protein, 21.64 percent protein on fat-free basis (Reid *et al.*, 1955) and 1,982 kcal./lb. TDN (Swift, 1957). Theoretical initial yield (56%), lean (63%) and fat (20%) were used.

[d](HH + HM) significantly different from (MH + MM) at $P \simeq 0.08$.

[e](HH + MH) significantly different from (HM + MM) at $P < 0.05$.

[f](HH + HM) significantly different from (MH + MM) at $P < 0.05$.

TABLE XLII

EFFICIENCY ON A CARCASS BASIS
(TRIAL II)

Treatment Group	HH	HM	MH	MM
Total lean (lb.)[a]	306.9[b]	302.6[b]	305.0	340.5
Total fat (lb.)[a]	176.4[c]	143.2	161.4[c]	144.7
Lb. TDN/lb. of				
Carcass[d]	10.2[e]	11.5	10.1[e]	11.2
Fat and lean[d]	10.9[f]	12.9	11.0[f]	12.2
Lean[d]	21.0	21.7	19.6	18.9
Therms NE/lb. of				
Carcass[d]	9.6	10.3	9.2	9.8
Fat and lean[d]	10.2	11.5	10.0	10.6
Lean[d]	19.7	19.4	17.9	16.5
Cal. feed/cal. fat and lean[d]	11.3[g]	14.6	11.8[g]	14.5
Lb. crude protein/lb.				
Carcass protein[d]	16.3	17.4	15.5	15.2

[a]Calculated from 9-10-11th rib physical separation data (Hankins and Howe, 1946).

[b](HH + HM) significantly different from (MH + MM) at $P \simeq 0.10$.

[c](HH + MH) significantly different from (HM + MM) at $P < 0.025$.

[d]Calculated using 9,367 kcal./kg. fat (Blaxter and Rook, 1953), 5,686 kcal./kg. protein, 21.64 percent protein on fat-free basis (Reid et al., 1955) and 1,982 kcal./lb. TDN (Swift, 1957). Theoretical initial yield (56%), lean (63%) and fat (20%) were used.

[e](HH + MH) significantly different from (HM + MM) at $P \simeq 0.10$.

[f](HH + MH) significantly different from (HM + MM) at $P < 0.05$.

[g](HH + MH) significantly different from (HM + MM) at $P < 0.005$.

TABLE XLIII

EFFICIENCY ON A CARCASS BASIS
(TRIAL III)

Treatment Group	HH	HM	MH	MM
Total lean (lb.)[a]	294.7	305.7	300.0	308.6
Total fat (lb.)[a]	145.2	131.4	127.3	122.1
Lb. TDN/lb. of				
Carcass[b]	11.9	11.2	10.7	11.4
Fat and lean[b]	12.9	12.3	12.2	11.7
Lean[b]	21.9	19.4	19.0	18.2
Therms NE/lb. of				
Carcass[b]	11.0[c]	10.2[c]	9.7	10.1
Fat and lean[b]	12.0	11.1	11.1	10.4
Lean[b]	20.3	17.6	17.3	16.2
Cal. feed/cal. fat and lean[b]	14.5	14.6	14.6	14.5
Lb. crude protein/lb. carcass protein[b]	17.2	16.5	15.4	15.4

[a]Calculated from 9-10-11th rib physical separation data (Hankins and Lowe, 1946).

[b]Calculated using 9,367 kcal./kg. fat (Blaxter and Rook, 1953), 5,686 kcal./kg. protein, 21.64 percent protein on fat-free basis (Reid et al., 1955) and 1,982 kcal./lb. TDN (Swift, 1957). Theoretical initial yeild (56%), lean (63%) and fat (20%) were used.

[c](HH + HM) significantly different from (MH + MM) at $P \simeq 0.10$.

TABLE XLIV

CORRELATIONS BETWEEN LIVE ANIMAL MEASUREMENTS AND SUBJECTIVE GRADING SCORES[a]

Variable[b]	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Live animal scores								
Compactness	-0.15	-0.03	-0.04	0.18	0.43	0.04	-0.04	0.42
Width of body	-0.31	-0.26	-0.10	-0.11	0.16	-0.36	0.20	0.07
Crops	-0.17	-0.26	0.00	-0.03	0.00	-0.35	0.21	-0.02
Loin	-0.32	-0.31	-0.10	-0.17	0.09	-0.36	0.23	0.00
Rump	-0.30	-0.24	-0.10	-0.16	0.07	-0.32	0.22	-0.01
Quarter	-0.34	-0.26	-0.20	-0.13	0.15	-0.28	0.16	0.06
Muscling	-0.29	-0.30	-0.10	-0.09	0.05	-0.32	0.24	0.00
Thickness of fat	-0.29	-0.32	-0.09	-0.08	0.05	-0.41	0.31	0.00
Live slaughter grade	0.02	-0.31	0.24	-0.05	-0.25	-0.40	0.50	-0.21
Carcass scores								
Compactness	0.15	-0.10	0.23	0.23	-0.04	-0.05	0.27	0.08
Thickness	-0.21	-0.27	-0.09	-0.09	-0.11	-0.44	0.29	-0.13
Rib eye (lean)	-0.18	-0.25	-0.04	-0.12	-0.18	-0.41	0.11	-0.20
Loin	-0.22	-0.26	-0.16	-0.17	-0.09	-0.47	0.22	-0.15
Round	-0.12	-0.21	-0.05	-0.06	-0.14	-0.25	0.24	-0.13
Fat thickness	-0.02	-0.20	0.11	-0.11	-0.16	-0.47	0.37	-0.18
Carcass grade	0.09	-0.14	0.25	-0.06	-0.25	-0.46	0.51	-0.22

[a] $r = 0.217$ at $P = 0.05$ and 0.283 at $P = 0.01$.

[b] X_1 = width of shoulder, X_2 = width of loin, X_3 = width of round, X_4 = height at withers, X_5 = length of body, X_6 = heart girth, X_7 = av. of width meas. and X_8 = av. of length meas.

TABLE XLV

CORRELATIONS BETWEEN CARCASS MEASUREMENTS AND SUBJECTIVE GRADING SCORES[a]

Variable[b]	X_1	X_2	X_3	X_4	X_5	X_6
Live animal scores						
Compactness	0.46	0.45	0.12	0.56	0.02	0.06
Width of body	0.14	0.16	-0.01	0.27	-0.34	-0.12
Crops	0.16	0.17	0.01	0.25	-0.26	-0.07
Loin	0.08	0.09	-0.05	0.17	-0.40	-0.10
Rump	0.07	0.06	-0.03	0.15	-0.23	-0.16
Quarter	0.07	0.11	-0.06	0.20	-0.24	-0.14
Muscling	0.11	0.10	0.02	0.17	-0.33	-0.13
Thickness of fat	0.14	0.18	0.01	0.20	-0.33	-0.09
Live slaughter grade	0.24	0.30	0.16	0.23	-0.22	0.00
Carcass scores						
Compactness	0.44	0.47	0.18	0.46	-0.07	0.20
Thickness	0.08	0.14	0.03	0.19	-0.35	-0.05
Rib eye (lean)	-0.05	-0.05	-0.04	0.02	-0.28	-0.12
Loin	-0.03	-0.02	-0.10	0.07	-0.39	-0.08
Round	0.14	0.21	0.07	0.18	-0.26	-0.08
Fat thickness	0.07	0.14	0.06	0.11	-0.28	0.00
Carcass grade	0.23	0.26	0.17	0.24	-0.18	0.00

[a] $r = 0.217$ at $P = 0.05$ and 0.283 at $P = 0.01$.

[b] X_1 = carcass length, X_2 = length of leg, X_3 = depth of body, X_4 = length of loin, X_5 = width of shoulder and X_6 = width of round.

VITA

Robert F. Hendrickson

Candidate for the Degree of

Doctor of Philosophy

Thesis: SOME EFFECTS OF DIFFERENT PLANES OF NUTRITION ON CARCASS CHARACTERISTICS OF FATTENING STEER CALVES AND RELATIONSHIPS AMONG VARIOUS LIVE ANIMAL AND CARCASS MEASUREMENTS

Major Field: Animal Nutrition

Biographical:

Personal Data: Born in LaCrosse, Wisconsin, September 12, 1934, the son of Howard O. and Mary J. Hendrickson. Married Norma K. Reitan, August 6, 1961.

Education: Received the Bachelor of Science degree in Agriculture, with a major in Animal Husbandry, from the University of Wisconsin, in June, 1956. Received the Master of Science degree, with a major in Animal Husbandry, from Oklahoma State University, in May, 1961.

Experiences: Raised on a farm in Western Wisconsin. Graduate Assistant in Animal Husbandry at Oklahoma State University, 1956-61.

Professional Organizations: Member of American Society of Animal Production and of Alpha Zeta, and Associate Member of Sigma Xi.

Date of Degree: August 11, 1962