THE USE OF LEG-LOIN CROSS-SECTIONAL TRACINGS FOR PREDICTION OF LAMB CARCASS COMPOSITION

By

ROBERT N. SPROWLS

Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1951

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 1971

THE USE OF LEG-LOIN CROSS-

SECTIONAL TRACINGS FOR

PREDICTION OF LAMB

CARCASS COMPOSITION

Thesis Approved:

Joe V. Whiteman

Thesis Adviser

Lowell E. Walters

Irwin T. Omtvedt

D. Durham

Dean of the Graduate College

ACKNOWLEDGMENTS

The author wishes to express his appreciation to Dr. Joe V. Whiteman, Professor of Animal Science, for counsel and guidance during the course of this study and in the preparation of this thesis.

Appreciation is also extended to Dr. L. E. Walters, Professor of Animal Science, for his supervision in the collection of carcass data used in this study and his assistance in the preparation of this thesis.

Further acknowledgment is extended to Dr. Arvid W. Munson, Ralston Purina Company, for work in collection of the carcass data used in this study.

Appreciation is also extended to Dr. R. D. Morrison of the Mathematics and Statistics Department and Mr. Don Holbert, Graduate Assistant, Department of Mathematics and Statistics, for their assistance in the analyses of the data.

Additional thanks are extended to fellow graduate students in the Department of Animal Sciences and Industry for their assistance during the course of this study.

The author extends appreciation to Mrs. Carol Taylor for typing this manuscript.

Special recognition is extended to the author's wife, Frances, and their children, James, Ken and Linda, for their understanding during the two years involved in this undertaking.

TABLE OF CONTENTS

Chapter		Page
I.	INTRODUCTION	1
II.	REVIEW OF LITERATURE	3
III.	MATERIALS AND METHODS	15
	Statistical Analysis	21
IV.	RESULTS AND DISCUSSION	26
	Correlations	26
	Correlations With Fat	27
	Correlation With Lean	29
	Correlations With Bone	32
	Prediction of Carcass Composition	34
	Prediction of Carcass Fat	34
	Prediction of Carcass Lean	41
	Prediction of Carcass Bone	46
	Cross-Sectional Tracing Equations	50
	Equations for Fat Differences	51
	Equations for Lean Differences	53
	Equations for Bone Differences	58
V.	SUMMARY	62
LITERATURE CITED		65
APPENDIX		69

LIST OF TABLES

Table		Page
I.	Intra-Year, Type of Rearing and Face Color Simple Correlations Between Independent Variables and Carcass Fat	28
II.	Intra-Year, Type of Rearing and Face Color Simple Correlations Between Independent Variables and Carcass Lean.	30
III.	Intra-Year, Type of Rearing and Face Color Simple Correlations Between Independent Variables and Carcass Bone.	33
IV.	Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Total Carcass Fat.	35
V.	Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Percentage Carcass Fat.	37
VI.	Comparison of Actual and Estimated Fat Deviations and Rank for Fat of 1963 Whiteface, Single Reared Lambs	40
VII.	Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Total Carcass Lean	42
VIII.	Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Percentage Carcass Lean.	44
IX.	Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Total Carcass Bone	47

Table		Page

Table		Page
X.	Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Percentage Carcass Bone	49
XI.	Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Total Carcass Fat	52
XII.	Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Percentage Carcass Fat	54
XIII.	Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Total Carcass Lean	55
XIV.	Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Percentage Carcass Lean	57
XV.	Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Total Carcass Bone	59
XVI.	Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Percentage Carcass Bone	60
XVII.	Overall Means and Standard Deviations for Various Lamb Carcass Measurements	70
XVIII.	Intra-Year, Type of Rearing and Face Color Simple Correlations Between Various Carcass Traits	71
XIX.	Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Total Carcass Fat	72
XX.	Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Percentage Carcass Fat	73

Table		Page

XXI. Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Total Carcass Lean 74

XXII. Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Percentage Carcass Lean. 75

XXIII. Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Total Carcass Bone 76

XXIV. Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Percentage Carcass Bone. 77

XXV. Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Total Carcass Fat. 78

XXVI. Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Total Carcass Fat. 79

XXVII. Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Percentage Carcass Fat. 80

XXVIII. Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Percentage Carcass Fat. 81

XXIX. Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Total Carcass Lean 82

XXX. Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Total Carcass Lean 83

XXXI. Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Percentage Carcass Lean. 84

Table		Page

XXXII. Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Percentage Carcass Lean. 85

XXXIII. Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Total Carcass Bone 86

XXXIV. Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Total Carcass Bone 87

XXXV. Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Percentage Carcass Bone. 88

XXXVI. Multiple Regression Equations Calculated on a Within Year, Rearing and Face Color Basis for Estimating Percentage Carcass Bone. 89

LIST OF FIGURES

Figure | Page

1. Posterior Surface of the Loin 90

CHAPTER I

INTRODUCTION

Knowledge of carcass composition is essential for the animal breeder if selection is to be effective for developing the efficient muscle production necessary for the modern meat-type animal. Knowledge of carcass composition is also needed by the nutritionist to better formulate rations to produce quality carcasses. A simple, inexpensive method of determining the relative amounts of fat, lean and bone of beef, pork and lamb carcasses has long been sought. Such a method would be of benefit to both the researcher and producer.

Various methods have been used in the past for the estimation of carcass composition. Visual appraisal, alone and combined with weight, has long been used to estimate carcass composition, but precise predictions by this method have not been attained. Although various single measurements such as specific gravity determinations, loin fat trim, physical composition of various cuts and fat thickness measurements have been used for estimation of the carcass components by regression equations, many researchers have found that by use of several measurements in one equation, greater precision has been obtained for the prediction of carcass composition.

Physical separation methods and chemical determination of the carcass are the most reliable means of determining carcass composition. These two methods are time consuming and expensive as they require destruction of the physical shape of the carcass.

The purposes of this study are to determine correlation coefficients for various measurements of the lamb carcass with carcass fat, lean and bone expressed both as pounds and as a percentage of the total carcass composition, to evaluate cross-sectional tracing measurements of the leg-loin junction expressed as area (square inches) and as a percentage of the total area, and to formulate stepwise linear regression equations for estimating within group differences of fat, lean and bone of lamb carcasses.

CHAPTER II

REVIEW OF LITERATURE

Researchers have long been interested in predicting carcass composition. Lush (1926) reported the correlation between carcass fat and percent offal fat in cattle to be 0.84 and reported that it was a reliable single predictor of carcass fat. He also stated that the use of dressing percent with percent offal fat had a multiple correlation coefficient of 0.93 with carcass fat.

Palsson (1939) investigated the use of sample joints to estimate carcass composition. He reported various carcass measurements that could be used as indices of carcass composition. His work indicated that the leg was early developing and contained little fat and that the loin was a late developing portion of the body which accumulated fat with maturity. He reported that the multiple correlation coefficients of the combined leg and loin with the total carcass lean and bone were 0.97, 0.92 and 0.97, respectively. These high coefficients were due to the wide variation of the population in this study.

He stressed that external carcass measurements were not as indicative of fat and muscle as they were of skeletal size. He reported a correlation coefficient of 0.96 for the weight of the four cannon bones to the total bone weight. He determined correlation coefficients of 0.67, 0.47 and 0.77 between the length, depth and length plus depth of the longissimus dorsi between the 12th and 13th ribs with carcass muscle. The thickest lower rib fat measurement at this location was determined to have a correlation coefficient of 0.82 with total carcass fat.

Other researchers have used various cuts as indices to total carcass composition. The rack, leg and loin are used for methods of physical separation and for specific gravity determinations.

Hankins (1947) reported the rack to be the best indicator of carcass composition in a study of 64 widely varying sheep carcasses. The method of physical separation was used to determine separated fat, lean and bone and the respective correlation coefficients between these values and carcass fat, lean and bone were 0.98, 0.92 and 0.97. The correlation coefficient determined between ether extract of the rack and ether extract of the total carcass was 0.98.

Barton and Kirton (1958b) reported on the use of the leg and loin as indices of the composition of New Zealand lamb and mutton carcasses when dissected into fat, lean and bone and correlated to the corresponding tissue of the total carcass. Fifty yearling ewe and wether carcasses and 70 lamb carcasses were used in this study. Ease of physical separation influenced the use of the leg and loin as sample joints even though the thorax was a better indicator. The use of the leg and loin in combination gave a more precise estimate of the total fat in the carcass than either joint alone. Of the two joints, the loin was a more accurate indicator of total carcass fat.

Adams and Carpenter (1970) reported a study using wholesale cuts for specific gravity determinations. The specific gravity of the rack had the highest negative correlation to carcass fat trim. The rack was also physically separated into fat, lean and bone. Chemical composition was then determined for the fat and lean portions of the rack. Both percent separable fat (37.78%) and lean (45.52%) of the rack were good indicators of measures of value in the carcass. They stated that the rack had an advantage over the other wholesale cuts for the separation method as it represented eight percent of the total carcass weight and required on the average one hour to separate into components.

Field et al. (1963a) in a study of 165 crossbred lambs utilizing specific gravity determinations and physical separation methods found the rib to be the best estimator of carcass fat and bone when physical separation was used.

Timon and Bichard (1965) reported results from two studies where 83 wether lamb carcasses ranging in weight from 29 pounds to 42 pounds were used. Carcass specific gravity obtained by adding of weights obtained from seven joints explained 86.1 percent and 78.1 percent of the variance of carcass fat and lean, respectively. When sample joints were used to predict carcass composition it was found that the loin was the most valuable predictor of total carcass composition and that the leg and shoulder were the preferred indices for prediction of bone. In both studies they stated that their prediction methods were not accurate enough to detect individual differences or small treatment differences.

Latham et al. (1966) in a study with 121 Prime and Choice crossbred lambs weighing 40 kg. at an average age of 196 days ± 42 days determined that the physical composition of the leg was a precise estimator of carcass composition. Groups of lambs of the same weight and grade but different genetic backgrounds were found to have similar carcass composition. Specific gravity values determined in this study were not precise for predicting carcass fat or lean.

Barton and Kirton (1956) reported a study of the relationship between specific gravity of the whole carcass, half carcass and certain joints to the percent fat of the carcass. Three groups of pasture-fed five to six year old Rommey ewes were used in this study. They reported that specific gravity methods as used for estimating percent fat of the carcass for other species may also be used for estimating percent fat of sheep carcasses.

Pradham et al. (1966) reported that specific gravity of the leg was a good index of chemical composition of the carcass and was more highly related to percent protein of the carcass than to percent fat of the carcass.

The relationship of specific gravity and dressing percent to carcass composition and the relationship of parts to the whole carcass was reported by Kirton and Barton (1962). Their results indicated that dressing percent was not satisfactory to estimate either carcass fat or protein. They found the right half of the loin to be the best predictor of carcass composition. Their low correlations between specific gravity and carcass fat were unexpected and they stated that use of an entire side was of more value than use of parts of the carcass to determine specific gravity.

Munson (1966) studied 123 crossbred lambs slaughtered at a constant weight and found that the weight of the four cannon bones accounted for 66 percent of the variation in percent carcass bone. The hindsaddle specific gravity was superior to the whole carcass specific gravity as a predictor of carcass fat and lean and accounted for 47 and 46 percent of the variation of the two components. Loin fat trim weight was the best indicator of carcass fat and lean accounting for 64 and 57 percent, respectively, of their variation. These results were confirmed in a separate study by Richards (1967).

Adams and Carpenter (1970) reported a study which was conducted using 46 ewe and wether Blackface x Rambouillet crosses. This study involved comparisons of specific gravity determinations of the whole carcass, foresaddle, hindsaddle and hindsaddle with kidney and kidney fat removed. Composition estimates were made utilizing the equations presented by Timon and Bichard (1965) and Meyer (1962). The specific gravity of the hindsaddle was found to be the best predictor of carcass composition. They stated that additional precision was needed for this method to be widely used.

Spurlock et al. (1966) reported the prediction of carcass traits in lambs using live animal and carcass measurements. Thirty-one Targhee ram lambs weighing 44 kg. were measured alive and then slaughtered and carcass measurements taken. They reported that when live animals were probed with a 22-gauge hypodermic needle behind the shoulder over the center of the left seventh rib, approximately midway between the dorsal and ventral surfaces of the body that the correlation coefficient between this probe and percent trimmed cuts was -.70. The correlation between fat measurement made at the l. dorsi after slaughter and percent trimmed cuts was -.49. Live shrunk weight was the most highly correlated single measurement to weight of trimmed cuts ($r = 0.96$) because of the pounds to pounds relationship that heavy carcasses have more trimmed cuts than small carcasses.

Hiner and Thornton (1962) determined body width (an average measure of width through the shoulders, loin and legs) and carcass weight as the best predictors of pounds of the more preferred trimmed cuts and expressed the thought that the results of their study indicated that rather accurate predictions could be made from measurements of live animals and carcasses that would be of value to both producers and packers in estimating these cuts. These results were also due to a pounds to pounds relationship.

Riley and Field (1969) in a study of data from 299 ewe, 265 wether and 64 ram lamb carcasses which were slaughtered at 50 kg.

live weight, obtained prediction equations for estimating percent carcass fat, percent retail cuts and weight of retail cuts using body wall thickness, fat depth 3.8 cm. from the midline between the 12th and 13th ribs and kidney weight that did not require breaking the carcass down. The equations using body wall thickness and fat depth had multiple correlation coefficients of 0.72 and 0.87 and standard errors of estimates of 2.95 and 3.90 for predicting percent fat of the boneless carcass of ewes and of boneless carcass of wethers and rams, respectively.

Kemp et al. (1970) in a study of the relationships of lamb carcass measurements and sample cut composition to carcass side composition, which utilized 63 wether and 63 ewe carcasses ranging in weight from 7.98 to 22.9 kg. and in grade from Prime to Utility, reported, "There was no significant correlation between sex and chemical composition of the side." However this may be because most of the lambs were slaughtered before fully developing secondary sex characteristics. Correlations of percent chemical composition of major cuts (cut New Zealand style) with percent chemical composition of the carcass were higher than correlations of percent wholesale cuts (cut American style) with percent chemical composition of the carcass.

Of the measurements taken, the minimum width behind the scapulae and fat depth at four places at the 12th rib had highest correlations with composition of the carcass. Water, protein and ash in the cuts were positively correlated with water, protein and ash in the carcass, but fat did not follow these same general patterns.

Barton and Kirton (1958a) reported on carcass weight as an index of carcass components with particular reference to fat. This study involved the use of carcass weights and chemical analyses of total half carcasses of 48 six-year-old ewes and 120 cold storage carcasses of various sizes. They reported that dissectible fatty tissue was more highly correlated with carcass weight in mature sheep than lambs when compared to correlations between carcass weight and muscular tissue. In lambs, fat and lean were laid down at about equal rate, while mature ewes lay down fat twice as fast as lean tissue. The relationship of carcass weight and carcass fat differ for different breeds. The methods used in this study were not precise for detection of small differences of carcass composition.

Hoke (1961) reported data on factors causing variation in yield of retail cuts in lamb carcasses. He utilized 166 lamb carcasses within eight grade-weight groups selected to be typical or highly variable. The results indicated that grade alone was not a reliable indicator of yield of retail cuts. Fat thickness was correlated to yield of retail cuts in Prime, Choice and Good grades, but not for Utility and Cull grades. Fat thickness at the 12th rib was the most reliable single measurement in higher grades. Fat thickness, conformation, grade and percent kidney fat accounted for 78 percent of the variation in yield of retail cuts and the addition of carcass weight made no improvement in yield estimates.

Judge et al. (1966) in a study utilizing 23 ewe and 28 wether lamb carcasses developed prediction equations using the mean of three fat thicknesses over the l. dorsi, kidney and kidney fat weight, and chilled carcass weight to estimate percent edible portion of the carcass. For ewe, wether and combined groups of carcasses the multiple correlation coefficients determined for these equations were 0.77, 0.85 and 0.77, respectively, with standard errors of estimate of 2.67, 2.54 and 2.83 percent.

Judge et al. (1963) reported that measurements made from a tracing of the carcass cross-section between the 12th and 13th rib of the l. dorsi area and linear fat measurements were equal or better predictors of carcass composition than estimates made by use of a K^{40} counter on both live lambs and carcasses. They stated that the K^{40} counts were thought to be inaccurate due to the nonedible components of the live lambs.

Schoonover and Stratton (1957) reported a method of using a photographic grid to measure rib eye areas in beef carcasses and from this work derived the following equation.

$$\text{proportion (\%) of lean} = \frac{\text{rib eye area}}{\text{rib eye area} + \text{area of external fat}}$$

They reported a correlation of 0.86 between the proportion (%) of lean determined by this equation and the percent lean estimated by the specific gravity of the 9th, 10th and 11th rib cut. This limited data indicates that the area of external fat and area of rib eye as determined from the photographic grid method may be directly related to carcass composition.

Carpenter et al. (1969) in a study of 202 ewe, 276 wether and 207 ram lamb carcasses with a weight range of 13 to 33 kg. concluded that precision is likely to be increased if separate analyses are developed for the various sex groups. They further stated that conformation evaluation may be in error as an estimate of muscling if a thick cover of subcutaneous fat is on ewe and wether carcasses.

Spurlock and Bradford (1965) made a comparison of six systems of lamb carcass evaluation. Two groups of lambs, one consisting of 30 lambs selected on a grade basis to get a wide distribution of fatness and the other group of 26 lambs not selected, were used to obtain live, slaughter and carcass data simultaneously for the different systems of evaluation. The systems were: University of California Score, Reciprocal Meat Conference System, Wyoming Index, Purdue Index, U.S.D.A. Index and Kentucky Index. The Kentucky, Purdue and U.S.D.A. Indices were found to be the more precise predictive systems. Specific gravity of the carcass was correlated to carcass fat at 0.90. In uniform lamb carcasses, loin eye area and fat measures between the 12th and 13th ribs had some degree of precision for predicting carcass composition.

Andrews and Orskov (1970) reported changes in body composition due to the effect of dietary protein concentration, feeding level and sex. Sixty-six ram and 33 ewe lambs weighing 15 kg. were obtained for this study. Six males and three females were slaughtered and analyzed and the other ninety lambs were stratified into six blocks of four males and two females each by live weight and then allocated into one of fifteen dietary treatments, five protein levels and three levels of feeding. Thirty males were slaughtered at 27.5 kg. and the rest at 40 kg. The carcass and non-carcass components were then chemically analyzed. They reported that as protein in the feed increased, the protein in the body increased and the body fat decreased. At 27.5 kg. there were no significant effects of feed levels on nitrogen and ether extract of the carcasses, but at 40 kg. there was a significant decrease in ether extract with increased feeding levels of all protein levels and an increase in body nitrogen.

Rouse et al. (1970) reported on carcass composition of lambs at three stages of development. Feeder lambs weighing 32 kg. and market lambs weighing 46 or 50 kg. were slaughtered without removing the head and pelt and then frozen in a standing position. They were then transversely cross-sectioned with a band saw at six locations. Each exposed cross-sectioned area was traced on acetate paper and the ratios of fat, lean and bone were obtained by using a calibrated grid. Each section was then skinned and evaluated by a specific gravity determination and dissected into separable fat, lean and bone. These components were finely chopped and mixed. Nitrogen, moisture and ether extract values were determined in duplicate for each sample using A. O. A. C. procedures (1960). The order of tissue maturation was reported as bone, lean and fat. Based on the 50 kg. weight group, three-fourths of the bone, one-half of the lean and one-third of the fat development occurred before the lambs weighed 32 kg. As live weight increased from 32 to 50 kg. the proportions of separable bone and separable lean decreased 6.1 and 3.8 percent, respectively, while the proportion of separable fat increased 9.9 percent. When cross-sectional surface areas were compared to the physical separation data, the bone area was the most reliable estimator, but was not precise enough to predict individual carcasses.

The review of literature indicated that specific gravity of the hindsaddle is a reasonably reliable simple measurement used to predict percent fat and lean in lamb carcasses. When physical separation methods are used, the rack is the most valuable cut for this method. Numerous researchers have stated that the area of the l. dorsi and fat thickness at the 12th rib are indicators of fat and lean in carcasses that vary widely. The leg and loin have been found to be valuable as indicators of carcass composition. The weight of the four cannon bones is a reliable predictor of percent bone in the carcass. Loin fat trim has been found to be a valuable indicator of carcass composition. Prediction equations using a combination of carcass measurements have been found to have greater precision in the prediction of total carcass composition than equations using only one variable.

CHAPTER III

MATERIALS AND METHODS

Sixty wether lambs were obtained in 1963 from the experimental flock at the Fort Reno Livestock Research Station. An additional 64 wether lambs were again selected in 1964. These lambs were all produced from grade Rambouillet ewes or Rambouillet x Dorset crossbred ewes. In each year, one-half of the lambs were sired by Dorset (whiteface) rams and the other half by Hampshire or Suffolk (blackface) rams. From the progeny of each sire, equal numbers of single and twin-reared lambs were utilized in the study. The only exception being in 1964 when one twin-reared lamb sired by a Dorset ram died before the completion of the study.

In both years the lambs were born between October 10 and November 25. The lambs and their dams were placed on wheat pasture when the lambs were ten days to two weeks of age. Creep feed consisting of a mixture of 32 percent ground alfalfa hay, 63 percent ground grain sorghum and 5 percent molasses was available at all times. Upon obtaining a minimum weight of 46 pounds and a minimum age of 66 days the lambs were weaned by removing the ewes from the pasture.

The lambs were weighed on a biweekly basis until they approached 95 pounds at which time the weights were taken weekly. Each week the lambs which had reached a full weight of one hundred pounds were taken off feed and transported to Stillwater (100 miles). The lambs were sheared on this same day and then slaughtered the next morning at the University Meat Laboratory after having been weighed following an 18-hour shrink. This weight was recorded as the shrunk live weight. The A. M. S. A. recommended slaughter procedure for lambs as described by Galloway (1953) and Zinn (1961) was followed for all lambs.

Precautionary measures were taken to minimize the entrapment of air during the determination of specific gravity. After the bung was dropped a 1 x 1 inch wooden plug was placed in the pelvic cavity to prevent the pelvic fat from forming potential air traps. The sternum was split and the ventral midline cut was held open by use of pork carcass flank spreaders. The kidney fat was pinned posterior to the 13th rib so as to remain with the hindsaddle. The spleen, right and left crura of the diaphram and the thymus glands were removed.

After slaughter the hot carcass weight was recorded, then the carcass was placed in a cooler at 34 to 38 degrees Fahrenheit for 48 hours. The cold carcass weight was then recorded. The carcass was photographed for further reference and graded as it hung on the rail.

A steel swine backfat probe was used to obtain the fat depth over the second sacral vertebra by probing approximately three inches anterior to the base of the tail directly over the dorsal vertebral process.

Specific gravity determinations were made by hydrostatic weighing as described by Rathbun and Pace (1945) and Whiteman et al. (1953) with care being taken to follow the necessary precautions as outlined in these two studies. The tank and water temperature was maintained at 34 to 38 degrees Fahrenheit so as to be constant with the carcass temperature. Carcass weights were obtained to the nearest five hundredths of a pound in a precise manner. The following formula was used for determining specific gravity of the carcasses:

$$\text{Specific Gravity} = \frac{\text{Weight of Carcass in Air}}{\text{Weight of Carcass in Air} - \text{Weight of Carcass in Water}}$$

Twenty minutes drying time was allowed for each carcass after being weighed in water.

To facilitate the removal of the breast, flank and shank at a later time the carcass was scored with a slight knife cut from the point of the patella to the junction of the humerus and radius on both sides. The carcass was then divided into fore and hindsaddle between the 12th and 13th ribs by making a cut perpendicular to the line of the back and thereby across the ventral tips of the 11th and 12th ribs. Specific gravity determinations were then made for both the fore and hindsaddles and recorded in the same manner as described previously for the whole carcass. Again a 20 minute drying period was allowed for each of the two saddles.

The carcass was then divided into wholesale cuts. The flanks were removed by a cut from the crotch out to and along the scored line made earlier. The pelvic and kidney fat was removed. The weight of the kidney and kidney fat was recorded. The leg and loin were then separated by a cut perpendicular to the line of the back between the second and third sacral vertebrae. By sawing through the tibia-metatarsal joint at the thickest part, the shanks were separated from the legs.

The breast and foreshank were removed from the foresaddle by cuts along the previously scored lines, and from each other by separation at the natural seam. A cut, perpendicular to the line of the back, between the fifth and sixth ribs, separated the rack from the shoulder. The neck was then removed from the shoulder by a cut which would be a continuation of the line of the back.

The posterior surfaces of the shoulder, rack and loin of each carcass was photographed. Tracings were made of these surfaces on transparent acetate paper and each area was designated as either fat, lean or bone so as to allow future measurements to be taken of these carcass cross-sections.

Specific gravity determinations were then made and recorded for the four major untrimmed wholesale cuts (shoulder, rack, loin and leg) in the same manner as previously described.

The weight of the subcutaneous fat which was trimmed from each of the four major wholesale cuts was recorded as the fat trim of each particular cut. These four cuts were then completely boned with extreme care to have all lean removed from the bones. Fat and lean were not separated. The boneless portion was termed as the edible portion. The bone weight was recorded for each cut.

The weight of only the right fore cannon bone (metacarpal) was recorded to the nearest gram in 1963, but in the second year of the study, 1964, the weight of all four cannon bones was recorded.

The remainder of the carcass, the neck, fore shank, breast and flank were completely boned. The bones which had been secured from the entire carcass were then weighed and that weight recorded. In preparation for grinding, the edible portion and the fat trim of the entire carcass were mixed together. The kidney and pelvic fat were not returned to this mixture. This boneless portion of the lamb carcass was then ground and sampled for chemical analysis according to the procedure of Munson et al. (1965). Two composite samples composed of four random, 50 gram, "grab" samples were used as duplicate determinations for each lamb carcass. This chemical analysis was done as prescribed by A. O. A. C. (1955) to include percent moisture and ether extract. The determination of carcass composition was done by determining the percent ether extract of the boneless portion of the carcass. To this was added the percentage separable bone and the lean portion of the carcass was then determined by difference.

The tracings of the posterior surface of the rack were used to determine the area of the longissimus dorsi muscle and the fat cover over this muscle. The average of three measurements taken on each side of the vertebra in a manner described by Kemp (1961) was recorded as the 12th rib fat. A compensating polar planimeter was used to measure the area of the longissimus dorsi. The recorded measurement was the average of values obtained for the right and left sides of the carcass.

The loin-leg cross-sectional tracing was measured by use of a compensating polar planimeter. The values recorded were averages of two independent measurements of each component. As a measurement of technique error, the standard deviation of the differences was computed. These standard deviations were .02, .02 and .01 (sq. in.) for fat, lean and bone, respectively. The three components of the carcass cross-section, e.g., fat, lean and bone, were recorded both as percentage of the total cross-section area and as square inches of the respective component area. Twenty-one tracings made in 1963 and four tracings made in 1964 were found to be incomplete as to labeling of the components (fat, lean or bone) or as to the omission of a dividing line between two components. Correction of these omissions were made by a comparison of the tracing with the photographic slide which was made at the same time as the tracing. The exception to this procedure was made when the slides corresponding to five incorrect tracings were not available, therefore estimates of the total area of each component was made by use of one side of the carcass cross-section tracing only. Varying degrees of cutting error may have occurred as large bone area measurements were noted for 16 carcasses in the 1963 study.

The components of the loin-leg cross-sectional tracing were in most cases a total of one to three separate areas for bone, two to eight separate areas for lean and two to six separate areas for fat. It was therefore necessary to measure each area of each component and sum the result so as to have the total area of each component. The sum of the total areas of all components were then compared to the area obtained by measuring the circumference of the leg-loin cross-sectional tracing. This was done as an additional measurement safeguard to prevent human error in obtaining the total area for cross-section.

A photograph of the cross-section of the leg-loin junction is presented in the Appendix.

Statistical Analysis

Twenty-four variables, six dependent and 18 independent, were analyzed in this study. The six were fat, lean and bone expressed both as total pounds and as a percentage of total carcass composition. The 18 independent variables were various carcass measurements of which 12 had been selected from a larger group previously evaluated by Munson (1966). The other six independent variables were measurements of the cross-sectional tracing of the leg-loin junction. The means, standard deviations, corrected sums of squares and correlation coefficients were calculated for each of the eight groups of lambs. The assumption was made in this study that the correlation coefficients for each group were estimates of the same ρ value, therefore, they were pooled. It was also assumed that the slopes of the regression lines of each group was an estimate of the same β values. The overall means, standard deviations, pooled sums of squares and pooled correlations were then obtained for all 24 variables. For ease of computation this procedure was done by use of four computing data decks of six variables each; thus the above pooled correlations are for groups of six variables each.

The raw data were corrected for group differences between years, type of rearing and face color by converting to deviations from the group means by the following procedure. For example, if Y_{ij} denoted the j^{th} raw response in group i, then Y_{ij} was replaced by $Y_{ij} - \bar{Y}_{i.}$, where $\bar{Y}_{i.}$ was the mean of the responses in the i^{th} group. These deviations were used to compute a covariance matrix and a correlation matrix to obtain all possible simple correlation coefficients of the 24 variables for use in a stepwise linear regression program. This was from the B.M.D. series (U.C.L.A.) by Dixon (1968). The particular program used was BMD02R. The program computed the covariance matrix and the correlation matrix for all 24 variables of the study. The stepwise procedure then entered one variable at a time into the regression equation starting with the independent variable that had the highest simple correlation coefficient with the dependent variable being estimated. The remaining independent variables were then re-evaluated by computing their partial correlation coefficients after the effect of the independent variable entered had been removed. The independent variable having the highest partial correlation coefficient was then entered into the equation. This process is equivalent to entering the independent variable which accounts for the greatest reduction in the residual sum of squares after the first variable has been entered. This procedure was continued until nine of the independent variables had been entered into the equation.

Draper and Smith (1966) report that the stepwise regression procedure is an improved version of the forward-selection procedure. These improvements involve re-examining the variables that are incorporated into the model at each stage of regression. The variable which at an early stage may have been found to be the best single variable to enter into the equation may be found to be unnecessary later due to relationships between it and other variables now in the regression. This is checked by using the partial F criterion for each variable in the regression and comparing it with a preselected percentage point of the appropriate F distribution. This evaluation may be done at any stage of the calculation. This provides a judgment on the contribution of each variable as if it was the most recently entered variable regardless of its point of entry into the model. All variables that do not make a significant contribution are removed from the model. This process continues until all variables are admitted to the equation or rejected.

For each independent variable, X_k, in the regression equation, the regression coefficient, b_k, its estimated standard error, s_{b_k}, and the F value for the test of the null hypothesis $H_o: b_k = 0$ versus the alternate hypothesis $H_1: b_k \neq 0$, are computed at each step of the procedure. The F is merely the square of the t test. That is

$$F_k = \left(\frac{b_k - 0}{s_{b_k}} \right)^2$$

where k indexes the particular coefficient which was being considered.

As the data had been corrected for the mean prior to performing the regression analysis, the fitted model had a zero intercept. That is, at each step the regression equation was

$$Y = \beta_1 X_1 + \beta_2 X_2 + \cdots \beta_k X_k.$$

The Y and X values in this equation are deviations from the group mean.

After the final variable is entered or removed from the equation, a summary is computed listing the variables entered or removed at each step with the multiple correlation coefficients, their square (R^2), the increase or decrease in R^2 and the F value to enter or remove the variable from the equation.

Draper and Smith (1966) recommend the stepwise regression procedure as the best variable selection procedure available. In a theoretical sense the all regression procedure would be better as it allows the investigator to look at everything, but in actual practice the backwards elimination and the stepwise procedure will pick the same equation as the all regression procedure.

CHAPTER IV

RESULTS AND DISCUSSION

The purpose of this study was to determine correlation coefficients for various measurements of the lamb carcass with carcass fat, lean and bone expressed both as pounds and as a percentage of the total carcass composition, to evaluate cross-sectional tracing measurements of the leg-loin junction expressed as area (square inches) and as percentage of the total area; and to formulate regression equations for estimating the fat, lean and bone in lamb carcasses.

The overall means and standard deviations of the 24 variables, 6 dependent and 18 independent, of the 123 lamb carcasses are shown in Table XVII in the Appendix.

Correlations

All possible simple correlation coefficients were computed for the 24 variables of this study. These coefficients are found in the Appendix in Table XVIII. Of these 24 variables, 6 are dependent variables which are carcass fat, lean and bone expressed as pounds and percentage. The 18 independent variables were carcass measurements, 12 of which had been selected from a larger group previously evaluated by Munson (1966). Loin fat trim, one of these 12 variables, was expressed as pounds and as a percentage of the untrimmed loin. The remaining six variables were the measurements of fat, lean and bone of the cross-section tracing of the loin-leg junction expressed as area (square inches) and as a percentage of the total area. These four measurements, i.e., loin fat trim, tracing fat, lean and bone were expressed in two ways so as to determine differences of correlation coefficients when correlated with the carcass components, which were also expressed in two ways.

The correlation coefficients in this thesis will be presented for discussion in this manner. The correlation coefficient between carcass weight and carcass fat was 0.60 (0.38); that is, the correlation coefficient calculated between carcass weight and carcass fat expressed as pounds was 0.60 and the correlation coefficient between carcass weight and percent carcass fat was 0.38 which was given in parenthesis. This same method will be followed for discussions of carcass lean and bone.

Correlations With Fat

The overall simple correlation coefficients of carcass fat with the 18 independent variables are shown in Table I. In general, the pairs of coefficients determined for each independent variable with fat are similar. An exception to this is carcass weight which was

TABLE I

INTRA-YEAR, TYPE OF REARING AND FACE COLOR SIMPLE CORRELATIONS BETWEEN INDEPENDENT VARIABLES AND CARCASS FAT

		Total Carcass Fat	Percent Carcass Fat
Chilled carcass weight	(X_1)	0.60	0.38
Hind specific gravity	(X_2)	-.70	-.74
Loin specific gravity	(X_3)	-.66	-.67
Untr. loin weight	(X_4)	0.60	0.50
Loin fat trim weight	(X_5)	0.76	0.75
Percentage loin fat trim	(X_6)	0.70	0.74
Rt. cannon weight	(X_7)	-.31	-.37
Kidney knob weight	(X_8)	0.65	0.63
Fat thickness over 12th rib	(X_9)	0.59	0.59
Loin eye area	(X_{10})	-.23	-.32
Loin probe	(X_{11})	0.54	0.51
Tracing fat percentage	(X_{12})	0.58	0.61
Tracing lean percentage	(X_{13})	-.51	-.56
Tracing bone percentage	(X_{14})	-.28	-.27
Tracing fat area	(X_{15})	0.59	0.58
Tracing lean area	(X_{16})	-.15	-.26
Tracing bone area	(X_{17})	-.23	-.24
Percent wholesale cuts	(X_{18})	-.05	-.19

$P < .05 = .18$

$P < .01 = .24$

correlated to fat as 0.60 (0.38), having a greater relationship when both variables were expressed as pounds. All variables expressed by weight had higher correlation coefficients with pounds of fat than with percentage fat except right cannon bone weight which was expressed in grams. Variables expressed as percentage in general had larger correlation coefficients with percentage fat than with pounds of fat.

The variable having the highest correlation with fat was loin fat trim. The correlation between loin fat trim (pounds) and carcass fat were 0.76 (0.75). Percentage loin fat trim was correlated with carcass fat as being 0.70 (0.74). Specific gravity determination of the hindsaddle and loin should also be good indices of carcass fat. The correlation coefficients of hindsaddle and loin specific gravities with carcass fat were -.70 (-.74) and -.66 (-.67), respectively. Other variables which would also be indicators of carcass fat are kidney knob weight, 12th rib fat thickness, loin probe, percentage tracing fat and lean, and tracing fat area. The variables which had nonsignificant correlations ($P < .05$) with carcass fat were percent wholesale cuts and tracing lean area.

Correlation With Lean

The correlation coefficients determined between the independent variables and carcass lean, shown in Table II, were lower than those determined when correlated with carcass fat. Percent wholesale

TABLE II

INTRA-YEAR, TYPE OF REARING AND FACE COLOR SIMPLE CORRELATIONS BETWEEN INDEPENDENT VARIABLES AND CARCASS LEAN

		Total Carcass Lean	Percent Carcass Lean
Chilled carcass weight	(X_1)	0.37	-.32
Hind specific gravity	(X_2)	0.47	0.68
Loin specific gravity	(X_3)	0.37	0.61
Untr. loin weight	(X_4)	0.06	-.41
Loin fat trim weight	(X_5)	-.35	-.69
Percentage loin fat trim	(X_6)	-.49	-.70
Rt. cannon weight	(X_7)	0.27	0.24
Kidney knob weight	(X_8)	-.29	-.57
Fat thickness over 12th rib	(X_9)	-.34	-.55
Loin eye area	(X_{10})	0.47	0.38
Loin probe	(X_{11})	-.24	-.49
Tracing fat percentage	(X_{12})	-.43	-.58
Tracing lean percentage	(X_{13})	0.45	0.55
Tracing bone percentage	(X_{14})	0.06	0.21
Tracing fat area	(X_{15})	-.27	-.52
Tracing lean area	(X_{16})	0.48	0.31
Tracing bone area	(X_{17})	0.12	0.18
Percent wholesale cuts	(X_{18})	0.56	0.27

P .05 = .18

P .01 = .24

cuts, which had been nonsignificantly correlated with carcass fat, had the highest correlation coefficient with pounds of carcass lean 0.56. Carcass weight, 12th rib fat thickness and tracing lean area also had higher correlation coefficients to pounds of carcass lean than to percentage carcass lean. For all other variables the coefficients were higher when correlated with carcass lean expressed as a percentage. Excluding wholesale cuts, the variables which should have the most predictive value for estimating carcass lean, are percent loin fat trim and hindsaddle specific gravity which had correlation coefficients of -.49 (-.70) and 0.47 (0.68), respectively, with carcass lean. Loin eye area which has been used as a predictor of carcass lean was determined to have coefficients of 0.47 (0.38) when correlated with carcass lean. It should have more value when predicting pounds of carcass lean rather than percentage because of the area to pounds relationship. This is also true for tracing lean area which was correlated with carcass lean as being 0.48 (0.31). These four variables should account for essentially the same amount of reduction in the residual mean square when used to predict pounds of carcass lean. If percentage carcass lean were to be estimated, loin fat trim and hindsaddle specific gravity would be of greater predictive value, as they have higher correlation coefficients with percentage carcass lean than the other independent variables in this study.

Correlations With Bone

Table III shows the correlation coefficients determined between the independent variables and carcass bone. The variable which has the highest correlation coefficient with carcass bone is right cannon bone weight. The correlation coefficients of the right cannon bone weight and carcass bone were 0.65 (0.58). Munson (1966) reported the correlation between the weight of all four cannon bones and percent carcass bone was 0.81. Palsson (1939) reported that the weight of all four cannon bones accounted for 92 percent of the variation in total carcass bone. As the weight of all four cannon bones was only available for the second year of this study, the weight of only one cannon bone was used. Although not proven in this study, other researchers have suggested that higher correlation coefficients would have been obtained if the weight of all four cannon bones had been available for use.

The correlation coefficients between carcass bone and hindsaddle specific gravity, loin fat trim (pounds) and percentage loin fat trim were 0.46 (0.59), -.39 (-.62), -.44 (-.56), respectively. Other variables which may be used as indices of carcass bone are loin specific gravity, kidney knob weight and tracing fat area. Non-significant correlations were determined between carcass bone, untrimmed loin weight, loin eye area and percent wholesale cuts.

The correlation coefficients evaluated in this study suggest loin fat trim and hindsaddle specific gravity should be of value for

TABLE III

INTRA-YEAR, TYPE OF REARING AND FACE COLOR SIMPLE CORRELATIONS BETWEEN INDEPENDENT VARIABLES AND CARCASS BONE

		Total Carcass Bone	Percent Carcass Bone
Chilled carcass weight	(X_1)	0.20	-.36
Hind specific gravity	(X_2)	0.46	0.59
Loin specific gravity	(X_3)	0.39	0.54
Untr. loin weight	(X_4)	-.15	-.50
Loin fat trim weight	(X_5)	-.39	-.62
Percentage loin fat trim	(X_6)	-.44	-.56
Rt. cannon weight	(X_7)	0.65	0.58
Kidney knob weight	(X_8)	-.35	-.54
Fat thickness over 12th rib	(X_9)	-.33	-.46
Loin eye area	(X_{10})	0.10	0.04
Loin probe	(X_{11})	-.22	-.39
Tracing fat percentage	(X_{12})	-.41	-.48
Tracing lean percentage	(X_{13})	0.36	0.39
Tracing bone percentage	(X_{14})	0.22	0.32
Tracing fat area	(X_{15})	-.37	-.52
Tracing lean area	(X_{16})	0.22	0.06
Tracing bone area	(X_{17})	0.27	0.30
Percent wholesale cuts	(X_{18})	0.20	-.05

P .05 = .18

P .01 = .24

estimating carcass fat, lean and bone. Percent wholesale cuts is a good indicator of pounds of carcass lean. The most valuable indicator of pounds of carcass bone is cannon bone weight. Tracing measurements may have some value in estimating carcass composition. Tracing lean area could be used as a predictor of carcass lean if loin fat trim and hindsaddle specific gravity were not available.

Prediction of Carcass Composition

The equations for prediction of carcass composition, utilizing all 18 independent variables, were determined for nine steps, that is, until nine independent variables had been entered into the equation. These equations are in the Appendix. For purposes of discussion in this thesis equations involving four variables will be used as the reduction in the residual mean square becomes too small to be of importance after the fourth step has been reached.

The equations determined using carcass weight and the tracing measurements were carried to completion and are presented in their entirety. The squared multiple correlation coefficients and standard errors of estimate are given to the fourth decimal place so as to examine small differences.

Prediction of Carcass Fat

The prediction equations determined for estimating total carcass fat are shown in Table IV. These equations predict deviations

TABLE IV

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING TOTAL CARCASS FAT

	R^2	Standard Error of Estimate
$\hat{Y}_1 = 3.77160X_5$	.58	1.43
$\hat{Y}_1 = 2.97843X_5 + 1.65030X_8$	.73	1.16
$\hat{Y}_1 = 2.57456X_5 + 1.40070X_8 + .27494X_1$	.78	1.06
$\hat{Y}_1 = 2.03675X_5 + .91043X_8 + .29329X_1 - .00966X_2$	.82	.96

$\hat{Y}_1$ = Total carcass fat (S. D. = 2.28 lbs.)

X_5 = Loin fat trim weight (lb.)

X_8 = Kidney knob weight (lb.)

X_1 = Chilled carcass weight (lb.)

X_2 = Hind specific gravity

X and Y are deviations from group means.

from the mean of carcass fat. The first variable entered into this equation was loin fat trim (pounds) which accounted for 58 percent of the variation of this trait. The standard error of estimate determined for this equation was 1.43 pounds. If loin fat trim had not been included in the group of independent variables, the variable chosen to be entered first into the equation would have been hindsaddle specific gravity. The second variable entered into the equation was kidney knob weight which accounted for an additional 14 percent of the variation and decreased the standard error of estimate to 1.16 pounds. If this variable had not been included in the group being evaluated for entrance into the equation, hindsaddle specific gravity would have been chosen. Carcass weight was the third variable entered. It accounted for an additional 4.9 percent of the variation and decreased the standard error of estimate to 1.06 pounds. The variable with the second highest partial correlation coefficient of those being considered for entry into the equation at the third step was again hindsaddle specific gravity. The variable which was entered in the fourth step of this regression equation was hindsaddle specific gravity. It increased the amount of variation accounted for by the equation by 4.1 percent for a total of 82 percent with a standard error of estimate of 0.96 pounds.

The prediction equations determined for estimation of percent carcass fat are shown in Table V. The first variable entered into the equation was loin fat trim (pounds) which accounted for 57 percent of

TABLE V

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING PERCENTAGE CARCASS FAT

	R^2	Standard Error of Estimate
$\hat{Y}_4 = 6.33929X_5$	.57	2.48
$\hat{Y}_4 = 4.20558X_5 - .02790X_2$	.72	2.00
$\hat{Y}_4 = 3.96705X_5 - .02018X_2 + 1.72513X_8$	.76	1.85
$\hat{Y}_4 = 3.31245X_5 - .01974X_2 + 1.66889X_8 + .24871X_{15}$	.78	1.80

$\hat{Y}_4$ = Percentage carcass fat (S. D. = 3.88%)

X_5 = Loin fat trim weight (lb.)

X_2 = Hind specific gravity

X_8 = Kidney knob weight (lb.)

X_{15} = Tracing fat area (sq. in.)

X and Y are deviations from group means.

the variation with a standard error of estimate of 2.48 percent. Hindsaddle specific gravity, the second variable entered, would have accounted for slightly less variation than loin fat trim if it had been entered as the first variable. When used in this equation as the second variable entered, hindsaddle specific gravity accounted for 15 percent additional variation and reduced the standard error of estimate to 2 percent. The third variable entered was kidney knob weight which accounted for 4 percent additional variation and reduced the standard error of estimate to 1.85 percent. An additional 2 percent variation was accounted for by entering tracing fat area into the equation. The equation with four variables entered accounted for 78 percent of the variation with a standard error of estimate of 1.8 percent.

The standard error of estimate or "average miss" of the equation for the equations in Tables IV and V estimating carcass fat are very similar. The first was stated in pounds and the second was stated in percent. Both were referring to carcasses of approximately 50 pounds. The equations used three of the same variables for estimating carcass fat in two ways. Munson (1966) reported an equation estimating percent carcass fat using loin fat trim, hindsaddle specific gravity and kidney fat weight as the first three variables entered. The fourth variable entered was weight of the trimmed leg. Munson's equation accounted for 79 percent of the variation and had a standard error of estimate of 1.87 percent.

The equations in this study do not estimate the total carcass fat of the individual, but rather, the deviation from the group mean. These equations may be used for comparisons of individuals within a group or as a guide for selecting variables to be entered into a multiple regression equation. The partial correlation coefficients determined in a stepwise regression indicate that a variable which has a similar coefficient to the variable entered may be substituted for the entered variable with only a small loss of precision. This loss of precision might be offset if the substituted variable was one which could be cheaper or easier to obtain.

Data pertaining to the 1963 whiteface, single reared lambs was entered into the equation derived for estimating differences of total carcass fat. This was done as an example of the use of these equations for fat comparisons. The rank and actual fat deviations of these fifteen lambs and the estimated rank and deviations obtained from these equations are given in Table VI. The size of the actual deviations range from 0.1 pounds to 6.5 pounds. The range of the estimated deviations was 0.2 pounds to 5.3 pounds. Eight actual deviations and ten estimated deviations were 1.5 pounds or less. Four of the estimated deviations missed the actual values by more than the standard error of estimate (0.96).

A comparison of the actual rank and estimated rank shows that the seven lambs having the most carcass fat to be the same lambs as estimated with one lamb out of order. Both comparisons chose the

TABLE VI

COMPARISONS OF ACTUAL AND ESTIMATED FAT DEVIATIONS AND RANK FOR FAT OF 1963 WHITEFACE, SINGLE REARED LAMBS

Lamb No.	Actual Fat Deviation	Estimated Fat Deviation[1]	Rank For Fat	Estimated Rank For Fat
640	6.5	5.3	1	1
211	2.0	0.9	2	5
190	1.7	2.5	3	2
474	1.5	1.2	4	3
106	1.3	1.6	5	4
107	0.7	0.6	6 tie	6
035	0.7	-.2	6 tie	7 tie
478	-.1	-.7	8	10 tie
295	-.8	-1.3	9	13
064	-1.1	-.2	10	7 tie
475	-1.2	-5.5	11	9
152	-2.3	-.7	12 tie	10 tie
150	-2.3	-.8	12 tie	12
193	-2.6	-2.9	14	14
087	-3.4	-3.0	15	15

[1]Standard Error of Estimate = 0.96

same lamb as being the one with the most finish and the same pair of lambs as having the least amount of fat.

Prediction of Carcass Lean

The prediction equations determined for estimating pounds of total carcass lean are shown in Table VII. Percent trimmed wholesale cuts was the first variable entered into the equation. It accounted for 31 percent of the variation with a standard error of estimate of 1.32 pounds. The correlation coefficients of total carcass lean with percentage loin fat trim, tracing lean area, hindsaddle specific gravity and loin eye area were -.49, 0.48, 0.47, 0.47, respectively. These four variables have essentially the same simple correlation coefficients. Each of these variables could be used as the first variable entered if percent wholesale cuts was not known. Hindsaddle specific gravity was the only variable of this group which had a high partial correlation coefficient and was therefore the second variable entered into the equation. It accounted for 14 percent additional variation and decreased the standard error of estimate to 1.19 pounds. The low partial correlation coefficients of the other three variables suggest that they account for a portion of the same variation as does percent wholesale cuts.

The third variable entered was carcass weight which accounted for an additional 11 percent variation and decreased the standard error of estimate to 1.07 pounds. Loin fat trim (pounds) which was

TABLE VII

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR REARING AND FACE COLOR BASIS FOR ESTIMATING TOTAL CARCASS LEAN

	R^2	Standard Error of Estimate
$\hat{Y}_2 = .58912X_{18}$	.31	1.32
$\hat{Y}_2 = .51061X_{18} + .00953X_2$	.45	1.19
$\hat{Y}_2 = .30842X_{18} + .01317X_2 + .30927X_1$	.56	1.07
$\hat{Y}_2 = .19650X_{18} + .01032X_2 + .42450X_1 - 1.13475X_5$	.61	1.01

$\hat{Y}_2$ = Total carcass lean (S.D. = 1.64 lbs.)

X_{18} = Percent wholesale cuts

X_2 = Hind specific gravity

X_1 = Chilled carcass weight (lb.)

X_5 = Loin fat trim weight (lb.)

X and Y are deviations from group means.

the first variable used for prediction of fat, was the fourth variable entered for prediction of lean. This variable accounted for five percent additional variation. This equation then accounted for 61 percent variation with a standard error of estimate of 1.01 pounds.

The equations (Table VIII) determined when percentage carcass lean was the dependent variable entered percentage loin fat trim as the first independent variable. It accounted for 49 percent of the variation with a standard error of estimate of 2.18 percent. This one variable expressed as a percentage accounted for 18 percent more variation of percentage carcass lean than did percent wholesale cuts when the carcass lean was expressed in pounds. Percent wholesale cuts accounts for seven percent variation of percentage carcass lean and was therefore not considered in these equations. Loin fat trim weight and hindsaddle specific gravity could be used as the first variable entered as they had slightly lower correlation coefficients with percentage carcass lean than did percentage loin fat trim.

Hindsaddle specific gravity and kidney knob weight had the highest partial correlation coefficients with percentage carcass lean after the effect of loin fat trim had been removed. Hindsaddle specific gravity was entered as the second variable of the equation and increased the R^2 value 11 percent with a standard error of estimate of 1.94 percent. This equation containing two independent variables should have approximately the same precision for estimated

TABLE VIII

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING PERCENTAGE CARCASS LEAN

	R^2	Standard Error of Estimate
$\hat{Y}_5 = -.58652X_6$	.49	2.18
$\hat{Y}_5 = -.38473X_6 + .01977X_2$	.60	1.94
$\hat{Y}_5 = -.36834X_6 + .01398X_2 - 1.26529X_8$	.63	1.86
$\hat{Y}_5 = -.31179X_6 + .01364X_2 - 1.20180X_8 - .19698X_{15}$	.65	1.83

$\hat{Y}_5$ = Percentage carcass lean (S. D. = 3.13%)

X_6 = Percentage loin fat trim

X_2 = Hind specific gravity

X_8 = Kidney knob weight (lb.)

X_{15} = Tracing fat area (sq. in.)

X and Y are deviations from group means.

carcass lean as does the previous equation (Table VII) containing four variables.

Kidney knob weight was the third variable entered. It accounted for three percent additional variation and reduced the standard error of estimate to 1.86 percent. Other variables considered for entry at this step were 12th rib fat thickness, tracing fat area and tracing fat percentage. These three variables and loin eye area had similar partial correlation coefficients when evaluated for the fourth step of the regression. Tracing fat area was entered in the fourth step. It increased the amount of variation accounted for by two percent to a total R^2 value of 65 percent. The decrease in the standard error of estimate was only .03 percent, therefore, this variable did not increase the precision of the equation very much.

The equations for estimating carcass lean would appear to be more precise when the dependent variable is expressed as a percentage. This was not true when estimating carcass fat. Munson (1966) reported an equation for estimating percent carcass lean using the variables loin fat trim weight, hindsaddle specific gravity, kidney fat weight and slaughter weight which had an R^2 value of 65 percent with a standard error of estimate of 1.89 percent.

The R^2 values reported by Munson differ from those in this study because of higher simple correlation coefficients determined in his study by a double precision computer program, whereas the coefficients in this study were determined by a single precision method and were in general smaller due to rounding errors.

Prediction of Carcass Bone

The equations determined for estimating total carcass bone are presented in Table IX. The weight of the right cannon bone had the highest simple correlation coefficient with carcass bone. It was the first variable entered into the equation and accounted for 42 percent of the variation with a standard error of estimate of 0.44 pounds. The results reported by Munson (1966) and Palsson (1939) indicate that the weight of all four cannon bones would have a higher correlation with total bone than that of one cannon bone. As the weight of all four cannon bones were not taken both years of this study, the weight of one cannon bone was used in these equations.

The variables having the highest partial correlation coefficients after the first step were hindsaddle specific gravity, percentage loin fat trim and tracing fat percentage. Hindsaddle specific gravity was entered as the second variable of the equation and accounted for eight percent additional variation with the standard error of estimate reduced to 0.41 pounds. Carcass weight and tracing bone area were considered for entry as the third variable. Carcass weight was entered as the third variable and tracing bone area as the fourth variable. They increased the R^2 value seven and five percent, respectively, to a total of 62 percent. The standard error of estimate was reduced to 0.36 pounds.

TABLE IX

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING TOTAL CARCASS BONE

	R^2	Standard Error of Estimate
$\hat{Y}_3 = .07206X_7$	.42	.44
$\hat{Y}_3 = .06275X_7 + .00270X_2$	.50	.41
$\hat{Y}_3 = .05836X_7 + .00347X_2 + .07697X_1$	.57	.39
$\hat{Y}_3 = .05785X_7 + .00332X_2 + .08006X_1 + .26268X_{17}$	.62	.36

$\hat{Y}_3$ = Total carcass bone (S. D. = .60 lbs.)

X_7 = Right cannon bone (gm.)

X_2 = Hind specific gravity

X_1 = Chilled carcass weight (lb.)

X_{17} = Tracing bone area (sq. in.)

X and Y are deviations from group means.

The equations for estimating percentage carcass bone are presented in Table X. Cannon bone weight, which had a simple correlation coefficient that was 0.2 higher than that of the second highest variable when correlated with total carcass bone, had a similar but lower coefficient than loin fat trim and hindsaddle specific gravity when correlated with percentage carcass bone. Loin fat trim was the first variable entered and accounted for 38 percent of the variation with a standard error of estimate of 0.94 percent. The variables having the highest partial correlation coefficients after the first step were cannon bone weight, kidney knob weight and hindsaddle specific gravity. Cannon bone weight was the second variable entered and accounted for 17 percent additional variation and reduced the standard error of estimate to 0.8 percent. Kidney knob weight was then entered into the equation and accounted for 9 percent additional variation and reduced the standard error of estimate to 0.72 percent. The fourth variable entered was tracing bone percentage. This equation had an R^2 value of 0.67 percent with a standard error of estimate of 0.69 percent. The other variables considered for entry at this step were tracing bone area, percent wholesale cuts, tracing lean area and loin eye area.

The two variables which were selected for entry into the preceding six groups of equations most often were loin fat trim (weight four times, percentage once) and hindsaddle specific gravity (five times). Both of these variables are good indices of carcass fat

TABLE X

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING PERCENTAGE CARCASS BONE

	R^2	Standard Error of Estimate
$\hat{Y}_6 = -1.63432X_5$	.38	.94
$\hat{Y}_6 = -1.28342X_5 + .09967X_7$	.55	.80
$\hat{Y}_6 = -.96355X_5 + .09528X_7 - .69772X_8$	.64	.72
$\hat{Y}_6 = -.74605X_5 + .09972X_7 - .73199X_8 + .11351X_{14}$	.67	.69

$\hat{Y}_6$ = Percentage carcass bone (S. D. = 1.23%)

X_5 = Loin fat trim weight (lb.)

X_7 = Right cannon weight (gm.)

X_8 = Kidney knob weight (lb.)

X_{14} = Tracing bone percentage

X and Y are deviations from group means.

and lean. Kidney knob weight was entered into both groups of equations estimating fat and into the equations estimating percentage lean and bone. Carcass weight was only entered into equations estimating pounds of each carcass component. Measurements of the cross-sectional tracing of the leg-loin junction were entered into four of the six equations at the fourth step. Additional groups of equations were formulated so as to better evaluate the tracing measurements.

Cross-Sectional Tracing Equations

Various cross-sectional tracings have been made by researchers and loin eye area and various fat thickness measurements were obtained from them. Area measurements of the entire cross-section have not been reported in the literature, therefore, this procedure was included in this study. As loin fat trim and loin specific gravity determinations were known to be indices of carcass composition and because of ease of measurement, the cross-section of the leg-loin junction was selected from a group of three cross-sectional tracings which were obtained from a previous study by Munson (1966). The total areas of fat, lean and bone were determined for 123 tracings of the posterior surface of the loin. These measurements expressed as area (square inches) and percentage were entered into stepwise regression equations (alone and with carcass weight) for the estimation of carcass fat, lean and bone (pounds and percentage). These equations are presented in the Appendix, but for discussion in this thesis tables presenting three

three steps of the equations using only tracing measurements and the equations using carcass weight and tracing measurements will be presented on the same table for each carcass component expressed as pounds or as a percentage.

Equations for Fat Differences

The equations for estimating total carcass fat are presented in Table XI. The equations in which all independent variables were tracing measurements account for 34.72 percent of the variation with a standard error of estimate of 1.7881 when fat area was entered as the first variable. Although three other tracing measurements (fat percentage, lean area and bone percentage) had a sufficient F-level to be entered into the equation, they account for only 2.5 percent additional variation and decrease the standard error of estimate 0.0126 pounds. The low partial correlation coefficients of these variables indicate that they estimate much of the same variation as does fat area. Very little precision is gained by the addition of these variables to the equation.

The equations which included carcass weight as an independent variable accounted for 36.15 percent of the variation with a standard error of estimate of 1.7685 pounds when carcass weight was the first variable entered. The addition of fat percentage to the equation increases the R^2 value to 59.87 percent with a standard error of estimate of 1.4078 pounds. This equation would be more precise

TABLE XI

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR REARING AND FACE COLOR BASIS FOR ESTIMATING TOTAL CARCASS FAT

	R^2	Standard Error of Estimate
$\hat{Y}_1 = .60250X_{15}$	.3472	1.7881
$\hat{Y}_1 = .37348X_{15} + .10808X_{12}$	.3590	1.7792
$\hat{Y}_1 = .16597X_{15} + .21433X_{12} + .14320X_{16}$	.3621	1.7824
$\hat{Y}_1 = .65391X_1$	.3615	1.7685
$\hat{Y}_1 = .56735X_1 + .21424X_{12}$	.5987	1.4078
$\hat{Y}_1 = .58515X_1 + .20233X_{12} - .05716X_{16}$	.6001	1.4111

$\hat{Y}_1$ = Pounds of carcass fat (S.D. = 2.28 lbs.)
X_{15} = Tracing fat area (sq. in.)
X_{12} = Tracing fat percentage
X_{16} = Tracing lean area (sq. in.)
X_1 = Chilled carcass weight (lb.)
X and Y are deviations from group means.

than the equation formulated previously using only loin fat trim, a measurement that would destroy the physical form and change the value of the loin. The addition of three tracing measurements (Table XXVI) to the equation increases the R^2 values and the standard error of estimate less than one percent and therefore would not be as precise as the equation using only two independent variables.

The equations estimating percentage carcass fat are presented in Table XII. Tracing fat percentage is the first variable entered into both equations. It accounts for 37.75 percent of the variation with a standard error of 2.9750 percent. The addition of four other tracing measurements (Table XXVII) increase both the R^2 value and the standard error of estimate by less than one percent, and therefore lessen the precision of these equations. When carcass weight is entered as the second variable in the equation for estimating percentage carcass fat, the R^2 value is increased to 46.06 percent and the standard error of estimate is decreased to 2.7807 percent. The addition of a third variable to this equation does not increase its precision. These equations indicate that only one tracing measurement need be entered into a regression equation for estimating differences in carcass fat.

Equations for Lean Differences

The equations estimating pounds of carcass lean are presented in Table XIII. Tracing lean area accounts for 22.66 percent of the

TABLE XII

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING PERCENTAGE CARCASS FAT

	R^2	Standard Error of Estimate
$\hat{Y}_4 = .45446X_{12}$	.3775	2.9750
$\hat{Y}_4 = .48239X_{12} + .14825X_{16}$	.3815	2.9777
$\hat{Y}_4 = .51960X_{12} + .23953X_{16} + .11918X_{14}$	.3834	2.9854
$\hat{Y}_4 = .45446X_{12}$	.3775	2.9750
$\hat{Y}_4 = .41962X_{12} + .54117X_1$	.4606	2.7807
$\hat{Y}_4 = .50958X_{12} + .58325X_1 - .24254X_{15}$	.4638	2.7840

$\hat{Y}_4$ = Percentage carcass fat (S.D. = 3.88%)

X_{12} = Tracing fat percentage

X_1 = Carcass weight (lb.)

X_{15} = Tracing fat area (sq. in.)

X_{16} = Tracing lean area (sq. in.)

X_{14} = Tracing bone percentage

X and Y are deviations from group means.

TABLE XIII

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING TOTAL CARCASS LEAN

	R^2	Standard Error of Estimate
$\hat{Y}_2 = .40450X_{16}$	.2266	1.4019
$\hat{Y}_2 = .29234X_{16} - .08064X_{12}$	.2757	1.3623
$\hat{Y}_2 = .34584X_{16} - .05574X_{12} + .37280X_{17}$	.2850	1.3591
$\hat{Y}_2 = .40450X_{16}$	.2266	1.4019
$\hat{Y}_2 = .34717X_{16} + .21442X_1$	.2970	1.3422
$\hat{Y}_2 = .14068X_{16} + .31362X_1 - .12940X_{12}$	.4083	1.2364

$\hat{Y}_2$ = Pounds of carcass lean (S.D. = 1.64 lbs.)

X_{16} = Tracing lean area (sq. in.)

X_1 = Carcass weight (lb.)

X_{12} = Tracing fat percentage

X_{17} = Tracing bone area (sq. in.)

X and Y are deviations from group means.

variation and has a standard error of estimate of 1.4019. It was the first variable entered in both equations. The addition of fat percentage to the equation increases the R^2 value to 27.57 percent and reduces the standard error of estimate to 1.3623 pounds. No significant increase in precision is gained by adding additional tracing measures to this equation.

Carcass weight entered into the equation with these two tracing measurements increases the R^2 value to 40.83 percent and decreases the standard error of estimate to 1.2364 pounds. Estimates made by this equation would be similar to estimates made using percent wholesale cuts and hindsaddle specific gravity in the equation previously determined in this study.

The equations for estimating differences in percentage carcass lean are presented in Table XIV. The equations in which only tracing measurements were entered as independent variables, were not made more precise by the addition of a second variable. The variable entered first was fat percentage which accounts for 33.74 percent variation with a standard error of estimate of 2.4773 percent. The addition of carcass weight as the second variable in the equations increases the R^2 value to 39.09 percent and decreases the standard error of estimate to 2.3850 percent. As in the previous equation, no precision is gained by adding additional tracing measures to the equation. Percentage loin fat trim would be a more precise estimator of percentage carcass lean than these equations using carcass

TABLE XIV

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING PERCENTAGE CARCASS LEAN

	R^2	Standard Error of Estimate
$\hat{Y}_5 = -.34681X_{12}$	.3374	2.4773
$\hat{Y}_5 = -.35935X_{12} - .31522X_{17}$	.3398	2.4830
$\hat{Y}_5 = -.35660X_{12} - .84216X_{17} + .14107X_{14}$	.3404	2.4992
$\hat{Y}_5 = -.34681X_{12}$	.3374	2.4773
$\hat{Y}_5 = -.32424X_{12} - .35043X_1$	.3909	2.3850
$\hat{Y}_5 = -.27597X_{12} - .42256X_1 + .23162X_{16}$	.4037	2.3697

$\hat{Y}_5$ = Percentage carcass lean (S.D. = 3.13%)

X_{12} = Tracing fat percentage

X_1 = Carcass weight (lb.)

X_{14} = Tracing bone percentage

X_{17} = Tracing bone area (sq. in.)

X_{16} = Tracing lean area (sq. in.)

X and Y are deviations from group means.

weight and tracing measurements.

Equations for Bone Differences

The equations for estimation of differences of total carcass bone are presented in Table XV. The first variable entered into each equation was fat percentage. This variable accounted for 17.1 percent of the variation and had a standard error of estimate of 0.5282 pounds. The addition of carcass weight, as in the equations estimating carcass fat and lean, increasing the R^2 value to 24.31 percent and decreases the standard error of estimate to 0.5068 pounds. The final equation using only tracing measurements has a six percent smaller R^2 value than the equation with carcass weight. The standard error of estimates for both equations were very similar. The weight of one cannon bone would be a more precise estimator of carcass bone than either of these equations.

The equations in Table XVI are those determined for estimating percentage bone differences. Tracing fat area was the first variable entered into both equations. It accounts for 26.92 percent of the variation with a standard error of estimate of 1.0181 percent. The addition of bone area to this equation does not decrease the standard error of estimate enough to be of practical value. Carcass weight increases the R^2 value to 31.33 percent but makes no significant reduction in the standard error of estimate.

In general, only one tracing measurement would be of value in

TABLE XV

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING TOTAL CARCASS BONE

	R^2	Standard Error of Estimate
$\hat{Y}_3 = -.04705X_{12}$	.1710	.5282
$\hat{Y}_3 = -.04160X_{12} + .13715X_{17}$	.1835	.5263
$\hat{Y}_3 = -.04593X_{12} + .97017X_{17} - .22301X_{14}$	.2223	.5158
$\hat{Y}_3 = -.04705X_{12}$	.1710	.5282
$\hat{Y}_3 = -.05205X_{12} + .07758X_1$	.2431	.5068
$\hat{Y}_3 = -.04659X_{12} + .07759X_1 + .13727X_{17}$	.2557	.5046

$\hat{Y}_3$ = Pounds of carcass bone (S.D. = 0.6 lbs.)

X_{12} = Tracing fat percentage

X_1 = Carcass weight (lb.)

X_{17} = Tracing bone area (sq. in.)

X_{14} = Tracing bone percentage

X and Y are deviations from group means.

TABLE XVI

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING PERCENTAGE CARCASS BONE

	R^2	Standard Error of Estimate
$\hat{Y}_6 = -.28541X_{15}$	.2692	1.0181
$\hat{Y}_6 = -.25956X_{15} + .27930X_{17}$	.2815	1.0135
$\hat{Y}_6 = -.29441X_{15} + 1.28865X_{17} - .27979X_{14}$	.2931	1.0096
$\hat{Y}_6 = -.28541X_{15}$	.2692	1.0181
$\hat{Y}_6 = -.24854X_{15} - .12902X_1$	.3133	.9909
$\hat{Y}_6 = -.21820X_{15} - .13377X_1 + .31317X_{17}$	.3288	.9837

$\hat{Y}_6$ = Percentage carcass bone (S.D. = 1.23%)

X_{15} = Tracing fat area (sq. in.)

X_1 = Carcass weight (lb.)

X_{17} = Tracing bone area (sq. in.)

X_{14} = Tracing bone percentage

X and Y are deviations from group means.

a prediction equation of carcass components. For estimating pounds of carcass lean the use of carcass weight and the tracing measurements of fat and lean may be of value to substitute for hindsaddle specific gravity and percent wholesale cuts, as this study suggests that these two groups of variables when used in regression equations have similar R^2 values and standard errors of estimate. The fat measurement of these tracings would be preferred measurement if only one component was to be measured.

CHAPTER V

SUMMARY

The data used in this study was collected over a period of two years from 123 wether lambs obtained from the experimental flock at Fort Reno Livestock Research Station. The lambs were produced by grade Rambouillet ewes or grade Rambouillet x Dorset crossbred ewes. They were sired by Dorset, Hampshire or Suffolk rams. They were placed on wheat pasture, had access to creep feed and were weaned at a minimum weight of 46 pounds and minimum age of 66 days. They were transported to Stillwater for slaughter on the first Monday after having reached 100 pounds live weight to minimize the variation of carcass weight. The lambs were sheared and fasted 18 hours before slaughter. Specific gravity determinations and various carcass measurements and weights were then taken on the chilled carcasses. The edible portion of the carcass was ground and the ether extract then determined. The separable bones were weighed. The percentage ether extract and percent separable bone were then used to determine the percent carcass lean by difference.

The raw data were used to determine group means, standard deviations, corrected sums of squares and correlation coefficients for four groups of six variables each. Deviations from the group means were then used as data which were corrected for groups differences (year, face color, rearing) to obtain all possible simple correlation coefficients for six dependent and 18 independent variables. These deviations were then used in a stepwise linear regression program. Equations were determined for estimating within group differences of fat, lean and bone of lamb carcasses.

When all independent variables of this study were considered as indices of carcass composition, loin fat trim (pounds) was the most valuable indicator of carcass fat accounting for 58 (57) percent of the variation. Loin fat trim (percent) was the best single measurement to estimate percentage carcass lean, accounting for 49 percent of the variation. Percent wholesale cuts was the best single predictor of pounds of carcass lean. Hindsaddle specific gravity, loin eye area, percentage loin fat trim and tracing lean area were of approximately equal value as single predictors of carcass lean weight and account for 23 percent of the variation.

Right cannon bone weight was the best single predictor of carcass bone weight. When carcass bone was expressed as a percentage, loin fat trim weight was a better indicator for the trait. Munson (1966) reported the weight of four cannons to be much better than the weight of one cannon bone and his results suggest that the weight of all cannon bones would be superior to loin fat trim for estimating bone expressed in either way.

Cross-sectional tracing measurements of the leg-loin junction were used alone and with carcass weight as independent variables for estimation of differences of carcass fat, lean and bone. This was done to determine their value as carcass measurements. Tracing measurements of fat and lean when used with carcass weight in equations estimating pounds of carcass lean account for the same percentage variation of the residual mean square with the same standard error of estimate as does an equation using hind-saddle specific gravity and percent wholesale cuts. For estimating carcass fat and bone with tracing measurements, tracing fat was the most valuable tracing measurement and the addition of a second measurement to the equation is of little value.

LITERATURE CITED

A. O. A. C. 1955. Official Methods of Analysis (8th Ed.). Association of Official Agricultural Chemists. Washington, D. C.

Adams, N. J. and Z. L. Carpenter. 1970. Indicator cuts for estimation of lamb carcass composition. Sheep and Angora Goat, Wool and Mohair Report P. R. -2744.

Andrews, R. P. and E. R. Orskov. 1970. The nutrition of the early weaned lamb. II. The effect of dietary protein concentration, feeding level and sex on body composition at two live weights. J. Agric. Sci. Camb. 75:19.

Barton, R. A. and A. H. Kirton. 1956. Determination of fat mutton carcasses by measurement of specific gravity. Nature. 178:920.

Barton, R. A. and A. H. Kirton. 1958a. Carcass weight as an index of carcass components with particular reference to fat. J. Agric. Sci. 50:331.

Barton, R. A. and A. H. Kirton. 1958b. The leg and loin as indices of the composition of New Zealand lamb and mutton carcasses. New Zealand J. Agr. Res. 1:783.

Botkin, M. P., M. Stanley and C. O. Schoonover. 1959. Relationship between live lamb measurement and meatiness. J. Animal Sci. 18:1165 (Abstr.).

Carpenter, Z. L., G. T. King, F. A. Orts and N. L. Cunningham. 1964. Factors influencing retail carcass value of lambs. J. Animal Sci. 23:741.

Carpenter, Z. L., G. T. King, Maurice Shelton and O. D. Butler. 1969. Indices for estimating cutability of wether, ram and ewe lamb carcasses. J. Animal Sci. 28:180.

Cassard, D. W., C. M. Bailey and L. G. McNeal. 1969. Evaluation of factors affecting lamb carcass characteristics. J. Animal Sci. 28:305.

Dixon, W. F. 1968. "Biomedical Computer Programs." (2d ed.). Univ. of Calif. Press. Berkeley and Los Angeles, Calif.

Draper, N. R. and H. Smith. 1966. "Applied Regression Analysis." John Wiley & Sons, Inc. New York, London and Sydney.

Field, R. A., J. D. Kemp, W. Y. Varney, P. G. Woolfolk and C. M. Derrickson. 1963b. Carcass evaluation of lambs from selected sires. J. Animal Sci. 22:364.

Field, R. A., J. D. Kemp and W. Y. Varney. 1963a. Indices for lamb carcass composition. J. Animal Sci. 22:218.

Galloway, J. H. 1953. Recommended method of cutting lamb carcasses. Proc. 6th Ann. Recip. Meat Conf.

Hiner, Richard L. and John W. Thornton. 1962. Study of certain lamb and carcass quality factors. J. Animal Sci. 21:511.

Hoke, K. E. 1961. Factors affecting yield of cuts in lamb carcasses. Proc. Recip. Meat Conf. 14:163.

Judge, M. D., M. Stob, W. V. Kessler and J. E. Christian. 1963. Lamb carcass and live lamb evaluations by Potassium-40 and carcass measurements. J. Animal Sci. 22:418.

Judge, M. D., T. G. Martin and J. B. Outhouse. 1966. Prediction of carcass composition of ewe and wether lambs from carcass weights and measurements. J. Animal Sci. 25:92.

Kemp, J. D. 1961. Recommended procedure for quality lamb contest. Proc. 14th Ann. Recip. Meat Conf.

Kemp, James D. and R. A. Barton. 1966. Composition of lamb carcasses and cuts of the New Zealand export grades. New Zealand J. Agric. Res. 9:590.

Kemp, J. D., T. R. Lambuth and R. A. Barton. 1970. Relationships of lamb carcass measurements and sample cut composition to carcass side composition. J. Animal Sci. 31:686.

Kirton, A. H. and R. A. Barton. 1962. Study of some indices of the chemical composition of lamb carcasses. J. Animal Sci. 21:553.

Kirton, A. H. and F. S. Pickering. 1967. Factors associated with differences in carcass conformation in lamb. New Zealand

J. Agric. Res. 10:183.

Latham, S. Duane, W. G. Moody and James D. Kemp. 1966. Techniques for estimating lamb carcass composition. J. Animal Sci. 25:492.

Luch, J. L. 1926. Practical methods of estimating the proportions of fat and bone in cattle slaughtered in commercial packing plants. J. Agric. Res. 32:727.

Munson. A.W., J. V. Whiteman and L. E. Walters. 1965. A method for estimating ether extract in lamb carcasses. J. Animal Sci. 24:282.

Munson, Arvid W. 1966. Association of various measurements with lamb carcass composition and preliminary estimates of some genetic parameters. Ph. D. dissertation, Oklahoma State University. Stillwater, Oklahoma.

Oliver, W. M., Z. L. Carpenter, G. T. King and Maurice Shelton. 1968. Predicting cutability of lamb carcasses from carcass weights and measures. J. Animal Sci. 27:1254.

Palsson, H. 1939. Meat qualities in the sheep with special reference to Scottish breeds and crosses. J. Agric. Sci. 29:544.

Pradham, S. L., W. R. McManus, C. L. Goldstone, R. F. Hart and V. N. Khandekar. 1966. Indices of carcass composition of Dorset horn top-cross lambs. III. J. Agric. Sci. 66:41.

Rathbun, E. N. and N. Pace. 1945. Determination of total body fat by means of body specific gravity. J. Biol. Chem. 158:667.

Richards, Ronald R. 1967. An investigation of some indices of lamb carcass composition. Master's thesis, Oklahoma State University. Stillwater, Oklahoma.

Riley, M. L. and R. A. Field. 1969. Predicting carcass composition of ewe, wether and ram lambs. J. Animal Sci. 29:567.

Rouse, G. H., D. G. Topel, R. L. Veter, R. E. Rust and T. W. Wickersham. 1970. Carcass composition of lambs at different stages of development. J. Animal Sci. 31:846.

Russel, A. J. F. and R. A. Barton. 1967. Bone-muscle relationships in lamb and mutton carcasses. J. Agric. Sci. 68:187.

Schoonover, C. O. and P. O. Stratton. 1957. A photographic grid used to measure rib eye areas. J. Animal Sci. 16:957.

Smith, G. C., Z. L. Carpenter and G. T. King. 1969. Ovine carcass cutability. J. Animal Sci. 29:272.

Snedecor, George W. and William G. Cochran. 1968. "Statistical Methods." (6th ed.). Iowa State University Press. Ames, Iowa.

Southam, Everett R. and Ray A. Field. 1969. Influence of carcass weight upon carcass composition and consumer preference for lamb. J. Animal Sci. 28:584.

Spurlock, G. M. and G. E. Bradford. 1965. Comparison of systems of lamb carcass evaluation. J. Animal Sci. 24:1086.

Spurlock, G. M., G. E. Bradford and J. D. Wheat. 1966. Live animal and carcass measures for the prediction of carcass traits in lambs. J. Animal Sci. 25:454.

Timon, V. M. and Maurice Bichard. 1965. Quantitative estimates of lamb carcass composition. 1. Sample Joints. Animal Prod. 7:173.

Timon, V. M. and Maurice Bichard. 1965. Quantitative estimates of lamb carcass composition. 2. Specific gravity determinations. Animal Prod. 7:183.

Whiteman, Joe V., J. A. Whatley and J. C. Hillier. 1953. A further investigation of specific gravity as a measure of pork carcass value. J. Animal Sci. 12:859.

Wilson, L. L., J. H. Ziegler, M. C. Rugh, J. L. Watkins, T. L. Merritt, M. J. Simpson and F. L. Kreugberger. 1970. Comparison of live, slaughter and carcass characteristics of rams, induced cryptorchids and wethers. J. Animal Sci. 31:455.

Zinn, D. W. 1961. Cutting methods as related to lamb carcass evaluation. Proc. 14th Ann. Recip. Meat Conf.

APPENDIX

TABLE XVII

OVERALL MEANS AND STANDARD DEVIATIONS FOR VARIOUS LAMB CARCASS MEASUREMENTS

		$\overline{X}$	Standard Deviation
Total carcass fat (lb.)	($\hat{Y}_1$)	14.88	2.28
Total carcass lean (lb.)	($\hat{Y}_2$)	28.00	1.64
Total carcass bone (lb.)	($\hat{Y}_3$)	8.37	.60
Percentage carcass fat	($\hat{Y}_4$)	28.84	3.88
Percentage carcass lean	($\hat{Y}_5$)	54.66	3.13
Percentage carcass bone	($\hat{Y}_6$)	16.32	1.23
Chilled carcass weight (lb.)	(X_1)	51.39	2.10
Hind specific gravity	(X_2)	1.0368	.0065
Loin specific gravity	(X_3)	1.0241	.0071
Untr. loin weight (lb.)	(X_4)	9.38	.70
Loin fat trim (lb.)	(X_5)	2.54	.46
Percentage loin fat trim	(X_6)	26.95	3.74
Right cannon weight (gm.)	(X_7)	58.46	5.38
Kidney knob weight (lb.)	(X_8)	2.06	.57
Fat thickness over 12th rib (in.)	(X_9)	.25	.07
Loin eye area (sq. in.)	(X_{10})	2.28	.24
Loin probe (in.)	(X_{11})	.72	.15
Tracing fat percentage	(X_{12})	40.16	5.25
Tracing lean percentage	(X_{13})	54.18	4.77
Tracing bone percentage	(X_{14})	5.53	2.09
Tracing fat area (sq. in.)	(X_{15})	12.73	2.23
Tracing lean area (sq. in.)	(X_{16})	16.93	1.93
Tracing bone area (sq. in.)	(X_{17})	1.65	.53
Percent trimmed wholesale cuts	(X_{18})	37.63	1.55

TABLE XXVIII

INTRA-YEAR, TYPE OF REARING AND FACE COLOR SIMPLE CORRELATIONS BETWEEN VARIOUS CARCASS TRAITS

	(Y_2)	(Y_3)	(Y_4)	(Y_5)	(Y_6)	(X_1)	(X_2)	(X_3)	(X_4)	(X_5)	(X_6)	(X_7)	(X_8)	(X_9)	(X_{10})	(X_{11})	(X_{12})	(X_{13})	(X_{14})	(X_{15})	(X_{16})	(X_{17})	(X_{18})
Car. fat (lb) (Y_1)	-.46	-.39	0.96	-.91	-.71	0.60	-.70	-.66	0.60	0.76	0.70	-.31	0.65	0.59	-.23	0.54	0.58	-.51	-.28	0.59	-.15	-.23	-.05
Car. lean (lb) (Y_2)		0.45	-.65	0.74	0.20	0.37	0.47	0.37	0.06	-.35	-.49	0.27	-.29	-.34	0.47	-.24	-.43	0.45	0.06	-.27	0.48	0.12	0.56
Car. bone (lb) (Y_3)			-.52	0.32	0.83	0.20	0.46	0.39	-.15	-.39	-.44	0.65	-.35	-.33	0.10	-.22	-.41	0.36	0.22	-.37	0.22	0.27	0.20
Car. fat % (Y_4)				-.96	-.70	0.38	-.74	-.67	0.50	0.75	0.74	-.37	0.63	0.59	-.32	0.51	0.61	-.56	-.27	0.58	-.26	-.24	-.19
Car. lean % (Y_5)					0.48	-.32	0.68	0.61	-.41	-.69	-.70	0.24	-.57	-.55	0.38	-.49	-.58	0.55	0.21	-.52	0.31	0.18	0.27
Car. bone % (Y_6)						-.36	0.59	0.54	-.50	-.62	-.56	0.58	-.54	-.46	0.04	-.39	-.48	0.39	0.32	-.52	0.06	0.30	-.05
Car. wt. (X_1)							-.27	-.31	0.62	0.42	0.29	0.06	0.37	0.27	0.09	0.31	0.16	-.10	-.17	0.30	0.25	-.06	0.41
Hind sp. gr. (X_2)								0.81	-.25	-.54	-.59	0.29	-.58	-.44	0.36	-.35	-.49	0.50	0.09	-.38	0.36	0.09	0.20
Loin sp. gr. (X_3)									-.33	-.59	-.60	0.26	-.42	-.53	0.32	-.39	-.50	0.50	0.12	-.45	0.28	0.09	0.10
Untr. loin wt. (X_4)										0.76	0.48	-.22	0.26	0.39	-.04	0.31	0.31	-.14	-.47	0.48	0.33	-.37	0.27
Loin fat tr wt (X_5)											0.93	-.30	0.39	0.63	-.31	0.55	0.59	-.49	-.36	0.60	-.13	-.31	-.21
Loin fat tr % (X_6)												-.26	0.39	0.61	-.36	0.55	0.63	-.58	-.27	0.54	-.32	-.24	-.42
Rt. cannon wt (X_7)													-.17	-.20	0.06	-.17	-.25	0.27	0.01	-.28	0.13	0.04	0.04
Kidney knob wt (X_8)														0.35	-.09	0.34	0.38	-.38	-.07	0.30	-.29	-.07	-.01
12th rib fat (X_9)															-.32	0.34	0.42	-.39	-.16	0.40	-.17	-.15	-.16
Loin eye area (X_{10})																-.06	-.20	0.25	-.08	-.04	0.35	-.03	0.48
Loin probe (X_{11})																	0.51	-.51	-.12	0.55	-.15	-.05	-.11
Tracing fat % (X_{12})																		-.92	-.42	0.90	-.51	-.39	-.27
Tracing lean % (X_{13})																			0.03	-.78	0.70	0.01	0.31
Tracing bone % (X_{14})																				-.49	-.31	0.97	-.04
Trac'g fat area (X_{15})																					-.14	-.39	-.05
Trac'g lean ar (X_{16})																						-.18	0.52
Trac'g bone ar (X_{17})																							0.05
T W S C % (X_{18})																							

$r > .18$; significance at $P < .05$ (d.f. = 114).
$r > .24$; significance at $P < .01$ (d.f. = 114).

TABLE XIX

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING TOTAL CARCASS FAT

	R^2	Standard Error of Estimate
$\hat{Y}_1 = 3.77160X_5$	.58	1.43
$\hat{Y}_1 = 2.97843X_5 + 1.65030X_8$	.73	1.16
$\hat{Y}_1 = 2.57456X_5 + 1.40070X_8 + .27494X_1$	.78	1.06
$\hat{Y}_1 = 2.03675X_5 + .91043X_8 + .29329X_1 - .00966X_2$	.82	.96
$\hat{Y}_1 = 1.67438X_5 + .88642X_8 + .28543X_1 - .00938X_2 + .14251X_{15}$	.83	.93
$\hat{Y}_1 = 1.57825X_5 + .86828X_8 + .30997X_1 - .00892X_2 + .12893X_{15} - .03772X_7$	.84	.92
$\hat{Y}_1 = 1.32681X_5 + .83898X_8 + .31213X_1 - .00857X_2 + .12685X_{15} - .03831X_7 + 2.96000X_9$	.84	.90
$\hat{Y}_1 = 1.20796X_5 + .83827X_8 + .34981X_1 - .00823X_2 + .13002X_{15} - .04222X_7 + 2.91362X_9 - .07792X_{18}$	.84	.90
$\hat{Y}_1 = 1.13788X_5 + .81376X_8 + .34522X_1 - .00826X_2 + .11299X_{15} - .04264X_7 + 2.98317X_9 - .07258X_{18} + .74423X_{11}$	.84	.90

$\hat{Y}_1$ = Total carcass fat (S.D. = 2.28 lbs.)
X_5 = Loin fat trim weight (lb.)
X_8 = Kidney knob weight (lb.)
X_1 = Chilled carcass weight (lb.)
X_2 = Hind specific gravity
X and Y are deviations from group means.

X_{15} = Tracing fat area (sq. in.)
X_7 = Right cannon weight (gm.)
X_9 = Fat thickness over 12th rib (in.)
X_{18} = Percent tr. wholesale cuts
X_{11} = Loin probe (in.)

TABLE XX

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING PERCENTAGE CARCASS FAT

	R^2	Standard Error of Estimate
$\hat{Y}_4 = 6.33929X_5$	.57	2.48
$\hat{Y}_4 = 4.20558X_5 - .02790X_2$	.72	2.00
$\hat{Y}_4 = 3.96705X_5 - .02018X_2 + 1.72513X_8$	.76	1.85
$\hat{Y}_4 = 3.31245X_5 - .01974X_2 + 1.66889X_8 + .24871X_{15}$	.78	1.80
$\hat{Y}_4 = 2.85636X_5 - .01910X_2 + 1.61878X_8 + .24546X_{15} + 5.45858X_9$	.78	1.79
$\hat{Y}_4 = 2.75573X_5 - .01824X_2 + 1.62947X_8 + .22626X_{15} + 5.52747X_9 - .05952X_7$	.79	1.77
$\hat{Y}_4 = 2.66033X_5 - .01706X_2 + 1.70092X_8 + .24768X_{15} + 4.99521X_9 - .06134X_7 - .84277X_{10}$	.79	1.77
$\hat{Y}_4 = 2.54621X_5 - .01728X_2 + 1.72432X_8 + .21338X_{15} + 5.17326X_9 - .06587X_7 - .93142X_{10} - .08397X_{14}$	.79	1.77
$\hat{Y}_4 = 2.31644X_5 - .01730X_2 + 1.67875X_8 + .16466X_{15} + 5.35080X_9 - .06956X_7 - 1.02431X_{10} - .11447X_{14} + 1.65577X_{11}$	.79	1.77

$\hat{Y}_4$ = Percentage carcass fat (S.D. = 3.88%)
X_5 = Loin fat trim weight (lb.)
X_2 = Hind specific gravity
X_8 = Kidney knob weight (lb.)
X_{15} = Tracing fat area (sq. in.)
X_9 = Fat thickness over 12th rib (in.)
X_7 = Right cannon weight (gm.)
X_{10} = Loin eye area (sq. in.)
X_{14} = Tracing bone percent
X_{11} = Loin probe (in.)
X and Y are deviations from group means.

TABLE XXI

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING TOTAL CARCASS LEAN

	R^2	Standard Error of Estimate
$\hat{Y}_2 = .58912X_{18}$	.31	1.32
$\hat{Y}_2 = .51061X_{18} + .00953X_2$	.45	1.19
$\hat{Y}_2 = .30842X_{18} + .01317X_2 + .30927X_1$	.56	1.07
$\hat{Y}_2 = .19650X_{18} + .01032X_2 + .42450X_1 - 1.13475X_5$	.61	1.01
$\hat{Y}_2 = .19798X_{18} + .00769X_2 + .46072X_1 - 1.11459X_5 - .60149X_8$	.64	.97
$\hat{Y}_2 = .13780X_{18} + .00662X_2 + .45928X_1 - 1.05346X_5 - .65316X_8 + .98156X_{10}$	.65	.96
$\hat{Y}_2 = .14037X_{18} + .00615X_2 + .45904X_1 - .73722X_5 - .64391X_8 + 1.16261X_{10} - .11295X_{15}$	.67	.94
$\hat{Y}_2 = .14267X_{18} + .00605X_2 + .45919X_1 - .60050X_5 - .62253X_8 + 1.08189X_{10} - .11002X_{15}$	.67	.94
$- 1.77390X_9$	.67	.94
$\hat{Y}_2 = .13539X_{18} + .00605X_2 + .46375X_1 - .53492X_5 - .60210X_8 + 1.11739X_{10} - .09521X_{15}$		
$- 1.81719X_9 - .68530X_{11}$	.67	.94

$\hat{Y}_2$ = Total carcass lean (S.D. = 1.64 lbs.)
X_{18} = Percent tr. wholesale cuts
X_2 = Hind specific gravity
X_1 = Chilled carcass weight (lb.)
X_5 = Loin fat trim weight (lb.)
X_8 = Kidney knob weight (lb.)
X_{10} = Loin eye area (sq. in.)
X_{15} = Tracing fat area (sq. in.)
X_9 = Fat thickness over 12th rib (in.)
X_{11} = Loin probe (in.)

X and Y are deviations from group means.

TABLE XXII

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING PERCENTAGE CARCASS LEAN

	R^2	Standard Error of Estimate
$\hat{Y}_5 = -.58652X_6$	.49	2.18
$\hat{Y}_5 = -.38473X_6 + .01977X_2$	.60	1.94
$\hat{Y}_5 = -.36834X_6 + .01398X_2 - 1.26529X_8$	.63	1.86
$\hat{Y}_5 = -.31179X_6 + .01364X_2 - 1.20180X_8 - .19698X_{15}$	.65	1.83
$\hat{Y}_5 = -.26356X_6 + .01107X_2 - 1.35687X_8 - .24863X_{15} + 2.03633X_{10}$	.67	1.79
$\hat{Y}_5 = -.23078X_6 + .01093X_2 - 1.30204X_8 - .23501X_{15} + 1.88291X_{10} - 3.87032X_9$	.67	1.78
$\hat{Y}_5 = -.20339X_6 + .01106X_2 - 1.24425X_8 - .19758X_{15} + 1.96985X_{10} - 3.99771X_9 - 1.71244X_{11}$	.68	1.78
$\hat{Y}_5 = -.18336X_6 + .01141X_2 - 1.21377X_8 - .16821X_{15} + 2.06682X_{10} - 3.58141X_9 - 1.82263X_{11} - .31136X_4$	.68	1.78
$\hat{Y}_5 = -.12359X_6 + .01200X_2 - 1.24121X_8 - .16277X_{15} + 1.68473X_{10} - 2.95238X_9 - 1.99603X_{11} - .54504X_4 + .19343X_{18}$	.68	1.77

$\hat{Y}_5$ = Percentage carcass lean (S.D. = 3.13%)
X_6 = Percentage loin fat trim
X_2 = Hind specific gravity
X_8 = Kidney knob weight (lb.)
X_{15} = Tracing fat area (sq. in.)
X_{10} = Loin eye area (sq. in.)
X_9 = Fat thickness over 12th rib (in.)
X_{11} = Loin probe (in.)
X_4 = Untr. loin weight (lb.)
X_{18} = Percent wholesale cuts

X and Y are deviations from group means.

TABLE XXIII

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING TOTAL CARCASS BONE

	R^2	Standard Error of Estimate
$\hat{Y}_3 = .07206X_7$	.42	.44
$\hat{Y}_3 = .06275X_7 + .00270X_2$	.50	.41
$\hat{Y}_3 = .05836X_7 + .00347X_2 + .07697X_1$	.57	.39
$\hat{Y}_3 = .05785X_7 + .00332X_2 + .08006X_1 + .26268X_{17}$	.62	.36
$\hat{Y}_3 = .05678X_7 + .00232X_2 + .09509X_1 + .25955X_{17} - .23095X_8$	.65	.35
$\hat{Y}_3 = .05484X_7 + .00164X_2 + .09872X_1 + .22731X_{17} - .22316X_8 - .02440X_6$	.66	.34
$\hat{Y}_3 = .05322X_7 + .00205X_2 + .10659X_1 + .21128X_{17} - .20538X_8 - .03109X_6 - .32177X_{10}$	.68	.34
$\hat{Y}_3 = .05262X_7 + .00203X_2 + .11105X_1 + .20885X_{17} - .19646X_8 - .02307X_6 - .36154X_{10} - .90475X_9$	.68	.34
$\hat{Y}_3 = .05211X_7 + .00216X_2 + .12207X_1 + .18340X_{17} - .22325X_8 - .02705X_6 - .32918X_{10} - .87257X_9 - .02859X_{16}$	.69	.34

$\hat{Y}_3$ = Total carcass bone (S.D. = 0.6 lbs.)
X_7 = Right cannon bone (gm.)
X_2 = Hind specific gravity
X_1 = Chilled carcass weight (lb.)
X_{17} = Tracing bone area (sq. in.)
X and Y are deviations from group means.

X_8 = Kidney knob weight (lb.)
X_6 = Percentage loin fat trim
X_{10} = Loin eye area (sq. in.)
X_9 = Fat thickness over 12th rib (in.)
X_{16} = Tracing lean area (sq. in.)

TABLE XXIV

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING PERCENTAGE CARCASS BONE

	R^2	Standard Error of Estimate
$\hat{Y}_6 = -1.63432X_5$	.38	.94
$\hat{Y}_6 = -1.28342X_5 + .09967X_7$	.55	.80
$\hat{Y}_6 = -.96355X_5 + .09528X_7 - .69772X_8$	.64	.72
$\hat{Y}_6 = -.74605X_5 + .09972X_7 - .73199X_8 + .11351X_{14}$	.67	.69
$\hat{Y}_6 = -.56153X_5 + .09548X_7 - .56711X_8 + .12172X_{14} + .00347X_2$	.68	.67
$\hat{Y}_6 = -.65771X_5 + .09367X_7 - .50607X_8 + .11003X_{14} + .00405X_2 - .12064X_{18}$	.71	.65
$\hat{Y}_6 = -.71726X_5 + .09189X_7 - .47343X_8 + .09988X_{14} + .00465X_2 - .08717X_{18} - .56655X_{10}$	.72	.65
$\hat{Y}_6 = -.58554X_5 + .09195X_7 - .45496X_8 + .10187X_{14} + .00456X_2 - .08488X_{18} - .62994X_{10} - 1.55367X_9$	.72	.64
$\hat{Y}_6 = -.09511X_5 + .09360X_7 - .45022X_8 + .10831X_{14} + .00418X_2 - .12609X_{18} - .56975X_{10} - 1.49928X_9 - .07039X_6$	.73	.64

$\hat{Y}_6$ = Percentage carcass bone (S.D. = 1.23%)
X_5 = Loin fat trim weight (lb.)
X_7 = Right cannon weight (gm.)
X_8 = Kidney knob weight (lb.)
X_{14} = Tracing bone percentage
X and Y are deviations from group means.

X_2 = Hind specific gravity
X_{18} = Percent tr. wholesale cuts
X_{10} = Loin eye area (sq. in.)
X_9 = Fat thickness over 12th rib (in.)
X_6 = Percentage loin fat trim

TABLE XXV

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING TOTAL CARCASS FAT

	R^2	Standard Error of Estimate
$\hat{Y}_1 = .60250X_{15}$	.3472	1.7881
$\hat{Y}_1 = .37348X_{15} + .10808X_{12}$	.3590	1.7792
$\hat{Y}_1 = .16597X_{15} + .21433X_{12} + .14320X_{16}$	.3621	1.7824
$\hat{Y}_1 = .33902X_{15} + .53147X_{12} + .58306X_{16} + .24612X_{14}$	.3722	1.7755

$\hat{Y}_1$ = Pounds of carcass fat (S.D. = 2.28 lbs.)

X_{15} = Tracing fat area (sq. in.)

X_{12} = Tracing fat percentage

X_{16} = Tracing lean area (sq. in.)

X_{14} = Tracing bone percentage

X and Y are deviations from group means.

TABLE XXVI

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING TOTAL CARCASS FAT

	R^2	Standard Error of Estimate
$\hat{Y}_1 = .65391X_1$	.3615	1.7685
$\hat{Y}_1 = .56735X_1 + .21424X_{12}$	.5987	1.4078
$\hat{Y}_1 = .58515X_1 + .20233X_{12} - .05716X_{16}$	.6001	1.4111
$\hat{Y}_1 = .59126X_1 + .19361X_{12} - .07681X_{16} - .11634X_{17}$	.6006	1.4162
$\hat{Y}_1 = .59710X_1 + .23250X_{12} - .04556X_{16} - 1.47330X_{17} + .41771X_{14}$	.6035	1.4170

$\hat{Y}_1$ = Pounds of carcass fat (S.D. = 2.28 lbs.)

X_1 = Carcass weight (lb.)

X_{12} = Tracing fat percentage

X_{16} = Tracing lean area (sq. in.)

X_{17} = Tracing bone area (sq. in.)

X_{14} = Tracing bone percentage

X and Y are deviations from group means.

TABLE XXVII

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING PERCENTAGE CARCASS FAT

	R^2	Standard Error of Estimate
$\hat{Y}_4 = .45446X_{12}$	.3775	2.975
$\hat{Y}_4 = .48239X_{12} + .14825X_{16}$	.3815	2.978
$\hat{Y}_4 = .51960X_{12} + .23953X_{16} + .11918X_{14}$	.3834	2.985
$\hat{Y}_4 = .83106X_{12} + .63190X_{16} + .27071X_{14} - .55510X_{15}$	.3858	2.992
$\hat{Y}_4 = .88343X_{12} + .75504X_{16} + .61501X_{14} - .59726X_{15} - 1.12569X_{17}$	.3864	3.003

$\hat{Y}_4$ = Percentage carcass fat (S.D. = 3.88%)

X_{12} = Tracing fat percentage

X_{16} = Tracing lean area (sq. in.)

X_{14} = Tracing bone percentage

X_{15} = Tracing fat area (sq. in.)

X_{17} = Tracing bone area (sq. in.)

X and Y are deviations from group means.

TABLE XXVIII

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING PERCENTAGE CARCASS FAT

	R^2	Standard Error of Estimate
$\hat{Y}_4 = .45446X_{12}$	.3775	2.9750
$\hat{Y}_4 = .41962X_{12} + .54117X_1$	.4606	2.7807
$\hat{Y}_4 = .50958X_{12} + .58325X_1 - .24254X_{15}$	.4638	2.7840

$\hat{Y}_4$ = Percentage carcass fat (S. D. = 3.88%)

X_{12} = Tracing fat percentage

X_1 = Carcass weight (lb.)

X_{15} = Tracing fat area (sq. in.)

X and Y are deviations from group means.

TABLE XXIX

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING TOTAL CARCASS LEAN

	R^2	Standard Error of Estimate
$\hat{Y}_2 = .40450X_{16}$	.2266	1.402
$\hat{Y}_2 = .29234X_{16} - .08064X_{12}$	.2757	1.362
$\hat{Y}_2 = .34584X_{16} - .05574X_{12} + .37280X_{17}$	.2850	1.359
$\hat{Y}_2 = .45655X_{16} - .03932X_{12} + .52591X_{17} - .17827X_{15}$	.2865	1.363
$\hat{Y}_2 = .41014X_{16} + .45823X_{17} - .10694X_{15}$ (X_{12} removed)	.2863	1.358

$\hat{Y}_2$ = Pounds of carcass lean (S.D. = 1.64 lbs.)

X_{16} = Tracing lean area (sq. in.)

X_{12} = Tracing fat percentage

X_{17} = Tracing bone area (sq. in.)

X_{15} = Tracing fat area (sq. in.)

X and Y are deviations from group means.

TABLE XXX

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING TOTAL CARCASS LEAN

	R^2	Standard Error of Estimate
$\hat{Y}_2 = .40450X_{16}$	.2266	1.4019
$\hat{Y}_2 = .34717X_{16} + .21442X_1$	.2970	1.3422
$\hat{Y}_2 = .14068X_{16} + .31362X_1 - .12940X_{12}$	.4083	1.2364

$\hat{Y}_2$ = Pounds of carcass lean (S. D. - 1.64 lbs.)

X_{16} = Tracing lean area (sq. in.)

X_1 = Carcass weight (lb.)

X_{12} = Tracing fat percentage

X and Y are deviations from group means.

TABLE XXXI

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING PERCENTAGE CARCASS LEAN

	R^2	Standard Error of Estimate
$\hat{Y}_5 = -.34681X_{12}$	.3374	2.4773
$\hat{Y}_5 = -.35935X_{12} - .31522X_{17}$	.3398	2.4830
$\hat{Y}_5 = -.35660X_{12} - .84216X_{17} + .14107X_{14}$	.3404	2.4922
$\hat{Y}_5 = -.42226X_{12} - 1.70368X_{17} + .38039X_{14} + .18741X_{15}$	.3421	2.4994
$\hat{Y}_5 = -.64701X_{12} - .96434X_{17} + .04611X_{14} + .53658X_{15} - .34288X_{16}$	.3440	2.5065
$\hat{Y}_5 = -.65860X_{12} - .82675X_{17} + .55000X_{15} - .36513X_{16}$ (X_{14} removed)	.3440	2.4959

$\hat{Y}_5$ = Percentage carcass lean (S. D. = 3.13%)

X_{12} = Tracing fat percentage

X_{17} = Tracing bone area (sq. in.)

X_{14} = Tracing bone percentage

X_{15} = Tracing fat area (sq. in.)

X_{16} = Tracing lean area (sq. in.)

X and Y are deviations from group means.

TABLE XXXII

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING PERCENTAGE CARCASS LEAN

	R^2	Standard Error of Estimate
$\hat{Y}_5 = -.34681X_{12}$	.3374	2.4773
$\hat{Y}_5 = -.32424X_{12} - .35043X_1$	.3909	2.3850
$\hat{Y}_5 = -.27597X_{12} - .42256X_1 + .23162X_{16}$	.4037	2.3697
$\hat{Y}_5 = -.36578X_{12} - .42670X_1 + .13900X_{16} + .19009X_{15}$	.4047	2.3777
$\hat{Y}_5 = -.38207X_{12} - .42052X_1 + .03833X_{16} + .30177X_{15} + .05490X_{13}$	.4049	2.3872
$\hat{Y}_5 = -.39359X_{12} - .41809X_1 + .34697X_{15} + .07066X_{13}$ (X_{16} removed)	.4049	2.3772

$\hat{Y}_5$ = Percentage carcass lean (S.D. = 3.13%)

X_{12} = Tracing fat percentage

X_1 = Carcass weight (lb.)

X and Y are deviations from group means.

X_{16} = Tracing lean area (sq. in.)

X_{15} = Tracing fat area (sq. in.)

X_{13} = Tracing lean percentage

TABLE XXXIII

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING TOTAL CARCASS BONE

	R^2	Standard Error of Estimate
$\hat{Y}_3 = -.04705X_{12}$	.1710	.5282
$\hat{Y}_3 = -.04160X_{12} + .13715X_{17}$	.1835	.5263
$\hat{Y}_3 = -.04593X_{12} + .97017X_{17} - .22301X_{14}$	.2223	.5158
$\hat{Y}_3 = -.00796X_{12} + 1.67733X_{17} - .41945X_{14} - .15383X_{15}$	.2545	.5071
$\hat{Y}_3 = -.02395X_{12} + 1.78230X_{17} - .46691X_{14} - .10425X_{15} - .04868X_{16}$	.2555	.5089

$\hat{Y}_3$ = Pounds of carcass bone (S.D. = 0.6 lbs.)

X_{12} = Tracing fat percentage

X_{17} = Tracing bone area (sq. in.)

X_{14} = Tracing bone percentage

X_{15} = Tracing fat area (sq. in.)

X_{16} = Tracing lean area (sq. in.)

X and Y are deviations from group means.

TABLE XXXIV

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING TOTAL CARCASS BONE

	R^2	Standard Error of Estimate
$\hat{Y}_3 = -.04705X_{12}$	.1710	.5282
$\hat{Y}_3 = -.05205X_{12} + .07758X_1$	.2431	.5068
$\hat{Y}_3 = -.04659X_{12} + .07759X_1 + .13727X_{17}$	.2557	.5046
$\hat{Y}_3 = -.02279X_{12} + .08893X_1 + .12598X_{17} - .06537X_{15}$	.2654	.5034
$\hat{Y}_3 = -.01445X_{12} + .07369X_1 + 1.34938X_{17} - .17927X_{15} - .33280X_{14}$	.3076	.4908
$\hat{Y}_3 = -.06283X_{12} + .07834X_1 + 1.58423X_{17} - .06018X_{15} - .44287X_{14} - .11852X_{16}$	.3134	.4908

$\hat{Y}_3$ = Pounds of carcass bone (S.D. = 0.6 lbs.)

X_{12} = Tracing fat percentage

X_1 = Carcass weight (lb.)

X_{17} = Tracing bone area (sq. in.)

X_{15} = Tracing fat area (sq. in.)

X_{14} = Tracing bone percentage

X_{16} = Tracing lean area (sq. in.)

X and Y are deviations from group means.

TABLE XXXV

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING PERCENTAGE CARCASS BONE

	R^2	Standard Error of Estimate
$\hat{Y}_6 = -.28541X_{15}$	.2692	1.0181
$\hat{Y}_6 = -.25956X_{15} + .27930X_{17}$	.2815	1.0135
$\hat{Y}_6 = -.29441X_{15} + 1.28865X_{17} - .27979X_{14}$	.2931	1.0096
$\hat{Y}_6 = -.34614X_{15} + 2.12421X_{17} - .53708X_{14} - .09015X_{16}$	.3017	1.0076
$\hat{Y}_6 = -.06357X_{15} + 2.60683X_{17} - .80435X_{14} - .43508X_{16} - .25015X_{12}$	.3152	1.0020

$\hat{Y}_6$ = Percentage carcass bone (S.D. = 1.23%)

X_{15} = Tracing fat area (sq. in.)

X_{17} = Tracing bone area (sq. in.)

X_{14} = Tracing bone percentage

X_{16} = Tracing lean area (sq. in.)

X_{12} = Tracing fat percentage

X and Y are deviations from group means.

TABLE XXXVI

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN YEAR, REARING AND FACE COLOR BASIS FOR ESTIMATING PERCENTAGE CARCASS BONE

	R^2	Standard Error of Estimate
$\hat{Y}_6 = -.28541X_{15}$	.2692	1.0181
$\hat{Y}_6 = -.24854X_{15} - .12902X_1$	.3133	.9909
$\hat{Y}_6 = -.21820X_{15} - .13377X_1 + .31317X_{17}$	.3288	.9837
$\hat{Y}_6 = -.27128X_{15} - .17615X_1 + 2.24096X_{17} - .53140X_{14}$	.3657	.9603
$\hat{Y}_6 = -.30336X_{15} - .17100X_1 + 2.72028X_{17} - .68021X_{14} - .05472X_{16}$	.3688	.9620
$\hat{Y}_6 = -.02820X_{15} - .16312X_1 + 3.01925X_{17} - .85440X_{14} - .28966X_{16} - .16920X_{12}$	.3748	.9615
$\hat{Y}_6 = -.16259X_1 + 3.03312X_{17} - .86635X_{14} - .31112X_{16} - .18551X_{12}$ (X_{15} removed)	.3747	.9575

$\hat{Y}_6$ = Percentage carcass bone (S.D. = 1.23%)
X_{15} = Tracing fat area (sq. in.)
X_1 = Carcass weight (lb.)
X_{17} = Tracing bone area (sq. in.)
X_{14} = Tracing bone percentage
X_{16} = Tracing lean area (sq. in.)
X_{12} = Tracing fat percentage

X and Y are deviations from group means.

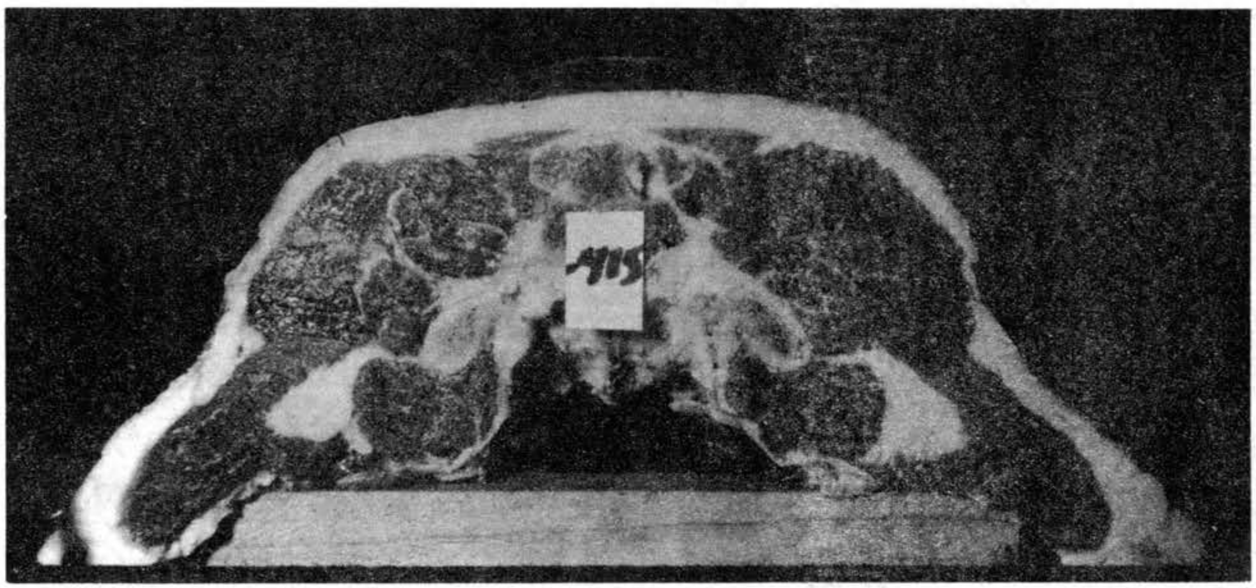

Figure 1. Posterior Surface of the Loin

VITA

Robert N. Sprowls

Candidate for the Degree of

Master of Science

Thesis: THE USE OF LEG-LOIN CROSS-SECTIONAL TRACINGS FOR PREDICTION OF LAMB CARCASS COMPOSITION

Major Field: Animal Science

Biographical:

Personal Data: Born at Cheyenne, Oklahoma, March 21, 1929, the son of James S. and Vera M. Sprowls; married Frances L. Palmeter, January 27, 1951; the father of James Robert, William Ken and Linda Lee Sprowls.

Education: Graduated from Elk City High School in 1947; received the Bachelor of Science degree from Oklahoma State University with a major in Animal Husbandry in May, 1951.

Professional Experience: Operated a cow-calf ranch in western Oklahoma, 1951 to 1969; Graduate Assistant in Animal Science at Oklahoma State University, 1969 to 1971.