AN INVESTIGATION OF SOME INDICES OF LAMB CARCASS COMPOSITION

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INTRODUCTION

A knowledge of carcass composition has become important in the livestock industry, both in research and in production. Accurate measures of the relative amounts of the different tissues in the carcass are needed to detect treatment differences in meat production experiments. Progress in breed improvement in the meat-type animal is largely dependent upon the development of accurate measures of carcass composition which are capable of simple application to large populations.

In the past visual appraisal and carcass weight have been the most popular means of estimating carcass composition. These measurements are simple to obtain, but their value for the accurate prediction of percent fat, lean and bone in carcasses has not been established. The most accurate methods of composition determination are physical separation of the tissues and chemical analysis. Either of these methods is inefficient in that they are time consuming and they destroy the form of the carcass.

Previous research conducted to find quantitative measurements which will accurately indicate carcass composition has yielded highly variable results. The objectives of this study were to formulate accurate and useable prediction equations for the estimation of percent fat, lean and bone in lamb carcasses and to determine the accuracy of some previously reported equations.

REVIEW OF LITERATURE

For many years, researchers have realized the need for a practical method of determining carcass composition from simple measurements on the intact carcass. Obviously the most easily obtainable measurement is carcass weight.

Barton and Kirton (1958a) attempted to measure the association of carcass weight with lamb carcass composition, as determined by both physical separation and chemical analysis of the half-carcass. On a group of 33 Romney-Southdown wether lambs of widely varying condition, they found the correlations between carcass weight and dissectible carcass fat, lean and bone to be 0.94, 0.95, and 0.79, respectively. When considering carcass weight and dissectible fat in other groups of lambs, they reported correlation coefficients of 0.87 for 26 ewe lambs, 0.90 for 44 wether lambs, and 0.86 for 70 lambs of mixed sex.

These figures are in agreement with Khandekar <u>et</u> <u>al</u> (1965a), who reported a highly significant ($P<0.001$) correlation of 0.81 between carcass weight and the total weight of dissectible fat in the half-carcass. However, they found a lower ($r = -0.51$) and non-significant correlation between carcass weight and carcass bone weight. In this study 66 lambs were used, 21 of which were raised on pasture and 45 raised in a feedlot. All the lambs were slaughtered at a mean live weight of 70.6 pounds. The carcass weights ranged from 25 to 41 pounds. They suggest a possible reason for this low correlation between carcass weight and bone weight is the fact that their experimental animals were of a wide range of ages and that in older animals, increasing fat deposition will weaken the relationship between carcass weight and total bone weight of the carcass. This agrees with observations of Pálsson and Vergés (1952) who state that the carcass of a sheep does not reach mature weight by a uniform rate of growth of its component tissues in proportion to their weight at birth or any other stage of development, but it does so by widely different and changing growth rates of the tissues.

In work with 132 beef carcasses, Cole <u>et al.</u> (1962) found that carcass weight was closely related to pounds of separable lean, reporting a correlation coefficient of 0.75.

In later research with 20 Southdown-Romney wether lamb carcasses, Kirton and Barton (1962) found correlations between carcass weight and carcass fat and protein to be 0.63 and 0.78, respectively. They concluded that carcass composition could be estimated with reasonable precision from carcass weight. However, more accuracy would be required to detect small differences between carcasses.

Some researchers have investigated the use of dressing percent, another easily obtainable measurement, for estimating carcass composition. Lush (1926) found dressing percent to be quite reliable in estimating fatness of cattle carcasses where wide ranges of fatness were compared. His correlation of dressing percent with percent carcass fat was 0.760. Munson (1966) found dressing percent a fairly good predictor of percent carcass bone in lambs reporting a negative correlation of -0.57. Conversely, Hopper (1944) and Kirton and Barton (1962) found that dressing percent was not a reliable indicator of carcass composition. The use of this measurement for the prediction of composition of carcasses would be difficult because it would require standardization of pre-slaughter environment.

Considerable variation has been found in the relative densities of the body tissues. Kraybill et al. (1952), in an investigation of the body composition of cattle, found the specific gravities of fat, muscle and bone to be 0.92, 1.06, and 1.50, respectively. Bieber et al. (1961) reported the specific gravities of fat and protein in beef as 0.9122 and 1.3118, respectively. These differences in density have led to extensive studies in the application of specific gravity as an indicator of carcass composition. In an early study conducted on guinea pigs, Rathbun and Pace (1945) found a strong inverse relationship between percent body fat and carcass specific gravity. More recent studies have been conducted concerning the relationship between carcass specific gravity and percent carcass fat in sheep. The results of these studies have been consistent in showing a negative correlation between the two variables; however, there has been considerable variation in the correlation coefficients reported.

Some of the more recent investigators and the reported coefficients of correlation between carcass specific gravity and carcass fat are as follows:

Barton and Kirton (1956)	-.88
Field et al. (1963a)	-.49
Khandekar et al. (1965b)	-.98
Kirton and Barton (1958)	-.883
Kirton and Barton (1962)	-.56
Pradhan et al. (1966)	-.70

Spurlock and Bradford (1965)	-.89
Stouffer (1955)	-.622
Timon and Bichard (1965a)	-.93
Munson (1966)	-.62

In an investigation conducted on 64 wether lambs, which were slaughtered in six different age and weight groups, Ament <u>et al</u>. (1962) found that the average values for specific gravity were closely associated with average fat content for each group. However, within groups specific gravity was not closely associated with total or percent fat.

Barton and Kirton (1956) used specific gravity to estimate the fat content of 15 six-year old Romney ewes. The carcasses ranged in weight from 55.2 to 78.2 pounds, in fat content from 26.1 to 45.4 percent, and in specific gravity from 1.009 to 1.049. They computed the relationship using the reciprocal of specific gravity with the following equation:

$$\text{Percent carcass fat} = 100 \quad \frac{5.680}{\text{specific gravity}} \quad - 5.138$$

with a standard error of estimate of 3.20 percent.

Field <u>et al</u>. (1963a) investigated the carcasses of 165 Southdown crossbred lambs ranging in age from 119 to 288 days and slaughtered at approximately 85 pounds. Specific gravity measurements of the carcasses were correlated with percent fat, lean, and bone in the carcass, -.49, .47, and .32 respectively. The percent fat and lean in the carcass were predicted with the following simple linear regression equation:

$$\text{Percent carcass fat} = -201.54 + 228.43 \text{ (carcass specific gravity)}$$

$$\text{Percent carcass lean} = -128.60 + 174.13 \text{ (carcass specific gravity)}$$

These equations had standard errors of estimate of 3.48 and 2.83 percent. They concluded that carcass specific gravity alone is not sufficiently accurate for individual carcass determinations.

Khandekar et al. (1965b) studied specific gravity as an index of the fat content of 24 lamb carcasses selected from the group of 66 lambs previously mentioned. They found correlations between specific gravity of the half carcass and percent fat in the half carcass, rib, loin, and leg to be -0.98, -0.97, and -0.96, and -0.93, respectively. They also found a correlation of -0.94 between specific gravity of the leg joint and percent fat in the half carcass. All these correlation coefficients were highly significant ($P < .001$). Their regression equations for predicting percent fat in the half carcass were as follows:

$$\text{Percent fat} = 590.7606 - 535.06 \text{ (specific gravity of half carcass)}$$

$$\text{Percent fat} = 578.891 - 535.589 \text{ (specific gravity of leg joint)}$$

The standard errors of estimate for these equations were 1.31 and 2.51 percent, respectively.

When Kirton and Barton (1958) used carcass specific gravity to predict carcass fat in 48 Romney ewe mutton carcasses, they obtained the following regression equation:

$$\text{Percent fat} = 537.8 - 483.4 \text{ (carcass specific gravity)}$$

However, when five very fat and four lean carcasses were added to the group, the equation became curvilinear and was as follows:

$$\text{Percent fat} = 8371.3 \text{ (specific gravity)} - 4382.9 \text{ (specific gravity)}^2 - 3932.9$$

The standard error of estimate was 4.45 percent, too high for specific gravity to be considered an accurate predictor of fat content.

Kirton and Barton (1962) found carcass specific gravity to be more highly correlated with carcass protein percent than with carcass fat percent. The correlation coefficients for specific gravity with fat and protein were -0.56 and 0.69, respectively. Their regression equations for the prediction of percent fat and protein were:

$$\text{Percent carcass fat} = 295.2 - 255.8 \text{ (carcass specific gravity)}$$

$$\text{Percent carcass protein} = 69.7 \text{ (carcass specific gravity)} - 57.8$$

These equations have standard errors of estimate of 3.31 and 0.64 percent, respectively.

Pradhan *et al.* (1966) also found specific gravity to be more highly correlated with carcass protein than carcass fat. In a study conducted on 12 Dorset Horn X Border Leicester-Merino lambs which were between three and five months of age, they obtained correlations of -.70 and .74 between carcass specific gravity and percent fat and protein in the half carcass. They also found that specific gravity of the leg was a better indicator of carcass fat and protein than was specific gravity of the whole carcass.

Spurlock and Bradford (1965) investigated different systems of carcass evaluation on the carcasses of 56 crossbred lambs. These lambs were from Dorset Horn rams mated to ewes of Hampshire, Suffolk, and grade Corriedale breeds. The lambs averaged 88.1 pounds alive, were approximately five months old at slaughter, and all the carcasses graded between Good and Prime. The percent fat predicted from specific gravity of the left half-carcass had a correlation of 0.90 with percent fat from chemical analysis of the same half-carcass. This was important because many researchers had previously believed that a broad range in grade was necessary in order to obtain a high correlation from specific gravity.

Timon and Bichard (1965a) studied the relationships between specific gravity and carcass fat and muscle in 83 purebred Clun Forest lambs slaughtered at approximately 80 pounds liveweight and ranging in carcass weight from 29 to 42 pounds. Carcass specific gravity accounted for 86.1 and 78.1 percent of the respective variances in carcass fat and muscle. The corresponding least squares prediction equations were:

$$\text{Percent carcass fat} = 603.7 - 550.1\ (\text{carcass specific gravity}) \pm 1.45$$

$$\text{Percent carcass muscle} = -367.6 + 403.8\ (\text{C.S.G.}) \pm 1.69$$

When confidence limits were attached to individual and group mean estimates of carcass fat and muscle, the errors were large, indicating that specific gravity cannot be relied on to reflect real differences in carcass composition between individuals or groups of individuals where differences are small.

Munson (1966) investigated the relationship between several measurements and carcass composition of 123 wether lamb carcasses sired by Dorset, Hampshire, and Suffolk rams and out of Western and Dorset X Western ewes. These lambs were all slaughtered at approximately 100 pounds live weight. He found that carcass specific gravity accounted for 34 and 32 percent of the variation in carcass fat and lean. The regression equations for estimating percent carcass fat and lean were:

$$\text{Percent carcass fat} = 45.830 - .042\ [10{,}000(\text{carcass specific gravity} - 1.0000)]$$

$$\text{Percent carcass lean} = 42.210 + .031\ [10{,}000(\text{carcass specific gravity} - 1.0000)]$$

The standard errors of estimate of the above equations were 3.03 and 2.54 percent, respectively. He found that hindsaddle specific gravity was a better indicator of carcass fat and lean, accounting for 57 and 49 percent of the variation of each. The prediction equations using hindsaddle specific gravity were:

$$\text{Percent carcass fat} = 45.808 - .046\ [10{,}000\ (\text{hindsaddle specific gravity} - 1.000)]$$

$$\text{Percent carcass lean} = 42.226 + .034\ [10{,}000\ (\text{hindsaddle specific gravity} - 1.0000)]$$

The standard errors of estimate for these equations were 2.85 and 2.29 percent, respectively.

Most of the measurements mentioned thus far relate either to the whole or the half carcass. More measurements are obtainable, possibly adding greater precision to prediction of carcass composition, when the carcasses are broken down into fore- and hind-saddles or into wholesale cuts (shoulder, rack, loin, and leg.).

The thickness of the subcutaneous fat across the back has long been used as an indicator of fatness in a carcass. Hankins and Ellis (1934) were among the first to test the accuracy of such a measurement.

They took the average of five backfat thickness measurements on each of 60 hogs. The correlation between this and the percent fat in the edible portion of the carcass was +0.84. McMeekan (1941) found the correlation between the mean of five back-fat thickness measurements and the total weight of fat in pork carcasses to be +0.9552 in a study conducted on 20 bacon pigs of 200 pound live weight.

Pálsson (1939) used sample joints and various carcass measurements to estimate the composition of eleven wether lamb and five wether hogget carcasses. The lambs, which were about four and one-half months old, yielded 40-pound carcasses; the hoggets were 13 months old and their carcasses averaged 60 pounds. Three measurements of fat thickness over the 12th rib were found to be the best single indicator of total carcass fat weight with a correlation of +0.8084. Timon and Bichard (1965b) reported a correlation of 0.82 between loin back-fat depth and carcass fat weight.

Ramsey et al. (1962) obtained similar results with cattle. In a study of carcass measurements from 133 steers representing eight breeds, they found that a single fat thickness measurement or an average of three fat thickness measurements over the ribeye was as good as or better than carcass grade or yield grade as an estimator of percent separable lean and fat. They also found no advantage in using an average of three fat thickness measurements instead of a single measurement. The correlations between fat thickness and separable fat, lean, and bone, were 0.82, -0.76, and -0.76, respectively.

Somewhat lower correlations were obtained by Field et al. (1963a), who reported correlations of 0.63 and -0.57 between fat thickness and percent fat and lean in the carcass. Spurlock and Bradford (1965) adjusted fat thickness to a 50-pound carcass basis and found the correlation between this and percent fat in the carcass to be 0.57. Hoke (1961) reported that fat thickness at the 12th rib was the most reliable single measurement for predicting yield of trimmed retail cuts in Prime, Choice, and Good grades of lamb carcasses.

Researchers for years have considered the area of the longissimus dorsi to be indicative of the amount of muscling in carcasses. However, reports from studies conducted to verify this belief have been highly variable. Some of this variability may be explained by differences in ribbing methods. Stouffer (1961) showed that the area of the longissimus dorsi may vary at different points between the 12th and 13th ribs in beef carcasses. Carpenter and Palmer (1961) also indicated the effect of variations in ribbing procedure.

Pálsson (1939) found length and depth measurements of the longissimus dorsi the best index of lamb carcass muscling. He reported correlations between carcass muscle and length, depth, and length plus depth as 0.67, 0.47, and 0.77, respectively. McMeekan (1941) found a higher correlation in pork. Although neither length nor depth alone were suitable for prediction of lean weight, the correlation between length plus depth and carcass lean weight was 0.9339. On the other hand, Khandekar (1965a) found that the depth of the loin eye muscle was an excellent index of total muscle in the lamb carcasses that they studied. The correlation between these two variables was 0.99 and was highly significant ($P < 0.001$). Timon and Bichard (1965b) determined the area of the longissimus dorsi with a planimeter and by using measurements of the length and depth. Their correlations with carcass muscle weight were 0.64 and 0.67, respectively. This indicated that the area of the loin eye muscle as obtained by planimeter measurement was no better an index of carcass muscle than when the area was estimated from the product of width and depth. These correlations are in agreement with those reported by Orme et al. (1962), who found a correlation of 0.60 between loin eye area and total carcass lean. Ament et al. (1962) reported a correlation of 0.80 between these two variables.

Other researchers have indicated that loin eye area is not such a valuable indicator of carcass muscling, possibly because of variation in ribbing technique. Field et al. (1963a) reported correlations between loin eye area per 45 pounds of carcass and percent fat and lean in carcass of -0.43 and 0.47, respectively. In studies with beef carcasses both Cole et al. (1960) and Gottsch et al. (1961) reported that loin eye area accounted for only 18 percent of the variation in total carcass lean. Goll et al. (1961) found no clear evidence that loin eye area is closely related to yield of wholesale beef cuts. Munson (1966) reported a correlation of 0.37 between loin eye area and percent lean in lamb carcasses.

Cannon bone weight has been shown to be highly related to total bone weight by several researchers. The coefficients of correlation for the weight of fore-cannon bone and the total weight of bone in the carcass reported by Pálsson (1939) were 0.94 for eleven wether lambs and 0.98 for five wether hoggets. McMeekan (1941) also found weight of cannon bones to be indicative of total bone weight in pigs. Khandekar (1965a) reported a correlation of 0.85 ($P < 0.001$) between weight of fore-cannon bone and total weight of bone in the lamb half-carcass. Their regression equation for predicting bone weight was:

Weight of bone in half-carcass = 76.522 (wt. of fore-cannon bone) -222.249

This equation yielded a standard error of estimate of 55.7 grams or .12 pounds.

Lush (1926) was among the first to find that carcass composition could be estimated from the composition of certain cuts. The percentage of leg bones to live weight was shown to be a good indicator of the percentage of bone in dressed sides of beef in animals that varied greatly in age and degree of fatness. The percent fat in the edible portion of the wholesale rib was the most accurate indicator of degree of fatness and yielded a correlation of 0.987 with a standard deviation of 0.003. Hooper (1944) found correlations between percent bone and ether extract of the 9th, 10th, and 11th rib cut and percent bone and ether extract of beef carcass to be 0.941 and 0.983, respectively. In a study conducted on 197 steer and heifer carcasses Hankins and Howe (1946) obtained a correlation of 0.93 ± 0.02 between fat content of the 9th, 10th, and 11th rib cut and fat content of the edible portion of the dressed beef carcass.

Pálsson (1939) stated that the leg region was relatively early developing and had a small percentage of fat. The loin is a relatively late developing region and accumulates fat later in life. He reported correlations of leg fat and muscle and carcass fat and muscle of 0.95 and 0.89, respectively. When the leg and loin were used together the results were even more predictive. The correlations between fat and muscle of the combined leg and loin with the fat and muscle of the carcass were 0.97 and 0.92, respectively.

Barton and Kirton (1958b) found that although the loin gave the best estimates of carcass fat content, the leg was more indicative of the muscle and bone contents. By dissecting 25 ewe carcasses into anatomical regions, the method utilized by Pálsson (1939), they found correlations between the leg and loin combined and fat, lean, and bone of the carcass of 0.98, 0.97, and 0.96, respectively. However, when these variables were used to form regression equations, they yielded standard errors of estimate as high as 8.5 percent.

In a later experiment, Kirton and Barton (1962) cut 20 lamb carcasses into wholesale cuts. The percent fat in the leg, loin, 9th, 10th, 11th rib cut, and fore were all found to be highly correlated to carcass fat, 0.93, 0.97, 0.96, and 0.94, respectively. They reported smaller standard errors of estimate this time when the fat content of each cut was used in regression equations to predict carcass fat. They were 1.55 percent, 1.07 percent, 1.16 percent, and 1.38 percent. The percent protein in these cuts were not as highly correlated with carcass protein, 0.71, 0.83, 0.77, and 0.79, respectively.

Khandekar et al. (1965a) also found that the total weight of bone, muscle, and fat in the half-carcass can be predicted with a high degree of accuracy from the weight of the respective tissues either in the leg or loin joints. Coefficients of correlation between fat, muscle, and bone in the leg and the tissues of the half-carcass were 0.99, 0.99, and 0.92, respectively. Correlations reported for the respective tissues of the loin and the half-carcass were 0.98, 0.94, and 0.89.

In a study conducted on 64 widely varying lamb carcasses, Hankins (1947) reported a correlation of 0.980 ± 0.003 between separable fat in 4th - 12th rib cuts and fat in carcass. His regression equation for prediction of carcass fat was:

Percent fat in carcass = (percent fat in rib cut) + 5.00

This equation had a standard error of estimate of 1.59 percent. Muscle and bone in the rib cut also had high correlations of 0.92 and 0.97 with their respective components in the carcass. Field et al. (1963) also found that physical separation of the rib was an accurate method of predicting fat, lean, and bone in the carcass. The leg and shoulder were also good predictors but required more labor in separation.

Timon and Bichard (1965b) found that the loin and mid-rib regions were the most accurate indicators of carcass composition. Correlations reported between physically separated fat, muscle and bone in the loin and in the carcass were 0.96, 0.93, and 0.84, respectively. Corresponding correlation for the 7 - 12th rib joint were 0.94, 0.92, and 0.76. Confidence limits (5 percent) were placed on the individual estimates based on loin composition. They were ± 2.22 percent, ± 2.44 percent, and ± 1.62 percent for fat, muscle and bone, respectively. For estimates based on rib joint composition they were ± 2.76, ± 2.52, and ± 2.26. These confidence limits indicate that these indices cannot be relied on to reflect small differences in carcass composition between individual animals.

Combinations of several different carcass measurements have been found to increase the accuracy of prediction of carcass composition. Lush (1926) combined measures of dressing percent and percent offal fat to live weight. The multiple correlation between these and percent fat in beef carcasses was 0.934. Cole et al. (1962) found that fat thickness combined with carcass weight accounted for over 70 percent of the variation in separable lean of beef carcasses.

Combinations of carcass measurements have also been used for lamb carcass evaluation. Carpenter et al. (1964) reported that fat thickness over the loin eye and loin eye area accounted for 65 percent of the variation in carcass value per hundred pounds of carcass in 169 wether lambs studied. In a study conducted on 166 lambs Hoke (1961) found that fat thickness, conformation grade and percent kidney fat accounted for 78 percent of the variation in the percent yield of wholesale cuts. Spurlock and Bradford (1965) utilized carcass weight, fat depth, and percent kidney fat to estimate the percent yield of trimmed cuts in 30 lamb carcasses. In another group of 26 more uniform carcasses a combination of loin eye area, fat depth and weight of kidney fat was the best indicator of percent trimmed cuts.

Meyer (1962) used carcass weight and specific gravity to estimate carcass fat and found a multiple correlation coefficient of 0.96. The multiple regression equation reported was:

$$\text{Carcass fat} = 436.8 - 398.7\ (\text{specific gravity}) + 0.1756\ (\text{carcass weight}) \pm 1.40$$

Judge and Martin (1963) developed regression equations using various combinations of predictors of percent edible portion of 51 ewe and wether carcasses of U. S. Prime, Choice and Good grades with a mean chilled weight of 49 pounds. The combination of factors having the smallest standard error of estimate (2.81 percent) and a multiple correlation coefficient (0.78) equal to that of all factors studied included fat thickness, kidney fat weight and leg and loin weights. They found, however, that chilled carcass weight could be substituted for leg and loin weight with only a slight increase in standard error of estimate (2.83 percent) and reduction in multiple correlation (0.77). The regression equation they reported was:

$$\text{Percent edible portion} = 87.76 - 16.586 \text{ (fat thickness, in.)} - 2.048 \text{ (kidney fat, lb.)} - .270 \text{ (chilled carcass wt., lb.)}$$

Field et al. (1963) obtained a multiple correlation of 0.79 between percent fat in carcass and area of loin eye, percent kidney and kidney fat and fat thickness over the rib eye. These same independent variables gave a multiple correlation coefficient of 0.71 when used to estimate percent lean in the carcass. When percent leg was added the correlation was increased to 0.75. The multiple regression equation reported was:

$$\text{Percent carcass lean} = 33.27 + 3.90 \text{ (area of loin eye/45lb. carcass)} - .46 \text{ (fat thickness over loin eye, mm.)} - .80 \text{ (percent kidney and kidney fat)} + 0.53 \text{ (percent leg)}$$

The standard error of estimate for this equation was 2.14.

Timon and Bichard (1965b) found that in predicting carcass fat percent, the most important measurements were caul fat weight, gigot width, cannon bone weight, flank flesh depth and eye muscle area. These variables explained 75.7 percent of the variation in this trait. The best muscle indicators were caul fat weight, cannon bone weight, carcass weight, four feet weight and eye muscle area; together they accounted for 60.8 percent of the variation in carcass muscle weight. Carcass bone percentage was best estimated from a combination of caul fat weight, gigot width, loin flesh depth, four feet weight and eye muscle area, which accounted for 60.8 percent of the variation in this trait. Increases in accuracy of prediction were found for each of these traits when carcass specific gravity was added to these measurements.

Munson (1966) developed the following multiple regression equations for estimating percent fat, lean and bone in lamb carcasses:

$$\text{Percent fat} = 14.484 + 3.741\ (\text{loin fat trim, lb.}) - .018\ [10{,}000\ (\text{hindsaddle specific gravity} - 1.000)] + 1.570\ (\text{kidney fat weight, lb.}) - .730\ (\text{weight of trimmed leg, lb.})$$

$$\text{Percent lean} = 62.620 - 2.803\ (\text{loin fat trim, lb.}) + .017\ [10{,}000\ (\text{hindsaddle specific gravity} - 1.000)] - 1.034\ (\text{kidney fat weight, lb.}) - .053\ (\text{slaughter weight, lb.})$$

$$\text{Percent bone} = 19.289 + 4.148\ (\text{leg bone weight, lb.}) - .141\ (\text{dressing percent}) - 2.514\ (\text{thickest fat at fifth rib, in.}) - .461\ (\text{kidney fat weight, lb.})$$

The multiple correlations between these traits and variables were 0.89, 0.81, and 0.90, respectively; the standard errors of estimate were 1.87, 1.89, and .62.

The review of literature indicated that carcass specific gravity is the most reliable simple measurement used to predict percent fat and lean in lamb carcasses. Several workers reported fat thickness and area of *longissimus dorsi* to be fairly good indicators of fat and lean in carcasses that vary widely in condition. Carcass composition can also be predicted from the composition of some of the major wholesale cuts, mainly the leg and loin. The weight of the cannon bones has been found to be a reliable index of percent bone in the carcass. Statistical theory indicates that the highest degree of accuracy may be obtained in the prediction of carcass composition using a combination of several carcass measurements.

MATERIALS AND METHODS

Sixty lambs were selected from the experimental flock at the Fort Reno Livestock Research Station for use in this study. They were out of grade Rambouillet ewes or grade Rambouillet X Dorset cross ewes. The lambs were sired by three Suffolk, three Hampshire and two Dorset rams. There were equal numbers of ewe, ram and wether lambs in each sire group and all were reared as twins. The lambs were born between October 15 and November 8, 1964. Approximately two weeks after birth they were placed on wheat pasture with their dams and were creep fed until they were weaned at approximately 70 days of age. At weaning the dams were removed and the lambs remained on wheat pasture with access to creep feed.

After weaning, the lambs were weighed bi-weekly until they approached ninety-five pounds. Weekly weights were then taken until they reached a minimum full weight of one-hundred pounds, at which time they were taken off feed and transported to Stillwater. Upon reaching Stillwater the lambs were sheared and kept off feed and water for approximately eighteen hours when they were weighed again and slaughtered.

All the lambs were slaughtered in the University abattoir. In order to obtain the most accurate specific gravity determinations possible, several precautionary measures were followed to avoid entrapment of air while the carcass was weighed under water. The sternum was split and the flanks were spread using pork flank spreaders. The thymus glands and the hanging tenderloin were removed. A one inch square wooden plug was placed in the pelvic cavity before chilling to keep the area open for the escape of air from the abdominal cavity during the weighing of the carcass in water. Also, the diaphragm was loosened to within one-half inch of the dorsal and vertical attachments. The kidney and kidney fat were pinned up posterior to the thirteenth rib so they would be left with the hindsaddle when the carcass was cut into fore- and hindsaddles.

The weight of the hot carcass was recorded after slaughter. The carcass was then chilled for forty-eight hours in a cooler at 34 to 38 degrees Fahrenheit and weighed again. The carcass was graded and photographed as it hung from the rail. A fat thickness measurement was taken at a point over the second sacral vertebra approximately three inches anterior to the base of the tail. A steel swine backfat probe was used for this measurement.

The specific gravity of each carcass, a function of its weight in air and its weight in water, was determined in the manner described by Rathbun and Pace (1945) and Whiteman *et al.* (1953). The tank and the water into which the carcasses were submerged were maintained at a constant temperature, equal to that of the chilled carcasses. The following formula was used to calculate the specific gravity of the carcasses:

$$\text{Specific gravity} = \frac{\text{weight of carcass in air}}{\text{weight of carcass in air} - \text{weight of carcass in water}}$$

After being weighed in water, each carcass was allowed to dry for twenty minutes.

Each carcass was scored with a knife from the point of the patella to the junction of the humerus and radius on both sides. These marks indicated the lines at which the flank, breast and foreshank were to be removed at a later time. The carcass was then divided into fore- and hindsaddles by making a vertical cut perpendicular to the line of the back between the twelfth and thirteenth ribs. The fore- and hindsaddles were weighed in air and water in the same manner as described previously, and air and water weights were recorded.

The carcasses were then cut into wholesale cuts. The flank, breast, and foreshank were removed along the scored line previously mentioned. The pelvic fat was removed and the kidney and kidney fat was removed and weighed. A cut perpendicular to the line of the back was made between the fifth and sixth ribs to separate the shoulder and rack. The neck was removed from the shoulder by cutting along a line which extends the line of the back. The loin and leg were separated by a cut between the second and third sacral vertebrae perpendicular to the line of the back.

Each wholesale cut (shoulder, rack, loin, and leg) was weighed in air and in water for the determination of specific gravity. After a twenty minute drying period, the posterior surfaces of the shoulder, rack and loin were photographed and traced onto transparent acetate paper. On the tracings each area was designated as fat, lean or bone. The area of the longissimus dorsi muscle was determined from the tracing of the posterior surface of the rack using a compensating polar planimeter. The average area of the two muscles was recorded. The fat cover over the longissimus dorsi was also determined from this tracing as the average of three fat measurements taken on each side of the vertebra. A measurement of the thickest fat along the twelfth rib was taken on each side from five to eight inches off the midline. The point of thickest fat along the fifth rib was measured on the right and left sides of the posterior surface of the shoulder. The average depth of fat over the second, third, and fourth sacral vertebrae was measured one and one-half inches off the midline on both the right and left sides approximately four, three and two inches anterior to the base of the dock.

The wholesale cuts were then cut in half longtitudinally. The legs were split through the pubic synthesis, and all the other cuts were split down the middle of the vertebrae. The weight of the right and left sides of each cut was recorded.

The subcutaneous fat was trimmed from the shoulder, rack, loin, and leg of the left side of each carcass. The weight of the fat from each cut was recorded as fat trim. The bone from each cut was then completely separated from the edible portion and weighed. The left half of the neck, the left foreshank, breast and flank were boned completely and bone and boneless portion were weighed separately. The weight of both the total bone and total boneless portion of the half carcass was then recorded. The four untrimmed cannon bones (metacarpals and metatarsals) were weighed to the nearest gram. The right fore cannon bone was also weighed individually.

The entire boneless portion of the half carcass, including the fat trim from each cut, was mixed and ground thoroughly. The kidney and kidney fat were not returned to this portion. After the tissue was ground and mixed, it was sampled for chemical analysis following the procedure outlined by Munson _et al._ (1965). Two composite samples, consisting of four, fifty gram random samples, were taken from each lamb carcass. The duplicate samples were analyzed as prescribed by A.O.A.C.

(1955) to include percent moisture and ether extract. The composition of the carcass was determined from the percent ether extract and percent separable bone. The percent lean was calculated by difference.

Similar work done by Munson (1966) indicated that some of the measurements taken were of little value as indicators of carcass composition and, therefore, could be eliminated from the statistical analysis. Twenty-six measurements were used in this study as independent (X_i) variables. Weight of fat, lean, and bone and their respective percentages of carcass weight were selected as dependent (Y_i) variables. Simple correlations between the X_i and Y_i variables were computed to determine which traits would measure carcass composition most effectively. This analysis was done on a pooled within sex basis. Traits with the highest simple correlation with the Y_i variables were used to form simple linear regression equations in a technique as outlined by Steele and Torrie (1960).

Multiple correlation coefficients were computed by the abbreviated Doolittle method using matrices of simple correlation coefficients. The traits that exhibited the highest reduction in variation were then entered into multiple regression equations one variable at a time. Regression equations with up to four independent variables were formulated to predict percentages of fat, lean and bone, using the abbreviated Doolittle method. The matrices were comprised of corrected sums of squares and cross products pooled within sex.

To test the significance of the added reduction of variance due to adding each successive variable, an F value was obtained by dividing the additional reduction mean square due to the last variable added by the residual mean square as outlined by Steele and Torrie (1960).

Since the prediction equations obtained by Munson (1966) were from a different but similar population, the measurements taken in this study were entered into his equations to determine the accuracy of their ability to predict carcass composition. The predicted percentages of fat, lean and bone for each carcass on a within year basis were compared with the actual values obtained and correlations were computed.

RESULTS AND DISCUSSION

Correlations Between Carcass Measurements and Carcass Composition

The purpose of this study was to find carcass measurements which would most accurately predict percentages of fat, lean and bone in lamb carcasses. Simple correlations were determined between 26 carcass measurements and pounds and percentages of fat, lean and bone in 60 lamb carcasses. These correlations are shown in Table I.

A difference may be noted between carcass composition expressed in pounds of each tissue and in percentage of each tissue. Generally it appeared that higher correlations were obtained between carcass measurements and percent fat, lean and bone than between the measurements and the weight of each tissue. This was not true, however, when slaughter weight and cold carcass weight were correlated with composition. Moderate increases in slaughter weight and cold carcass weight would affect the weight of each tissue, generally, more than the relative proportions of each tissue. Higher correlations might have been found if there had been more variation in the weights of the carcasses used in study. If all the lambs were killed at exactly the same weight and if dressing percent was a random variable, then there would be no difference in measuring the tissues as weight or as percent. However, dressing percent appears to be affected by the amounts of fat, lean and bone present. There was also some variation in the weights of these lambs at slaughter, although they were from a fairly narrow range (83-97

TABLE I

SIMPLE CORRELATIONS CALCULATED ON A WITHIN SEX BASIS BETWEEN DEPENDENT VARIABLES AND CARCASS TRAITS

		Carcass bone weight	Carcass fat weight	Carcass lean weight	Percent carcass bone	Percent carcass fat	Percent carcass lean
Slaughter weight	X_1	.60	-.11	.47	.39	-.28	.19
Cold carcass weight	X_2	.28	.33	.43	-.09	.09	-.09
Dressing percent	X_3	-.25	.51	.02	-.48	.40	-.31
Right fore cannon bone weight	X_4	.77	-.49	.55	.69	-.59	.46
Total cannon bone weight	X_5	.85	-.62	.61	.81	-.71	.56
Percent cannon bone weight	X_6	.76	-.74	.45	.84	-.74	.59
Specific gravity of carcass	X_7	.32	-.59	.46	.37	-.58	.59
Specific gravity of foresaddle	X_8	.00	-.21	.09	.06	-.17	.20
Specific gravity of hindsaddle	X_9	.48	-.76	.55	.56	-.74	.73
Specific gravity of rack	X_{10}	.40	-.60	.48	.45	-.60	.59
Specific gravity of loin	X_{11}	.39	-.66	.52	.45	-.66	.66
Specific gravity of leg	X_{12}	-.02	-.26	.23	.02	-.24	.31

TABLE I (Continued)

		Carcass bone weight	Carcass fat weight	Carcass lean weight	Percent carcass bone	Percent carcass fat	Percent carcass lean
Percent trimmed wholesale cuts	X_{13}	.18	-.18	.50	.04	-.27	.34
Kidney knob weight	X_{14}	-.52	.70	-.36	-.64	.65	-.57
Percent kidney knob	X_{15}	-.59	.66	-.45	-.66	.66	-.57
Fat at 12th rib	X_{16}	-.56	.52	-.50	-.56	.59	-.52
Fat at 5th rib	X_{17}	-.58	.69	-.52	-.63	.69	-.63
Three inch loin probe	X_{18}	-.45	.55	-.52	-.45	-.58	-.56
Loin fat trim weight	X_{19}	-.51	.76	-.48	-.62	.72	-.68
Percent loin fat trim of carcass weight	X_{20}	-.61	.70	-.62	-.63	.73	-.68
Percent loin fat trim of untrimmed loin weight	X_{21}	-.58	.73	-.62	-.61	.75	-.71
Trimmed leg weight	X_{22}	.68	-.45	.72	.52	-.59	.54
Percent trimmed leg weight	X_{23}	.57	-.72	.52	.64	-.72	.66
Leg bone weight	X_{24}	.83	-.59	.54	.79	-.66	.51
Percent leg bone weight	X_{25}	.73	-.69	.39	.82	-.69	.54
Loin eye area	X_{26}	.15	.03	.29	.00	-.07	.10

pounds). On lambs of a wide range of weights, slaughter weight should be more highly associated with percent fat, lean and bone in the carcass.

Specific gravity appeared to measure composition expressed as percent better than composition expressed as weight. This can be expected since differences in specific gravity essentially reflect differences in the fat:lean ratio as seen in the relative proportions of each tissue.

The correlations between chilled carcass weight and percent fat, lean and bone were found to be nonsignificant. Contrary to results reported by Barton and Kirton (1958a), Khandekar et al. (1965a) and Kirton and Barton (1962), these low correlations indicate that chilled carcass weight is not a good indicator of composition in this group of carcasses when composition is expressed as percent. This is probably due to the fact that these carcasses were from a narrower range in weights than carcasses used in most previous studies. Low correlations of .19 (nonsignificant), -.28 ($P < .05$) and .39 ($P < .01$) were also found between slaughter weight and percent lean, fat and bone, respectively.

Carcass specific gravity should be a fairly good predictor of percent fat and lean since it had correlations of -.58 and .59, respectively, with these traits. However, specific gravity of the hindsaddle had higher correlations of -.74 and .73 with percent fat and lean found in the carcass. This is probably due to the fact that differences in maturity are more evident in this region. Pálsson (1939) reported that the loin is a relatively late developing region and, therefore, one of the last areas where fat is deposited. Differences in fat content of carcasses should be more apparent in this region. The leg is a good indicator of lean because it is a relatively early developing region and contains only a small percentage of fat. Also, errors in measurement of specific gravity are probably reduced when the hindsaddle is measured separately. Some factor involved in the measurement of specific gravity of the foresaddle appears to be a real source of error, as indicated by the very low correlation between its specific gravity and measures of fat, lean and bone. When this source of error is removed by the removal of the foresaddle from specific gravity determinations, a more accurate measurement should be obtained.

Prediction of Carcass Lean

Specific gravity of the hindsaddle had the highest correlation with percent carcass lean of all the measurements studied in this trial. It accounted for 53 percent of the variation in percent lean in the carcass when used in the following equation:

$$\text{Percent carcass lean} = .0399\,[10{,}000\,(\text{hindsaddle specific gravity} - 1.0000)] + 35.4283$$

This equation had a standard error of estimate of 2.78 percent.

Fat trim from one side of the loin expressed as a percentage of the whole untrimmed loin accounted for the most variation in percent carcass lean after the effect of hindsaddle specific gravity was removed. It was entered into a multiple regression equation with hindsaddle specific gravity to predict percent carcass lean and the following equation was obtained.

$$\text{Percent lean} = 53.9892 + .0238\,[10{,}000\,(\text{hindsaddle specific gravity} - 1.0000)] - .4380\,(\text{percent loin fat trim})$$

These two independent variables had a multiple correlation coefficient of .77 with carcass lean and accounted for 59 percent of the variation in that trait. The standard error of estimate for this equation was calculated as 2.62 percent.

When the effects of hindsaddle specific gravity and percent loin fat trim were removed, the most important independent variable in the prediction of percent carcass lean was the weight of one trimmed hind leg expressed as percent of carcass weight. There was very little advantage in adding this variable into the prediction equation, because it accounts for only one percent more of the variation not explained by hindsaddle specific gravity and percent loin fat trim. When percent carcass lean was regressed on these three independent variables together, the following equation was obtained:

$$\begin{aligned}\text{Percent lean} = {} & 41.2334 + .0194\ [10{,}000(\text{hindsaddle specific} \\ & \text{gravity} - 1.0000)] - .3502\ (\text{percent loin fat trim}) \\ & + 1.1744\ (\text{percent trimmed leg weight})\end{aligned}$$

The standard error of estimate for this equation was 2.58 percent.

The independent variable which had the next highest correlation with percent carcass lean was specific gravity of the loin. However, no advantage was gained in the prediction of carcass lean when this variable was entered into the multiple regression equation.

Prediction of Carcass Fat

The percent loin fat trim measurement used in the prediction of carcass lean was found to be the most valuable measurement obtained in the prediction of percent carcass fat. It accounts for 57 percent of the variation in this trait and the regression equation, which had a standard error of estimate of 3.52 percent, was as follows:

$$\text{Percent fat} = 1.1364\ (\text{percent loin fat trim}) + 1.0547$$

Specific gravity of the hindsaddle was almost as valuable as percent loin fat trim in predicting percent carcass fat, accounting for 55 percent of the variation. When these independent variables were used together, the following multiple regression equation was obtained:

$$\text{Percent fat} = 25.9098 + .6718\ (\text{percent loin fat trim}) - .0291\ [10{,}000(\text{hindsaddle specific gravity} - 1.0000)]$$

These two variables accounted for 63 percent of the variation in percent carcass fat. The addition of hindsaddle specific gravity to the prediction equation decreased the standard error of estimate to 3.27 percent.

The total weight of the four cannon bones, expressed as a percentage of the chilled carcass weight, was found to be an important measurement in the prediction of percent carcass fat. This is probably due to the relationship between the three dependent variables, i.e. percent fat, percent lean and percent bone. These variables are actually dependent on each other, an increase in one requiring a decrease in one or both of the others. When percent fat was correlated with percent lean in these carcasses, a coefficient of -.96 was obtained. Likewise, when percent fat and percent bone were correlated, a coefficient of -.79 was found, indicating a fairly strong relationship between the two variables. Therefore, percent cannon bone weight, which was found to be a good indicator of percent bone, should be a fairly good indicator of percent fat. The addition of percent cannon bone weight to the two previously used independent variables resulted in the following multiple regression equation:

$$\text{Percent fat} = 45.4052 + .4774\ (\text{percent loin fat trim}) - .0200\ [10{,}000(\text{hindsaddle specific gravity} - 1.0000)] - 13.8952\ (\text{percent cannon bone weight})$$

These variables had a multiple correlation coefficient of .86 and accounted for 74 percent of the variation in percent carcass fat. This multiple regression equation had a standard error of estimate of 2.74 percent. The addition of a fourth independent variable failed to cause a significant reduction in the variance of the dependent variable.

Prediction of Carcass Bone

Consistent with reports by Pálsson (1939), McMeekan (1941), Khandekar (1965a) and Munson (1965), this study found cannon bone weight to be the best indicator of percent bone. Percent cannon bone weight accounted for 71 percent of the variation in percent bone and the following regression equation was obtained:

$$\text{Percent bone} = 3.2788 + 9.8086\ (\text{percent cannon bone weight})$$

This equation had a standard error of estimate of one percent.

The weight of the bone in the wholesale leg cut of the half carcass, expressed as a percentage of the chilled carcass weight, was the next best indicator of percent carcass bone. This seems logical since these bones represent a large part of the total bone weight. The addition of percent leg bone weight resulted in the following multiple regression equation:

$$\text{Percent bone} = 1.8520 + 6.0410\ (\text{percent cannon bone weight}) + 3.6088\ (\text{percent leg bone weight})$$

These variables had a multiple correlation coefficient of .90 when correlated with percent carcass bone, and they accounted for 81 percent of the variation in this trait. The addition of percent leg bone weight reduced the standard error of estimate to .82 percent. No particular advantage in the prediction of percent carcass bone was obtained in the addition of any other independent variables to the multiple regression equation.

A summary of the prediction equations for percent lean, fat and bone may be found in Tables II, III and IV. These are the most accurate equations to be obtained from the data taken in this study. However, several of the measurements used would require that the carcass be destroyed, and, therefore, would be both expensive and time consuming. Measurements such as loin fat trim, trimmed leg weight and leg bone weight could be taken only at research abattoirs. Purchase of the carcass would be required for the commercial producer to obtain such measurements.

Simplified Equations for Prediction of Carcass Composition

A reasonable degree of precision could be obtained in the prediction of percent fat, lean and bone using only percent cannon bone weight and specific gravity of the hindsaddle. These measurements are quick and easy to obtain in places where packers handle carcasses in fore- and hindsaddles. The following prediction equations could be

TABLE II

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN SEX BASIS FOR ESTIMATING PERCENT CARCASS LEAN

	R^2	$S_{Y \cdot X_i}$
$\hat{Y} = 35.4283 + .0399\ X_9$	.53	2.78
$\hat{Y} = 53.9892 + .0238\ X_9 - .4380\ X_{21}$	.59	2.62
$\hat{Y} = 41.2334 + .0194\ X_9 - .3502\ X_{21} + 1.1744\ X_{23}$	.60	2.58
$\hat{Y} = 41.1413 + .0177\ X_9 - .3425\ X_{21} + 1.1713\ X_{23} + .0023\ X_{11}$	.59	2.61

$\hat{Y}$ = Percent carcass lean

X_9 = 10,000(hindsaddle specific gravity - 1.0000)

X_{21} = Percent loin fat trim (percent of untrimmed loin)

X_{23} = Percent trimmed leg weight

X_{11} = 10,000(loin specific gravity - 1.0000)

S_y = 4.0841 percent

TABLE III

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN SEX BASIS FOR ESTIMATING PERCENT CARCASS FAT

	R^2	$S_{Y \cdot X_i}$
$\hat{Y} = 1.0547 + 1.1364 X_{21}$	.57	3.52
$\hat{Y} = 25.9098 + .6718 X_{21} - .0291 X_9$	.63	3.27
$\hat{Y} = 45.4052 + .4774 X_{21} - .0200 X_9 - 13.8952 X_6$	.74	2.74
$\hat{Y} = 41.2610 + .4279 X_{21} - .0187 X_9 - 12.2306 X_6 + 4.3409 X_{17}$	.74	2.73

$\hat{Y}$ = Percent carcass fat

X_{21} = Percent loin fat trim (percent of loin)

X_9 = 10,000(hindsaddle specific gravity - 1.0000)

X_6 = Percent cannon bone weight

X_{17} = Fat thickness at 5th rib

S_y = 5.3919 percent

TABLE IV

MULTIPLE REGRESSION EQUATIONS CALCULATED ON A WITHIN SEX BASIS FOR ESTIMATING PERCENT CARCASS BONE

	R^2	$S_{Y \cdot X_i}$
$\hat{Y} = 3.2788 + 9.8086\ X_6$	.71	1.00
$\hat{Y} = 1.8520 + 6.0410\ X_6 + 3.6088\ X_{25}$	.81	.82
$\hat{Y} = 4.8202 + 5.2530\ X_6 + 3.2464\ X_{25} - .3618\ X_{15}$	.81	.82
$\hat{Y} = 5.4185 + 5.5896\ X_6 + 3.3249\ X_{25} - .3455\ X_{15} - .1181\ X_{23}$	.81	.83

$\hat{Y}$ = Percent carcass bone

X_6 = Percent cannon bone weight

X_{25} = Percent leg bone weight

X_{15} = Percent kidney knob

X_{23} = Percent trimmed leg weight

S_y = 1.8691 percent

used to predict percent fat, lean and bone from these two measurements:

$$\text{Percent fat} = 67.1741 - .0352\,X_9 - 15.8187\,X_6$$

$$\text{Percent lean} = 29.8440 + .0316\,X_9 + 6.9641\,X_6$$

$$\text{Percent bone} = 2.9109 + .0036\,X_9 + 8.9112\,X_6$$

where X_9 = 10,000(hindsaddle specific gravity - 1.0000)

X_6 = Percent cannon bone weight

These measurements had multiple correlation coefficients of .84, .76 and .85 when correlated with percent fat, lean and bone, respectively. They accounted for 71, 58 and 72 percent of the variation in these traits, which is little reduction from 74, 60 and 81 percent of the variation accounted for in these traits when all measurements were used. These equations had standard errors of estimate of 2.92, 2.65 and .98 percent, respectively.

These equations indicate that any one set of two or three independent variables will not predict percent fat, lean and bone with equal accuracy. However, these two measurements should be of some value for estimating the differences between groups of lamb carcasses. Their simplicity makes them more desirable than the longer equations when a large number of carcasses are to be measured and when time and facilities are limited.

In order to determine the usefulness of prediction equations derived in this manner, measurements taken from the lambs used in this study were entered into some of the prediction equations proposed by Munson (1966). These equations, shown on Table V, were expressed on a within year basis and were derived from a population of lambs similar

TABLE V

MULTIPLE REGRESSION EQUATIONS FOR PREDICTING PERCENT FAT, LEAN AND BONE ON A WITHIN YEAR BASIS PROPOSED BY MUNSON (1966)

Whole Carcass

$$\text{Percent fat} = 24.006 - .028\ X_4 + .384\ X_2 + 6.760\ X_{23} - .144\ X_{14}$$

$$\text{Percent lean} = 58.173 + .023\ X_4 - .202\ X_2 - 5.454\ X_{23} + .027\ X_{14}$$

$$\text{Percent bone} = 23.671 - .230\ X_3 + .089\ X_{14} - 1.700\ X_{23} + .004\ X_4$$

Fore- and Hindsaddles

$$\text{Percent fat} = 23.230 - .031\ X_6 + .174\ X_2 + 5.845\ X_{23} + 1.362\ X_{18}$$

$$\text{Percent lean} = 56.878 + .025\ X_6 - .128\ X_2 - 3.649\ X_{23} - 7.924\ X_{19}$$

$$\text{Percent bone} = 22.227 - .210\ X_3 + .088\ X_{14} + .005\ X_6 - 1.511\ X_{23}$$

All Measurements

$$\text{Percent fat} = 14.484 + 3.741\ X_{13} - .018\ X_6 + 1.570\ X_{18} + .730\ X_{15}$$

$$\text{Percent lean} = 62.620 - 2.803\ X_{13} + .017\ X_6 - 1.034\ X_{18} - .053\ X_1$$

$$\text{Percent bone} = 19.289 + 4.148\ X_{17} - .141\ X_3 - 2.514\ X_{21} - .461\ X_{18}$$

X_1 = Slaughter weight

X_2 = Cold carcass weight

X_3 = Dressing percent

X_4 = 10,000 (carcass specific gravity - 1.000)

X_6 = 10,000 (hindsaddle specific gravity - 1.000)

X_{13} = Loin fat trim

X_{14} = Right forecannon weight

X_{15} = Trimmed leg weight

X_{17} = Leg bone weight

X_{18} = Kidney fat weight

X_{19} = Fat cover over 12th rib

X_{21} = Thickest fat at 5th rib

X_{23} = Loin probe

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to the one used in this study, except the lambs were all wethers. The predicted values for composition were correlated to the actual values obtained from these lambs by physical separation and chemical analysis.

As expected, greater accuracy in predicting composition was achieved in the later stages of the cutting of the carcass. The correlations between the actual and predicted values for percent fat, lean and bone were .71, .65 and .84, respectively, for equations derived from carcass measurements taken from whole carcasses. Equations using measurements taken from carcasses cut into fore- and hindsaddles yielded predicted values that had coefficients of .68, .74 and .86 when correlated with actual values of percent fat, lean and bone. When measurements obtained from bone-in and boneless wholesale cuts were used, the regression equations yielded predicted values that had coefficients of .85, .82 and .90 when correlated with the actual values. These high correlations indicate that, in a population of lamb carcasses similar to this, these equations are reasonably precise in the prediction of percent fat, lean and bone.

The squared correlation coefficients yielded coefficients of determination which are given in Table VI. These coefficients of determination compared favorably with those computed by Munson (1966). These equations generally failed to accurately predict the most extreme fat and lean carcasses. This is largely due to the fact that the equations were derived from data from only wether lamb carcasses in which less variation existed when compared to the lamb carcasses used in this study. The standard deviations reported by Munson (1966) on a pooled within year basis were 4.02, 3.20 and 1.36 percent for fat, lean and bone, respectively, while the standard deviations on a pooled within sex basis

TABLE VI

COMPARISON OF COEFFICIENTS OF DETERMINATION

	R^2 computed in this study	R^2 computed by Munson (1966)
Whole carcass		
Percent fat	.50	.62
Percent lean	.42	.48
Percent bone	.70	.65
Fore- and hindsaddles		
Percent fat	.47	.69
Percent lean	.55	.58
Percent bone	.73	.67
All measurements		
Percent fat	.72	.79
Percent lean	.67	.65
Percent bone	.81	.81

found in this study were 5.39, 4.08 and 1.87 percent. Since ewes reach maturity at an earlier age than rams, it is expected that their carcasses contain a higher percentage of fat than ram carcasses, when fed to a constant weight. Therefore, an adjustment for sex on the data entered into these equations would probably increase the accuracy of the equations.

SUMMARY

Growth and carcass data were collected on 60 lambs selected from the experimental flock at the Fort Reno Livestock Research Station for this study. These lambs were out of grade Rambouillet ewes or grade Rambouillet X Dorset cross ewes, and were sired by three Suffolk, three Hampshire and two Dorset rams. There were equal numbers of ram, ewe and wether lambs in each sire group.

Approximately two weeks after birth the lambs and their dams were placed on wheat pasture with access to a creep ration. When the lambs reached approximately 70 days of age, their dams were removed. Upon reaching a minimum full weight of 100 pounds, the lambs were taken off feed and transported to Stillwater. They were slaughtered after being sheared and held off feed for 18 hours. Various carcass measurements were obtained. The carcasses were split and the half-carcasses were boned out for determination of percent fat, lean and bone.

Simple correlations on a pooled within sex basis were obtained between 26 carcass measurements and weights and percentages of tissues in the carcasses. Multiple regression equations were formulated for the prediction of percent fat, lean and bone.

Specific gravity of the hindsaddle was the best indicator of percent carcass lean, accounting for 53 percent of the variation in this trait. Percent loin fat trim accounted for six percent more of the variation after the effect of hindsaddle specific gravity was removed.

Little advantage was gained in the prediction of percent carcass lean by the addition of other variables to the regression equation.

Percent loin fat trim accounted for 57 percent of the variation in percent carcass fat. The addition of hindsaddle specific gravity and percent cannon bone weight raised this coefficient of determination to .63 and .74.

Percent carcass bone was estimated by percent cannon bone weight, which accounted for 71 percent of the variation in this trait. When percent leg bone weight was added into the multiple regression equation, 82 percent of the variation was explained.

A reasonable degree of accuracy could be obtained in the prediction of carcass composition using percent cannon bone weight and specific gravity of the hindsaddle. These variables accounted for 71, 58 and 72 percent of the variation in percent fat, lean and bone.

Data from these lambs were entered into prediction equations proposed by Munson (1966) to determine their accuracy on a different population of animals. Correlations of .85, .82 and .90 between the predicted and actual values indicated that the equations were reasonably accurate in the prediction of percent fat, lean and bone, respectively.

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APPENDIX

TABLE VII

MEAN VALUES AND STANDARD DEVIATIONS FOR SLAUGHTER AND COMPOSITION MEASUREMENTS

	Rams		Wethers		Ewes		All Lambs	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
Slaughter weight (lb.)	92.67	2.17	92.10	3.47	90.08	4.02	91.62	3.31
Chilled carcass weight (lb.)	48.73	2.17	50.71	1.59	50.50	2.63	49.98	2.18
Dressing percent	52.61	2.30	55.10	1.72	56.21	1.66	54.64	1.92
Total bone weight (lb.)	8.53	.72	7.94	.89	7.66	1.19	8.07	.96
Total fat weight (lb.)	12.36	2.06	17.07	3.14	17.60	3.21	15.68	2.85
Total lean weight (lb.)	27.78	1.35	25.67	2.23	25.27	2.90	26.24	2.25
Percent carcass bone	17.62	1.70	15.73	1.79	15.15	2.09	16.17	1.87
Percent carcass fat	25.27	3.40	33.62	5.93	34.88	6.37	31.26	5.39
Percent carcass lean	57.08	2.51	50.65	4.43	49.99	4.89	52.58	4.08
Percent trimmed wholesale cuts	36.32	2.21	36.37	1.58	36.49	1.62	36.39	1.82

TABLE VIII

MEAN VALUES AND STANDARD DEVIATIONS FOR SPECIFIC GRAVITY AND VARIOUS CARCASS MEASUREMENTS

	Rams		Wethers		Ewes		All Lambs	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
Specific gravity of carcass	1.0456	.0079	1.0441	.0085	1.0451	.0071	1.0449	.0079
Specific gravity of foresaddle	1.0468	.0111	1.0454	.0137	1.0486	.0074	1.0469	.0110
Specific gravity of hindsaddle	1.0454	.0059	1.0421	.0080	1.0415	.0082	1.0430	.0074
Specific gravity of rack	1.0419	.0096	1.0359	.0075	1.0338	.0094	1.0372	.0089
Specific gravity of loin	1.0318	.0053	1.0273	.0077	1.0258	.0091	1.0283	.0075
Specific gravity of leg	1.0696	.0058	1.0667	.0079	1.0636	.0119	1.0666	.0089
Right forecannon bone weight (gm.)	54.20	6.86	50.10	7.16	46.60	7.13	50.30	7.05
Total cannon bone weight (gm.)	315.10	34.04	295.30	33.44	281.70	41.37	297.37	36.46
Percent cannon bone weight	1.43	.16	1.28	.14	1.23	.17	1.31	.16
Kidney knob weight (lb.)	1.30	.27	1.98	.58	2.11	.45	1.79	.45
Percent kidney knob	2.66	.48	3.89	1.10	4.17	.90	3.57	.86

TABLE IX

MEAN VALUES AND STANDARD DEVIATIONS FOR VARIOUS CARCASS MEASUREMENTS

	Rams		Wethers		Ewes		All Lambs	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
Trimmed leg weight, half carcass (lb.)	5.31	.35	5.18	.33	5.20	.46	5.23	.38
Percent trimmed leg weight	10.90	.71	10.22	.59	10.31	.77	10.48	.69
Leg bone weight, half carcass (lb.)	.94	.10	.89	.12	.82	.12	.88	.11
Percent leg bone weight	1.94	.22	1.75	.25	1.62	.21	1.77	.22
Loin eye area (in.)	2.18	.19	2.21	.15	2.19	.21	2.19	.18
Loin probe (in.)	.49	.13	.57	.16	.58	.22	.55	.18
Fat thickness at 5th rib (in.)	.52	.11	.65	.17	.71	.14	.63	.14
Fat thickness at 12th rib (in.)	.17	.05	.24	.06	.30	.09	.24	.07
Loin fat trim, half carcass (lb.)	1.03	.16	1.32	.22	1.42	.25	1.26	.21
Percent loin fat trim (of carcass)	2.12	.29	2.61	.44	2.80	.48	2.51	.41
Percent loin fat trim (of loin)	23.30	2.56	27.64	4.06	28.79	3.90	26.58	3.57

VITA

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