FEEDLOT PERFORMANCE AND CARCASS CHARACTERISTICS

OF RAM LAMBS SLAUGHTERED

AT DIFFERENT WEIGHTS

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TABLE OF CONTENTS

LIST OF TABLES

FIGURE

CHAPTER I

INTRODUCTION

The continuous, almost yearly decline in lamb production since World War II has prompted considerable interest within the sheep industry to find ways of increasing production. Feeding lambs to heavier slaughter weights has been encouraged by some researchers and is probably the most immediate method available to increase the supply and efficiency of lamb production. Several workers have discussed the advantages of feeding lambs to heavier weights. These advantages include the increased tonnage to absorb fixed costs and the resulting larger retail cuts which are more desirable to most consumers. Still, heavy weight lambs are often discriminated against by lamb packers partly because of the tendency for lambs of some breeds and sex condition to be excessively fat at those weights.

Ram lambs are generally expected to grow more efficiently and faster than ewe or wether lambs. In addition, several workers have determined ram lamb carcasses have a higher proportion of lean than ewe or wether lamb carcasses. These studies have generally concluded that ram lamb growth and development is similar to that of ewes and wethers but that it occurs over a much wider weight range in the later maturing rams. Lean from ram lambs has been criticized for being less palatable than that from ewes and wethers. However, researchers have recently found that the meat from young rams is highly acceptable and only slightly less palatable than that from ewes and wethers. Yet, because ram lambs are not normally fed for slaughter, relatively little work has been done to study the growth and carcass merit of heavy ram lambs.

An important but often overlooked consideration in meat production is the offsetting effect higher dressing percentage has on the reduced carcass cutability of heavy weight market animals. Previous work at Oklahoma State University and elsewhere has indicated that so long as lean growth continues the percentage lean in a live animal does not differ greatly as live weight increases. This occurs even though lean as a percentage of the carcass declines substantially as live weight increases.

The objectives of this study were: 1) to determine the feed efficiency and growth rate of ram lambs slaughtered at different weights, 2) to determine how much the carcass composition and lean tenderness of ram lambs change as live weight increases, and 3) to evaluate the offsetting effect higher dressing percentages have on the reduced cutability of carcasses from heavier and fatter lambs.

CHAPTER II

REVIEW OF THE LITERATURE

This literature review will concern itself with previous research in the general area of lamb growth and development and then more specifically with ram lamb growth, carcass composition, and quality.

Lamb Growth and Development

An extensive study of the growth and development of forty-two male and female lambs fed on high and low planes of nutrition was reported by Palsson and Verges (1952). They found that the dressed carcass was later maturing than the offal parts and that of these the rumen and reticulum were later maturing organs that grew at nearly twice the rate of muscle from birth to forty-one weeks of age. The abdominal fats matured later than the organs, with kidney fat the earliest maturing of these fats and caul fat the latest. They also noted that different body regions develop at different times and in an orderly manner. This order of development, they concluded, generally moves from the early maturing head and feet to the later maturing loin. These researchers found that the leg, neck, and shoulder were intermediate in maturity, but that the leg matured earlier than the shoulder.

Luitingh (1962) in a study of beef steers grown from 600 to 1200 pounds also found different rates of growth among components of the live animal. He reported that blood, shoulder, buttock, rump, neck, loin, and rib change in proportion to their size at a rate similar to the proportional change in body weight. Parts changing proportionately less than body weight included the head, feet, intestine, kidney, hide, pluck, liver, and channel fat. He found the parts changing proportionately more than body weight to include the chuck, prime rib, plate, brisket, and major fat deposits. He also noted that the ventral parts comprised more of a fattened steer than of an unfattened steer.

Growth and Distribution of Fat, Lean, and Bone

McMeekan (1940) studied swine growth and concluded that growth in body parts followed an anterior to posterior gradient from the earliest to latest maturing. He also noted that individual tissues (bone, lean, and fat) each followed that same gradient of maturation among the body parts. From these studies it was concluded that the ratio of shoulder fat to loin fat might be a useful index to indicate an animal's stage of fattening.

Fat deposition accumulates in the following order: kidney fat, intermuscular fat, subcutaneous fat, and finally marbling, according to Palsson (1955). This worker noted that in lambs subcutaneous fat was a major fat deposit accounting for 37 percent of the total fat at birth and 61 percent of the total at forty-one weeks of age.

Rouse et al. (1970) slaughtered wether lambs at live weights of 32, 46, and 50 kilograms to study lamb growth and development. They found that carcasses from the 32 kilogram lambs contained 75 percent as much bone, 59.6 percent as much lean, and 37.5 percent as much fat as in carcasses from the 50 kilogram lambs. They concluded that this indicated the general order of development of bone then lean and finally fat. In addition, their data indicated that the percentage of the live animal in bone and lean decreased while percentage fat increased as the lambs became heavier. However, the percentages of fat and bone changed the most while percentage lean changed relatively little. These researchers concluded that lean deposition declined markedly after the 46 kilogram weight and that rib eye area was a better predictor of total lean deposition than of the amount of lean per unit of carcass weight. They also concluded that fat deposition did not show a proportional increase as live weight increased from 32 to 50 kilograms but rather a disproportionally greater increase at heavier weights. Furthermore, these workers found that percentage fat did not increase as rapidly in the hindsaddle as the foresaddle indicating that lambs fatten in an "anterior" to "posterior" order at heavier weights.

Lambuth et al. (1970) studied the development of lambs slaughtered at 36, 45, and 54 kilograms. They reported that percentage of the carcass in bone and lean decreased and percentage fat increased as live weight increased. In addition, they found that the percentage of leg and shoulder decreased while the percentage of loin and rack increased, again indicating the loin and rack are later maturing and are sites of additional fat deposition as weight increases. Kemp et al. (1970) also noted that the rack and loin increased as a percentage of carcass as live weight increased and they concluded that this was normally due to an increase in weight and proportion of subcutaneous fat. They also noted that the percentage of the carcass in rack and loin was positively correlated with the percentage fat in the carcass. However, the percentage of leg and shoulder was positively correlated with the water, ash, and protein content. Percentages of breast, flank, and kidney and pelvic fat followed the same trend as the rack and loin in relation to carcass fat.

Problems in Expressing Growth

The work reviewed thus far has largely analyzed and reported the composition and growth of various components and tissues as a percentage of a larger entity. Craddock et al. (1973) and Carpenter et al. (1969) have both shown that less variation is accounted for in an analysis using percentages than in one using actual weights. Seebeck (1968) cited Tulloh (1964) and made the following comment regarding percentages:

> In considering the mathematical and statistical operations that could be used on the data ... the use of any of the following four commonly used methods of describing development may complicate an otherwise simple situation:
> (a) The weight of the part (or organ or tissue) expressed as a percentage of body weight at various body weights or ages.
> (b) The weight of the part expressed as a fraction of body weight at one age (or weight) compared with the fraction calculated at another age (or weight).
> (c) The measurement of the part expressed as a percentage of its measurement at an earlier age or weight.
> (d) The part expressed by a measurement in any one of the above three ways in relation to a measurement of a standard part (instead of body weight). The part which is chosen is one which shows relatively little change throughout post-natal life (p. 169).

Instead, Seebeck recommends that a part-whole relationship be expressed by the allometric equation $y = ax^b$ where a and b are constants.

Tanner (1949) warned of analyses involving a spurious correlation, the correlation between a ratio and the denominator of that ratio. He reported that a spurious correlation other than zero indicates the ratio may be misleading. Dinkel et al. (1965) suggested that the beef yield grade cutability equation may not be a useful method for evaluating carcasses in experiments where weight adjustment is not desired. He further explained this by noting cutability is expressed as a percentage of carcass weight and that carcass weight is a variable in the prediction equation. This is an example of a spurious correlation which indicates the cutability ratio may be misleading.

Weight Changes in Fat, Lean, and Bone

The percentage changes in fat, lean, and bone of the carcass as weight varies have been reviewed. However, the actual amounts of tissue deposition may present a different relationship than the percentage changes. Rouse et al. (1970) found that the percentage of lean in the carcass dropped 3.9 percent as lambs increased from 32 to 46 kilograms in live weight. However, they also noted that the weight of lean increased by approximately one-half between those weights. Computing the weight change of tissues from the data of Lambuth et al. (1970) indicates that lean weight increased more than fat (2.5 vs. 1.6 kg) in lambs grown from 36 to 45 kilograms live weight but that fat increased more than lean (2.7 vs. 1.9 kg) from 45 to 54 kilograms. In addition, according to their data the weight of lean and bone was increasing at a lower rate as live weight increased, while fat was increasing at a higher rate. This relationship is similar to that noted by Guenther et al. (1965) with beef. They found that the weight increase in lean was greater than fat during the early part of a feeding trial but that at heavier weights the weight increase in fat was greater. In both of these studies (Lambuth and Guenther) rib eye area increased less at the heavier live weights than at the lighter weights.

Growth on a Live Weight Basis

Mendenhall and Ercanbrack (1979) indicated that the lower retail cutting yields of heavy lambs were generally offset by higher dressing percentages. The data of Lambuth et al. (1970) indicate that while edible portion of the carcass decreased 3.4 percent in lambs grown from 36 to 45 kilograms, edible portion as a percent of live weight increased .05 percent. In addition, their data indicate that edible portion declined 4.6 percent on a carcass basis in lambs grown from 45 to 54 kilograms but only 1.6 percent on a live weight basis. In addition, Adams (1978) determined that the percentage of closely trimmed major cuts of live weight was very similar for light (100 lb.) and heavy (125 lb.) ram and ewe lambs. Tulloh (1964) found in beef cattle that as empty body weight increased the proportion of empty body weight in bone and offal decreased while fat increased and muscle remained almost constant. This relationship explains the offsetting effect that dressing percentage has on reduced carcass cutability.

Ram Lamb Growth, Carcass Composition, and Quality

Live Performance of Ram Lambs

The performance of an animal depends upon its environment. While given environmental conditions can never be exactly repeated, trends for growing conditions in certain times of the year are evident. Stritzke (1980) collected growth data from 870 lambs born at three different times of the year over a five year period. She found that season of birth was associated with large differences in average daily gain from 70 days of age to market weight. She noted that winter born lambs outgained fall and summer born lambs by 41 and 81 grams per day, respectively. In addition, this researcher reported that increased disease problems with the summer born lambs may have been partly responsible for the lower summer performance. Stritzke also found that the 431 ram lambs in that study gained 345, 382, and 278 g/day for the fall, winter, and summer born lambs, respectively.

Harrison and Crouse (1978) reported on the feed intake, weight gain, and feed efficiency for ram lambs. The sixty-nine rams in their study, fed a medium energy diet, were slaughtered over a range in live weight of 75.6 to 155.4 pounds. The data showed the M_{cal} of ME/lb. gain increased from 4.35 for lambs fed from 45 to 75 pounds to 9.48 for lambs fed from 45 to 155 pounds. This equated to 3.9 and 8.5 pounds of feed per pound of gain for these two weight intervals respectively. In addition, the lambs slaughtered at 155 pounds had a feed to gain ratio of 11.7 for the final 42 days of the test in which the lambs gained almost 20 pounds. The average daily gains reported were quite variable with weight changes but appeared to change relatively little at heavier weights and averaged nearly .45 pounds/day. Feed intake increased from 4.0 pounds per head daily during the first 28 days of the trial to 4.7 pounds for the last 42 days. In addition, these workers noted that the M_{cal} of feed energy required to produce a pound of gain increased five fold for 143 pound lambs when compared with 66 pound lambs. Harrison and Crouse concluded from an economic study of the data that profits could be obtained from ram lambs weighing as high as 154 pounds although profits were maximized at lower weights.

Shelton and Carpenter (1972) studied the live performance of ram lambs slaughtered at 38, 48, 58, and 68 kilograms. They found an overall average daily gain of 292.4 grams and a feed to gain ratio of 5.8. In addition, they noted that rate of gain was not significantly affected by live weight although a trend for slightly lower gains at heavier weights was observed. Feed efficiency, however, was greatly affected by changes in body weight. Feed required per gram of gain increased

.046 grams for each kilogram increase in live weight. This trend for average daily gain to remain relatively constant while the feed to gain ratio increases as live weight increases has also been reported by Antoniewicz and Pope (1967). Lloyd et al. (1981) slaughtered 86 lambs at 54 and 64 kilograms and found that average daily gain increased slightly from .23 for the lighter lambs to .26 kg for the heavier lambs.

These measures of live performance, while very important to a producer, have little effect on carcass value. In fact, a relationship between live performance and carcass composition at a given live weight has not been determined. Lambuth et al. (1970) found faster gaining lambs had no significant difference in retail yield or edible portion but a lower percent fat and higher percent bone than slow gainers. Craddock et al. (1970) reported that average daily gain or carcass weight per day of age did not increase the accuracy of a prediction equation for retail yield in lambs. Makarechian et al. (1978) concluded that the association between measures of growth and carcass composition are very low in lambs slaughtered at about 45 kilograms.

Carcass Characteristics of Ram Lambs

Considerable work has been done to study the composition of ewe and wether lambs and to develop cutability prediction equations for lamb. Of these prediction equations, the one which the U.S.D.A. Yield Grades are based upon has the most widespread usage. In this equation a one grade change in lamb yield grade corresponds to a 1.8 percent decline in the expected percentage of closely trimmed, boneless, major retail cuts in the carcass (USDA, 1969). This relationship is based on research done by Johnston et al. (1967). They developed a cutability prediction equation from the data obtained from 144 wether lamb carcasses ranging in weight from 12.1 to 33.0 kilograms and grading U.S.D.A. Prime, Choice, and Good. They also developed prediction equations to estimate the percentage of total salable, boneless lean in the carcass. An equation using finish group (based on fat thickness), leg conformation score, and percent kidney fat to predict total salable lean had a multiple correlation coefficient of .77.

The usefulness of the yield grade formula for rams, however, may be limited. Riley and Field (1969) evaluated 564 ewe and wether carcasses and 64 ram carcasses to develop equations to predict the percentage of retail cuts in the carcass. They used the equation developed from the ewe and wether data to predict percentage retail cuts in the ram carcasses. The correlation between the actual and predicted values was .82 with a standard error of estimate of 1.99. They also used the prediction equation developed for the ram carcasses to predict percentage retail yield of the ewe and wether carcasses. The correlation between actual and predicted values was .71 with a standard error of estimate of 1.52. These correlations and standard errors were not greatly different than those obtained from equations used within each sex. They concluded that there appears to be little value in using different equations for each sex of the carcass. However, Carpenter et al. (1969) obtained data from 276 wether, 207 ram, and 202 ewe carcasses ranging in weight from 13 to 33 kilograms. They developed prediction equations to estimate kilograms of retail cuts as well as the percentage and concluded that increased precision could be attained if a separate prediction equation was developed for each sex grouping. In addition, their data pointed out the desirability of predicting weight instead of percentages. The best equation to predict percentage yield had a multiple correlation coefficient and standard error of estimate of .571 and 2.249, respectively, as compared to .927 and .519, respectively, for the weight prediction equation.

While most lamb carcass studies have involved ewe and wether lambs, several have studied ram carcass composition in detail. Campion et al. (1976) studied the carcass composition changes of 120 ram lambs slaughtered at average ages of 26, 34, and 42 weeks. Carcass weights ranged from 16 to 51 kilograms and the data were analyzed by regressing carcass traits on carcass weight. They found all compositional traits measured in terms of weight, depth, or area appeared to increase in a linear manner with hot carcass weight. In addition, they noted for each 10 kilogram increase in carcass weight, retail primal cut weight increased by 5.46 kilograms. Their analysis indicated that a 35.5 kg. ram carcass would have 5.39 mm of adjusted fat at the twelfth rib, loin eye area of 15.98 cm^2, and a yield grade of 3.4. They concluded that over this wide and heavy weight range (16 to 51 kg), changes in ram carcass composition were similar to those previously observed for much lighter ewe and wether carcasses. This relationship indicated that ram lambs mature later and over a wider range in live weight than do ewe and wether lambs.

Shelton and Carpenter (1972) slaughtered 53 ram lambs ranging in live weight from approximately 36 to 64 kilograms. A regression analysis of carcass traits on carcass weight indicated that carcass compositional traits increased in essentially a linear manner with increasing carcass weight. Yield grade, however, showed a curvilinear increase as carcass weight increased, increasing relatively more at heavier weights. They concluded that ram lambs may be slaughtered over a wide range in weights without becoming excessively fat.

Crouse et al. (1978) reported detail composition data on 68 ram lambs. The lambs were fed three different energy level diets and slaughtered at approximate live weights of 17, 32, 42, 54, and 66 kilograms. One side of the carcasses was ground (after removing kidney fat) and the percentages of protein, moisture, fat, and ash were chemically determined. The percentage protein of the carcass for the medium and high energy fed rams decreased from approximately 18 to 16.5 percent and the percentage fat increased from nearly 8.5 to 28 percent for the 17 and 64 kilogram lambs, respectively. In addition, dressing percentage increased from 44 to 50.6 percent and loin eye area from 7.6 to 18 square centimeters for the 17 and 64 kilograms lambs, respectively. Fat thickness at the twelfth rib increased from 0 to .38 cm for the medium fed lambs and to .618 cm for the high fed lambs while yield grade increased from 2.0 to 3.1 for the medium fed and to 4.2 for the high fed lambs slaughtered at 17 and 64 kilograms, respectively. Crouse et al. concluded that these carcasses, which weighed up to 33 kg. had acceptable lean to fat ratios. A regression equation to predict carcass fat developed from this data indicated that ram carcasses under 27.4 kg. would contain less than 25 percent fat.

Adams (1978) studied the carcass composition of ram lambs slaughtered at 100 and 125 pounds. Between those weights loin eye area increased from about 2.1 to 2.5 square inches, twelfth rib fat thickness from .17 to .25 inches, and yield grade from about 3.0 to 3.6. In addition, the percent of closely trimmed major cuts decreased from 55.8 to 53.4 on a carcass basis at the 100 and 125 pound slaughter weights, respectively, but changed little as a percentage of live weight. He noted that the price discrimination against heavy weight lambs may not always be warranted when retail yield is considered on a live weight basis.

In addition to the overall changes in lean content the distribution of the lean among the wholesale and retail cuts is also important. Kemp et al. (1970) studied this distribution in 30 ram and 30 wether carcasses. They found that the percentage of breast, flank, and kidney and pelvic fat increased while the percentage of leg, shank, and kidney decreased as live weight increased. These researchers predicted carcass composition from leg composition and estimated the carcass from a 36 kg. ram lamb to have 25.7 percent fat, 57.4 percent lean, and 15.8 percent bone while the carcass from a 54 kg. lamb would be expected to have 31.9 percent fat, 54.5 percent lean, and 13.2 percent bone. It is interesting to note that the 2.6 percent difference in dressing percentage they reported causes the percentage lean on a live weight basis to be essentially the same at those two weights.

Another, sometimes overlooked, factor affecting the value of a ram lamb is the value of the testicles (lamb fries). Kemp et al. (1970) noted that the testicles accounted for about .75 percent of a ram's live weight and that their wholesale price per pound was about twice that of the carcass. Therefore, they concluded that the wholesale value of a ram carcass plus the lamb fries was comparable to the wholesale value of the carcass from a higher dressing wether lamb when live weights were equal.

Other researchers have also noted the significance of the value of testicles as food. Bradford and Spurlock (1964) found that testicle weight accounted for about one-half of the difference in dressing percentage between rams and wethers indicating testicle weight was .6 to 1.5 percent of live weight. Wilson et al. (1970) found testicle weight to be about .6 percent of live weight.

Quality Considerations in Ram Lamb Carcasses

An important consideration in meat production is the quality or palatability and salability of the meat. The U.S.D.A. lamb quality grades were established to identify palatability and salability differences. Smith et al. (1970) reported on a palatability study involving 120 lamb carcasses selected from a commercial packer. They found that the U.S.D.A. quality factors were associated with less than 17 percent of the variation in palatability ratings. Still, overall they concluded the U.S.D.A. quality grades were reasonably consistent in identifying carcasses with respect to tenderness, juiciness, and overall satisfaction. However, Jeremiah et al. (1972) evaluated the palatability of 148 lamb carcasses from the Prime, Choice, and Good grades and reported that carcasses of the different grades did not differ significantly in any of the palatability traits. This indicates some disagreement regarding the effectiveness of lamb quality grades to reflect palatability differences, especially within the top three grades.

The ability of quality grades to identify differences in ram carcass palatability specifically is even more questionable. Campion et al. (1976) studied 120 ram carcasses ranging in weight from 16 to 51 kilograms. They determined correlations for quality grade with taste panel (1 = dislike extremely, 9 = like extremely) tenderness, juiciness, and overall acceptability to be -.31, -.26, and -.26, respectively. These workers concluded from these negative correlations that quality grade did not adequately reflect the palatability of ram carcasses over very heavy weight ranges. The researchers noted that new palatability indicators would be needed to identify palatability differences among retail cuts from heavy ram lamb carcasses.

Flavor is probably the most important palatability characteristic of cooked lamb (Batcher et al. 1969). These workers found that sex or age did not significantly influence the flavor of cooked meat slices from 7 to 16 month old ram and wether lambs. However, the researchers did note flavor differences due to sex and age when the meat broth was evaluated by panelists. From this they concluded that the sex and age related differences in flavor were probably small and were masked by the other palatability factors in the evaluation of sliced lamb.

Relatively little work has been done to study the flavor of meat from heavy ram lambs. Misock et al. (1976) studied the palatability of 72 ram lambs slaughtered at 183, 237, and 295 days of age which provided carcasses between 29.3 and 43.1 kilograms. They reported the meat from lambs over 183 days old had objectionable flavor and aroma. Furthermore, they noted approximately 10 percent of the carcasses from the two oldest groups were returned to the meat lab as being undesirable. However, Jacobs et al. (1972) compared taste panel flavor scores of 47 wether and 50 ram lambs slaughtered at 68 kilograms and found no significant differences in flavor or overall acceptability.

Another important palatability characteristic is tenderness. A common objective measure of tenderness is the Warner-Bratzler Shear value. Field et al. (1967) recommended one-half inch cores from the biceps femoris, semimembranosus or l. dorsi muscle be used for this evaluation. These workers suggested cooking the meat to an internal temperature of 175°F (80°C). An average shear force value of 8 lb. (3.6 kg.) or less was considered as acceptable.

A Warner-Bratzler Shear force can be obtained from the standard device or from a unit mounted on an Instron measuring device. Smalling et al. (1970) compared these methods and found that the standard values were more variable and significantly less than those determined on the Instron. They noted with both units that the shear values were lower in cores which had the muscle fibers in a perpendicular position to the blade. In addition, they also reported no significant difference in shear values made 5, 15, 30, or 60 minutes or 24 hours after cooking.

The relationship of the Warner-Bratzler Shear with subjective tenderness evaluation has also been reported. Paul et al. (1964) evaluated the lean obtained from 29 lambs fed on pasture and in the feedlot and the lean from 33 lambs either 5½ or 12 months old. These workers reported that taste panel tenderness scores had a correlation of about .7 with shear force values. Lloyd et al. (1981) studied the lean from 86 young lambs fed a high concentrate diet and slaughtered at approximately 54 or 64 kilograms. These scientists found a correlation of .68 for taste panel tenderness and shear force.

The tenderness of the meat from ram lambs has been reported by numerous researchers. Shelton and Carpenter (1972) slaughtered rams, ewes, and wethers at live weights ranging from 38 to 68 kilograms. They found no significant differences in Warner-Bratzler Shear values due to sex or slaughter weight. Kemp et al. (1981) made the same conclusion after evaluating meat from ewe, wether, and ram lambs slaughtered at 41 and 50 kilograms. However, Kemp et al. (1972) found in lambs slaughtered at 36, 45, or 54 kilograms that meat from wether lambs was more tender than that from rams although the ram meat was considered to be acceptable in this regard. These workers observed that tenderness increased as slaughter weight increased. Shelly et al. (1970) reported that carcass grade, juiciness, tenderness, and overall satisfaction of rib roasts from ram and wether lambs improved as slaughter weight increased from 36 to 54 kilograms.

The tenderness of meat from very heavy ram lambs (carcass weights between 16 and 51 kg.) was studied by Campion et al. (1976). These researchers determined that the meat from these carcasses had taste panel tenderness scores and Warner-Bratzler Shear values which indicated that the meat was less tender as carcass weight increased. The data were analyzed by regression analyses and they reported a 3.28 kilogram shear force at an average carcass weight of 35.5 kilograms with a significant regression coefficient (slope) of .076. These workers noted that meat from a 45 kilogram carcass would have an estimated shear force of 4.01 kg. and a 4.95 taste panel tenderness score on a scale of 1 (dislike extremely) to 9 (like extremely). They concluded that consideration of tenderness factors would be increasingly important at heavy weights.

The meat from lighter weight ram lambs, however, is generally considered acceptable. Mendenhall and Ercanbrack (1979) evaluated the meat from 426 ram, ewe, and wether lambs slaughtered between 41.5 and 69.5 kilograms. They found that the meat from rams was significantly less tender than that from ewes and wethers. However, the ram meat had shear values less than 3.6 kilograms which was considered acceptable. In addition, these researchers noted no taste panel palatability differences with weight and concluded, "Price discrimination due to carcass weight and sex condition at best, reflect the inequities in buying, packing, grading, and marketing lambs rather than the preferences of the ultimate consumer" (Mendenhall and Ercanbrack, 1979, p. 1066).

Other factors affecting the value of meat reflect its "salability." Southam and Field (1969) conducted an in-store consumer study and found that rib and loin chops from a 30 kg. carcass were selected over similarly finished chops from a 23 kg. carcass by a ratio of approximately

6 to 5. This indicated to them that the larger chops from heavier lambs may be more desirable to the consumer.

Another apparently important factor affecting the "salability" of meat from heavy rams is the softness of the fat. Shelton et al. (1972) reported fast-gaining intact males or wether lambs with a minimum of external fat are likely to have an oily fat. They cited the major factors affecting fat softness were cool weather and high energy rations. These workers reported that these factors cause the deposition of fat with a lower melting point. They indicated that soft fat is caused by a decrease in the length of carbon chains or an increase in the amount of unsaturation in the fatty acids of fat. These researchers noted that this soft fat was apparently a problem at the retail level in merchandising cuts. However, this is apparently not a palatability problem. Kemp et al. (1981) evaluated the meat from ram, ewe, and wether lambs fed four different diets ranging from pasture to high concentrate. These workers were unable to identify any definite relationship between fatty acid content and organoleptic score.

Marchello et al. (1967) reported that a slight decrease in the hardness of lamb fat might be desirable because it is the hardest fat of the domestic animals and many consumers do not consider this to be desirable. They also found that lambs synthesize a higher degree of unsaturated fat as growth progresses.

Apparently, however, the softer ram fat can be undesirable. Tichenor et al. (1970) noted that castration had a marked effect on the fatty acid composition of lamb fat. Busboom et al. (1981) reported that almost all ram lambs fed a high energy diet had a soft, yellow fat. They found that as the proportion of odd-numbered and branched chain fatty acids increased, the fat became softer. These workers also noted yellow fat was associated with softer fat. Moreover, they determined a rather high correlation (.71) between fat color and hardness. They concluded, based on the 63 and 76 kilogram slaughter weights in their study, that the soft fat of the 76 kilogram lambs would be undesirable under most market conditions. Therefore, these researchers discouraged the production of extremely heavy ram lambs.

Summary

It is quite universally held that the carcass of an animal matures later than the offal items which generally results in an increase in dressing percentage as live weight increases. The various parts of the carcass also seem to mature at different rates. Research in the area of animal growth indicates that a gradient of maturation moves from the early maturing head and feet to the later maturing loin. Some researchers describe the growth in body parts to follow an "anterior" to "posterior" gradient from earliest to latest maturing. The literature generally supports the concept that development of the tissues progresses from bone to lean to fat with fat deposition occuring first around the kidneys and certain other organs then as intermuscular fat, subcutaneous fat, and finally as marbling. A preponderance of research data indicate that as an animal grows, the percentages of bone and lean in the carcass decrease while the percentage fat increases. In addition, due to the different maturation rates, the carcass percentages of rack and loin appear to increase while the percentages of leg and shoulder decrease as live weight increases.

Expressing and analyzing growth and composition changes as a percentage of some entity appears to account for less of the variation than an analysis based on actual weights. In addition, the use of ratios may sometimes be misleading. While the percentage of lean generally decreases and fat increases as carcass weights increase, the weight of lean may be increasing more than the weight of fat. Often, it is not until late in an animal's life that fat growth exceeds lean growth. Thus, the percentage yield of lean on a live weight basis, which considers dressing percentage, often changes little as an animal grows while the carcass percentage in lean declines substantially.

Lamb feeding research has shown that feed efficiency declines substantially as an animal grows while average daily gain may decline only slightly as live weight increases. Ram lambs can generally grow to heavy weights before becoming excessively fat. Their growth and composition changes at heavy weights have been reported as similar to those of the earlier maturing ewe and wether lambs at much lighter weights. The palatability of ram meat is generally recognized as acceptable, although at a somewhat lower level than lamb from ewes and wethers. Research indicates that undesirable flavor and tenderness, however, may occur in lamb from ram carcasses weighing over 40 kilograms.

Development of soft and oily fat in heavy ram carcasses may also create problems in merchandising. However, this problem is generally not evident until ram lambs reach slaughter weights above approximately 75 kilograms.

CHAPTER III

MATERIALS AND METHODS

Live Animal Procedures

On four occasions groups of crossbred ram lambs born at three different times of the year were selected from an eight-month lambing interval project at the Southwestern Livestock and Forage Research Station, El Reno, Oklahoma. The distribution of these 144 lambs among the four groups (seasons) by year and season of birth is presented in Table I. In some seasons fewer lambs were available than in others; however, in each season there were from three to six times as many ram lambs to choose from than were actually selected. In addition, lambs in different seasons were born and raised under different environmental conditions which may have affected their growth.

These lambs were the progeny of Hampshire, Suffolk, Hampshire x Suffolk and Suffolk x Hampshire rams mated to crossbred ewes consisting of various levels of Rambouillet, Dorset and Finnsheep breeding, but not more than one-quarter Finnsheep. The lambs were born within a forty-day lambing season and were weaned within one week of reaching 70 days of age. The lambs were creep fed a ration consisting of 50 percent milo, 35 percent alfalfa, 10 percent soybean oil meal, and 5 percent molasses. When 12 normally growing lambs similar in weight and age averaged 70 pounds, they were started as a "pen" on a finishing ration of 45 percent alfalfa, 50 percent milo, and 5 percent molasses. This ground and mixed ration was fed in a self feeder.

TABLE I

DISTRIBUTION OF LAMBS AMONG FEEDING GROUPS (SEASONS)

Season	Number	Time of Birth	Time of Feeding
1	36	Fall 1977	Spring/Summer 1978
2	48	Summer 1978	Fall/Winter 1978-79
3	24	Winter 1979	Summer 1979
4	36	Fall 1979	Spring/Summer 1980
	144		

The lambs were individually weighed twice weekly at approximately the same time of the morning in an attempt to minimize differences in fill between weigh days. When a pen of 12 lambs averaged near 100 pounds live weight, the lambs were sorted into upper, average, and lower one-third weight groups and one lamb from each group was randomly chosen for slaughter. The same procedure was followed at average pen weights of approximately 120 and 140 pounds and the last three lambs were slaughtered when their average weight was about 160 pounds. This procedure gave each lamb an equal chance of being slaughtered at any weight and it prevented the average pen weight from changing substantially each time lambs were slaughtered. However, this selection procedure resulted in feedlot performance data on fewer lambs as live weight increased (Table II). When lambs were removed from a pen the remaining feed was weighed back and feed consumption recorded on a pen basis.

TABLE II

DISTRIBUTION OF LAMBS FOR FEEDLOT PERFORMANCE ANALYSES

Item	Season 1	2	3	4	Overall
Number of pens	3	4	2	3	12
Weight Interval (lbs.)					
70-100	36	48	24	36	144
100-120	27	36	18	27	108
120-140	18	24	12	18	72
140-160	9	12	6	9	36

Lambs in Seasons one and two were shorn when a pen averaged 120 pounds. Those lambs in Seasons one and two slaughtered at 100 pounds were shorn before slaughter. Lambs in the final two seasons were shorn when the pen weight averaged 100 pounds. The weights of all fleeces were recorded and added to the final slaughter weights. Therefore, all calculations involving live weight were made as if the lambs had never been shorn.

Carcass Procedures

Lambs ready for slaughter were trucked to the Oklahoma State University Meat Laboratory and held overnight without feed. The live weight used to compute dressing percentage and other calculations was the full Fort Reno weight (fleece included) obtained the day before slaughter.

Lambs were slaughtered according to common procedures and under Federal Inspection. After a 24 hour chill maturity, feathering, flank streaking, and flank fullness and firmness were evaluated. These factors were used to arrive at a quality score which differed from the U.S.D.A. Quality Grade (U.S.D.A., 1969) only in that it did not consider carcass conformation. A leg conformation score was also assigned to the nearest one-third of a grade and U.S.D.A. Yield Grade was determined. The carcasses were then wrapped in heavy beef shrouds to prevent undue shrinkage before fabrication.

On the day a carcass was fabricated the "cold carcass weight" was recorded to the nearest one-tenth of a pound. A slight knife cut (score) was made on each side of the carcass from the point of the patella, across the ventral edge of the eleventh rib to a point approximately one-half inch proximal of the junction of the humerus and radius. This score would later facilitate removal of the shank, breast, and flank.

The fore and hindsaddles were separated between the twelfth and thirteenth ribs along a line that followed the contour of the twelfth rib. The flank, including cod fat, was removed by a cut starting in the crotch and proceeding along the previously mentioned scored line. This line was ventral to the thirteenth rib so the flank was boneless.

The aitch bone was split and all kidney and pelvic fat, including the kidneys, was removed and weighed. The breast and foreshank were removed along the previously mentioned scored line and the shank was separated from the breast along the natural seam.

The shoulder and rack were separated between the fifth and sixth ribs by a cut made perpendicular to the backbone. Area of the longissimus dorsi muscle at the twelfth rib was traced onto transparent acetate paper and later measured by a compensating polar planimeter. Fat thickness over the l. dorsi muscle was measured over the center of the muscle on each side. Loin eye area and fat thickness from the right and left sides were averaged to obtain single values. Body wall fat was also the average of the two sides as measured two inches ventral to the lateral edge of the l. dorsi muscle. A cut down the median plane, on a rotating band saw, separated the neck, shoulder, rack, and hindsaddle into right and left sides. All additional trimming and cutting was done on the right side. The only weight recorded from the left side was a total side weight. Fat thickness over the second sacral vertebra was measured and recorded. The loin was separated from the leg between the second and third sacral vertebra by a cut made perpendicular to the line of the back. The neck was removed from the shoulder by cutting along a line parallel to the angle of the scapula.

A retail rack was obtained by removing the riblets from the full rack. This line of separation was determined much like that described by Wellington (1953) for separating the rib and plate in beef. In this study, a reference point was determined on the posterior end of the rack, 55 percent of the distance from the center of the twelfth thoracic vertebra to the costal cartilage of the twelfth rib. This point was connected to a point just inside the cartilage of the scapula on the anterior end by a line running parallel to the backbone. The same distance used to separate the riblets from the rack was used as the reference point to separate the flank portion of the loin from the retail loin. This line of separation went from that reference point on the anterior end of the loin to a point just outside the tenderloin on the posterior end.

The "retail trim" weights of the shoulder, full rack, full loin, and leg were recorded when the external fat of the cut was trimmed to a thickness not greater than two-tenths of an inch. Virtually all external fat was then removed to obtain a "very closely trimmed" weight for each of these cuts. The leg and shoulder were then boned out and most intermuscular fat was removed for a "closely trimmed, boneless lean" weight.

Of the rough cuts, the flank was separated into lean and fat and the neck, foreshank and breast into lean, fat, and bone. The lean from these rough cuts was ground, mixed and two samples were saved for fat analysis. The front (metacarpus) and rear (metatarsus) cannon bones were trimmed of all soft tissue and weighed on a gram scale.

This fabrication method broke the carcass into eight wholesale cuts: the leg, loin, rack, shoulder, neck, foreshank, breast, and flank. The four primal cuts, leg, loin, rack, and shoulder, were trimmed to a "retail trim" weight then a "closely trimmed weight" and the leg and shoulder were separated into lean, fat, and bone. The "primal cut lean" weight consisted of the boneless, closely trimmed leg and shoulder and the closely trimmed, bone-in full rack and loin. Total "lean" weight consisted of the primal cut lean and the closely trimmed, boneless weight of the rough cuts. Therefore, this total "lean" weight included all carcass lean as well as the bone and intermuscular fat of the closely trimmed, full rack and loin. Fat trim from all cuts was used as the estimate of total fat and the bone from all cuts boned out as the estimate of total bone. Wholesale cut, lean, fat and bone weights, obtained from the right side were doubled to get the weights on a carcass basis. Carcass components expressed as a percentage are based on the "cold" weight while dressing percent was based on the "hot" carcass weight obtained the day of slaughter. These calculations reduced the influence that unequal cooler shrinkage may have had among carcasses.

A Warner-Bratzler Shear mounted on an Instron measuring device was used to evaluate tenderness in the 36 lambs of the final season. Two 1½ inch thick chops were taken from each carcass, one from the posterior end of the rack and the other from the anterior end of the loin. These chops were frozen, thawed at a later date and then cooked in a 275°F convection oven to an internal temperature of 155°F. After cooling overnight, two one-half inch cores were removed from each chop and two shears made on each core. The eight shear values obtained for each carcass were averaged to establish a single estimate of tenderness for each carcass.

Statistical Analysis

The live performance and carcass data were analyzed differently. Although individual animal weights were obtained, feed consumption was recorded on a pen basis. Therefore, the pen was used as the experimental unit for the daily gain, feed intake, and feed efficiency analyses. These live performance data were available for lambs grown from 70 to 100 pounds, 100 to 120 pounds, 120 to 140 pounds, and 140 to 160 pounds. These weight intervals were designated as "slaughter weight groups" and the data were statistically analyzed by the following linear model:

$$Y_{ijk} = u + S_i + P_j(S_i) + W_k + SW_{ik} + PW_{jk}(S_i)$$

where:

Y_{ijk} = the observed performance trait from the kth slaughter weight group of the jth pen in the ith season

u = population mean

S_i = effect of the ith season, i = 1, 2, 3, 4

$P_j(S_i)$ = effect of the jth pen in the ith season, j = 1, 2, 3, 4

W_k = effect of the kth slaughter weight group, k = 1, 2, 3, 4

SW_{ik} = interaction effect of the ith season and kth slaughter weight group

$PW_{jk}(S_i)$ = effect of the jth pen and kth slaughter weight group in the ith season

The analysis of variance for the live performance data is shown in Table III. This table also exhibits the breakdown of the slaughter weight group sum of squares into linear, quadratic and cubic components along with the associated interactions of these components with season. All analyses in this report were done by using the Statistical Analysis System (SAS Users Guide, 1979).

The selection of lambs for slaughter in a stratified manner at given average pen weights spread the individual lamb weights over a wide range. The average live weight and standard deviation of lambs slaughtered at the designated average pen weights (100, 120, 140, and 160 pounds) are shown in the Appendix (Table XVII). This selection procedure resulted in a somewhat continuous distribution of live weights between 87 and 187 pounds. Therefore, the carcass data were analyzed by fitting the following multiple regression model to the individual lamb data: $Y = B_0 + B_1X + B_2X^2 + E$, where X = the individual weight and E = random error. The residual mean square was used as the error term for testing the presence of the linear and quadratic effects in the model. If the quadratic effect was not significant at the $P<.05$ level, the following linear model was used to describe the relationship: $Y = A_0 + A_1X + Z$, where X = the individual weight and Z = random error. Thus, if the quadratic effect was not significant, the mean square associated with it was included in the error term for the linear analysis. If the quadratic effect was not significant and the linear effect was, an apparent linear relationship was assumed to exist because the non-linear effect could not be proven. The analysis of variance for the carcass data is shown in Table IV.

TABLE III

ANALYSIS OF VARIANCE FOR FEED INTAKE,
DAILY GAIN, AND FEED EFFICIENCY

Source			d.f.
Total			47
Season	S		3
Pen (Season)[a]	P(S)		8
Slaughter Weight Group	W		3
Linear	W_L	(1)	
Quadratic	W_Q	(1)	
Cubic	W_C	(1)	
Season x Sl. Wt.	S*W		9
Linear x Seas	W_L*S	(3)	
Quadratic x Seas	W_Q*S	(3)	
Cubic x Seas	W_C*S	(3)	
Pen * Sl. Wt. (Seas)[b]	PW(S)		24

[a] error (a) Used to test Season effect

[b] error (b) Used to test Slaughter Weight Group effect and Season x Sl. Wt. interaction

TABLE IV

ANALYSIS OF VARIANCE FOR CARCASS DATA

Source	d.f.
Total	143
Linear	1
Quadratic	1
Error	141

CHAPTER IV

RESULTS AND DISCUSSION

This chapter is divided into two major sections: 1) live performance of ram lambs fed through four weight gain intervals, and 2) carcass characteristics of ram lambs slaughtered at different live weights.

Live Performance of Ram Lambs Fed Through Four Weight Gain Intervals

The feed efficiency, daily gain, and daily feed intake data for these ram lambs are presented in Tables V, VI, and VII. As one would expect, the live performance of these ram lambs differed among seasons (Table XVI, Appendix). This most likely resulted from the different environmental conditions among seasons. In addition, within season environmental changes most likely affected the performance of lambs in different weight intervals within a season. For example, the lambs in Seasons 1 and 4 were fed from 70 to 100 pounds during the winter months of January and February but they were fed from 140 to 160 pounds during the summer months of May and June.

Several additional factors may have influenced the live performance data of the lambs both within and among seasons. Variation in "fill" between weigh days can greatly affect the observed amount of weight gain for animals fed for short weight gain intervals. While an attempt was made to minimize differences in "fill," this variation most likely influenced the daily gain and feed efficiency data of these lambs. In addition, since the live performance data were collected on a pen basis the mean reported for a season was determined by relatively few observations (two to four pens per season).

Season 2 lambs suffered a poly-arthritic disease condition common in feedlot lambs. While severe development of the disease was limited, the subclinical effects most likely influenced performance to some extent. Much of the disease problem in that season was overcome by the end of the experiment. This possibly accounted for the more efficient and faster gains of lambs fed from 140 to 160 pounds than for lambs fed from 120 to 140 pounds in Season 2 (Tables V and VI).

The seasonal influences evident in these data indicate the well recognized effects environmental conditions have on lamb performance. However, lambs are fed in all seasons of the year and under widely varying environmental conditions. Therefore, the average of the live performance measures across seasons should be a good estimate of the performance of ram lambs fed in this manner.

Feed Efficiency

The data presented in Table V indicate the feed efficiency of the ram lambs by weight interval and season. As live weight increases, one would expect the amount of feed required per unit of gain to also increase, partially as a result of the increased maintenance requirements for a larger animal. Differences in feed efficiency among weight intervals were significant while the seasonal differences only approached significance (Table XVI, Appendix).

Across seasons, the amount of feed required per unit of gain increased ($P<.01$) from 6.4 for ram lambs grown from 70 to 100 pounds to

TABLE V

MEAN FEED EFFICIENCY[a] BY SEASON FOR RAM LAMBS FED FOR FOUR WEIGHT GAIN INTERVALS

	Weight Interval (lbs.)			
Season	70-100	100-120	120-140	140-160
1	5.8	6.8	7.9	8.5
2	7.3	8.6	9.5	9.1
3	6.0	5.9	10.2	7.7
4	6.2	7.2	6.4	8.2
Overall Mean	6.4	7.3	8.5	8.5

[a]Pounds of feed/pound of liveweight gain

8.5 for rams grown from 140 to 160 pounds. The absence of the expected increase in feed to gain ratio for the two heaviest intervals (both 8.5) may have resulted from the relatively poor performance of Season 3 lambs in the 120 to 140 pound interval. Harrison and Crouse (1978) reported a feed to gain ratio of 11.7 for ram lambs grown from 135 to 155 pounds or a cumulative feed to gain ratio of 8.5 for the entire weight range of 75 to 155 pounds. However, the results of Shelton and Carpenter (1972) are more similar to those reported here. They found that the cumulative feed to gain ratio was 7.1 for ram lambs grown from 44 to 150 pounds compared to 7.5 (calculated from Table V) for rams grown from 70 to 160 pounds in this study.

Daily Gain

As shown in Table VI, lamb average daily gain across seasons declined ($P<.05$) as live weight increased. This decline was apparent in three of four seasons. However, the largest decrease in daily gain appeared to occur in the 140 to 160 pound interval. Daily gain averaged .67 pounds for the first three weight intervals before declining to .59 pounds for the 140 to 160 pound interval. Other researchers have reported similar trends. Lloyd et al. (1981) indicated that daily gain increased slightly from .23 to .26 kilograms for ram lambs fed to 54 and 64 kilograms, respectively. Generally, however, when lambs were fed over a longer interval, daily gains remained quite constant but tended to decline slightly (Antoniewicz and Pope, 1967; Shelton and Carpenter, 1972).

Feed Intake

Daily feed intake followed a quadratic response ($P<.01$) as live

TABLE VI

MEAN AVERAGE DAILY GAIN[a] BY SEASON FOR RAM LAMBS FED FOR FOUR WEIGHT GAIN INTERVALS

	Weight Interval (lbs.)			
Season	70-100	100-120	120-140	140-160
1	.74	.70	.73	.62
2	.53	.57	.55	.63
3	.75	.86	.60	.56
4	.70	.69	.76	.50
Overall Mean	.67	.68	.66	.59

[a]Pounds

weight increased. This intake increased initially, reached a maximum and then declined as live weight increased (Table VII). Feed intake was 4.2, 4.9, 5.3, and 4.9 pounds per day for the 70 to 100, 100 to 120, 120 to 140, and 140 to 160 pound weight intervals, respectively. This type of response is what one would most likely expect in a normally maturing market animal. Energy requirements for maintenance increase as the animal grows. However, growth eventually occurs more slowly, thereby reducing the total energy required. Harrison and Crouse (1978) noted a somewhat similar response in ram lambs grown from 76 to 155 pounds. They reported that daily feed intake increased from 4.0 to 4.7 pounds for the 76 and 155 pound rams, respectively. In addition, their data showed that it reached a peak between those weights; however, the trend was less obvious and more variable for the intermediate weights than in this study.

As these ram lambs grew from 70 to 160 pounds, feed intake increased until the lambs reached about 140 pounds, at which time it began to decrease. Average daily gain remained relatively constant to approximately 140 pounds at which time it decreased. Consequently, the increasing feed intake and constant daily gain resulted in a higher feed to gain ratio as weight increased to 140 pounds after which declining daily gain and feed intake resulted in the feed to gain ratio remaining approximately the same between 140 and 160 pounds.

Carcass Characteristics of Ram Lambs Slaughtered at Different Live Weights

A purpose of this study was to evaluate the composition of ram lamb carcasses and to determine how that composition changed as live weight increased. Since growth is a continuous process, a regression

TABLE VII

MEAN DAILY FEED INTAKE[a] BY SEASON FOR RAM LAMBS FED FOR FOUR WEIGHT GAIN INTERVALS

	Weight Interval (lbs.)			
Season	70-100	100-120	120-140	140-160
1	4.3	4.6	5.4	5.4
2	3.9	4.9	5.2	5.7
3	4.4	5.0	6.1	4.3
4	4.4	5.0	4.9	3.8
Overall Mean	4.2	4.9	5.3	4.9

[a]Pounds

analysis should provide an accurate description of animal growth. Therefore, the following results and discussion are based on regression analyses of the raw data which should represent the best estimate of the various traits at a given weight within the weight range of this study.

All carcass measurements and component weights increased (P<.0001) as live weight increased. The analysis for weight of the rough cuts indicated it followed a quadratic increase with increasing live weight. Since a non-linear response could not be detected for the other variables, those data are presented as if responses were linear.

The regression coefficients for each trait regressed on live weight and the associated standard errors are presented in Table XIX (Appendix). These coefficients were used to calculate the data presented in all of the tables in this discussion. These predicted data are presented at slaughter weights of 100, 120, 140, and 160 pounds to allow easier comparison with the live performance data and to illustrate the changes occurring over this wide range in live weight.

The raw means for selected traits of the lambs slaughtered at average pen weights of 100, 120, 140, and 160 pounds are also presented in the Appendix. As shown in Table XVII (Appendix), a comparison of the raw means with the values estimated by regression at those weights indicates that the model is in fact an accurate representation of the data.

Carcass Measurements

The proportion of lean in the carcass of a meat animal is often used as the primary factor to determine the value of that animal. This proportion of lean is often estimated from various carcass measurements.

In addition, these measurements are often used to identify the stage of growth and development of the animal. The carcass composition of these ram lambs at different slaughter weights can be characterized by the carcass measurements presented in Table VIII. Loin eye area, U.S.D.A. Yield Grade, and all fat thickness measurements increased in an apparent linear manner as live weight increased. Since carcass weight also appeared to increase linearly with live weight, a linear relationship between these carcass measurements and carcass weight would also be expected. An apparent linear relationship for loin eye area, fat thickness, and yield grade with carcass weight has been previously reported for ram lambs (Campion et al., 1976). Shelton and Carpenter (1972) also determined that loin eye area and fat thickness of ram lambs appeared to increase linearly with carcass weight but they found a significant quadratic increase for yield grade. However, the magnitude of that quadratic increase was very small.

Eventually one would expect the rate of increase in loin eye area with increasing carcass weight to decline as the lamb reaches maturity (Lambuth et al., 1970). Apparently, these ram lambs maintained rather consistent muscle growth, as indicated by loin eye area, throughout the live weight range of this study. Loin eye area increased from 2.16 square inches in the 100 pound ram to 2.92 square inches in the 160 pound ram. This rate of increase is similar to that reported by Campion et al. (1976). However, those researchers determined from regression analysis a slightly different loin eye area at a given weight. They predicted loin eye area to be approximately 1.83 square inches in a 100 pound ram and 2.67 square inches in a 160 pound ram. Shelton and Carpenter (1972) studied ram lambs slaughtered from 80 to 140 pounds.

TABLE VIII

ESTIMATED CARCASS MEASUREMENT MEANS[a] FROM RAM LAMBS AT FOUR SLAUGHTER WEIGHTS

	Slaughter Weight (lbs.)			
Measure	100	120	140	160
Loin eye area (in.^{2})	2.16	2.41	2.67	2.92
Yield Grade	2.9	3.3	3.7	4.1
Fat Thickness (in.)	.16	.22	.27	.32
Body Wall Fat (in.)	.43	.55	.67	.79
Sacral Fat (in.)	.43	.61	.80	.99

[a]Determined by regression analysis; therefore, the increase in each trait is constant between weight intervals

Using their prediction equation, the estimated loin eye areas for 100 and 160 pound rams are 2.2 and 2.72 square inches, respectively.

Table VIII presents the expected increase in twelfth rib fat thickness from an estimated .16 inches in the 100 pound ram to .32 inches in the 160 pound ram. These amounts and changes in fat thickness are similar to the .19 and .34 inches for 100 and 160 pound rams, respectively, estimated from the data of Shelton and Carpenter (1972). However, Campion et al. (1976) studied considerably trimmer ram lambs. The regression analysis of their data indicated 100 pound ram lambs would have .10 and 160 pound rams .24 inches of fat at the twelfth rib. The rate of increase in fat thickness, however, is similar in the present study to that in the two studies referenced above.

The yield grade of these ram lambs increased .4 with each 20 pound increase in live weight. A change of one full yield grade corresponds to a 1.8 percent decline in the expected yield of closely trimmed and boneless major retail cuts in the carcass. Therefore, this linear relationship of yield grade with live weight implies that the percent cutability of the carcass should also decline in a linear manner.

Carcass Composition

As already indicated by the carcass measurements, the weight of lean, fat, and bone in the carcass increased in an apparent linear manner with increasing live weight (Table IX). Campion et al. (1976) and Shelton and Carpenter (1972) reported similar trends for carcass component weights regressed on carcass weight. The estimate of carcass lean in this study includes the bone and intermuscular fat of the rack and loin. Although this value does not represent the "true" lean in the

TABLE IX

ESTIMATED MEANS[a] FOR COMPOSITION OF CARCASSES FROM RAM LAMBS AT FOUR SLAUGHTER WEIGHTS

	Slaughter Weight (lbs.)			
Item	100	120	140	160
Cold Carcass	47.9	59.3	70.6	82.0
Lean[b,c]	29.5	35.0	40.4	45.8
Fat[c,e]	11.6	16.4	21.2	25.9
Bone[d,e]	6.4	7.3	8.2	9.0

[a]Determined by regression analysis (lbs.)

[b]Total closely trimmed lean plus the bone and intermuscular fat of the rack and loin

[c]All trimmable fat plus kidney and pelvic fat

[d]Total bone except from rack and loin

[e]Failure of component weight to equal carcass weight attributed to cutting loss

carcass it should accurately reflect the relative changes in lean content as live weight changes.

Regression analysis indicated that the quadratic term in the equation for "lean" approached significance ($P<.10$). The quadratic effect, if used, would have resulted in greater estimated lean content at the heavier weights. Furthermore, comparison of the raw means (Table XVII, Appendix) with the estimated values indicates that the values determined by regression may be underestimated at the heavy weights. This apparent trend for increased "lean" deposition at the heavy weights was undoubtedly influenced by the additional intermuscular fat accumulating in the rack and loin as well as additional intramuscular fat in all lean at the heavier live weights. Also, it was more difficult to trim the heavier and fatter carcasses so that fat content of the trimmed lean would be similar to that from the lighter and trimmer carcasses.

Because the quadratic effect was not significant at the $P = .05$ level, the linear model was used to determine the estimated "lean" amounts presented in Table IX. Therefore, at the heavy lamb weights those amounts may underestimate the amount of "lean" as defined in this study. The amounts of "lean" in Table IX, then, most likely reflect some discrimination for the additional fat content at the heavy lamb weights. Therefore, changes in those amounts of estimated "lean" should closely approximate the trend for changes in the "true" lean content of the animal.

As live weight increased from 100 to 160 pounds the amount of "lean" increased from 29.5 to 45.8 pounds or an increase of .28 pounds per pound of live weight. The amount of fat in the 100 and 160 pound lambs was estimated as 11.6 and 25.9 pounds, respectively, which equates to a .24 pound increase per pound of live weight gain. Bone increased from 6.4 pounds in the 100 pound lamb to 9.0 pounds in the 160 pound lamb, a rate of .04 pounds per pound of live weight gain. The small increase in bone indicates the early maturation of this tissue which is well established (Rouse et al., 1970).

The .28 and .24 pound increases in lean and fat, respectively, per pound of live weight gain indicate that these tissues were developing at about the same rate. These rates appear even closer when one considers that the increase in lean also consisted of some bone and fat as previously discussed. Still, these data indicate that lean growth occurred at approximately the same rate in the heavy as in the light lambs. Other researchers have reported that more lean than fat was deposited in growing market animals during the initial part of a feeding period. However, during the latter stages of growth fat increased more than lean (Lambuth et al., 1970; Guenther et al., 1965). It appears that the ram lambs in this study did not reach the stage in maturity of declining lean growth. Campion et al. (1976) came to a similar conclusion when they determined that 16 to 51 kilogram ram carcasses changed in composition through this weight range in a manner similar to the changes previously reported in much lighter ewe and wether carcasses.

Carcass composition is often reported as a percentage of carcass weight; however, Craddock (1973) and Carpenter (1969) have shown that less variation is accounted for by an analysis using percentages than one using actual weights. Other workers have also warned that analyses based on percentages can be misleading (Seebeck, 1968; Tanner, 1949; Dinkel et al., 1965). Therefore, no analyses were conducted on percentage values but they are presented for comparative and discussion purposes.

The carcass tissue weights from Table IX are presented as a percentage of the carcass in Table X. The percentages of lean and bone in the carcass decreased while fat increased as live weight increased. This is in agreement with the well established relationship for these tissues (Rouse et al., 1970). Percent lean declined from 61.6 to 55.9 percent and bone from 13.4 to 11.0 percent while fat increased from 24.2 percent to 31.6 percent as live weight increased from 100 to 160 pounds. In addition, each tissue was changing less on a percentage basis at the heavier weights than at the lighter weights due to the mathematical situation of dividing the same pounds of growth by a larger number. This is evident by comparing the 2.6 percent decline in lean between 100 and 120 pounds and the 1.3 percent decline between 140 and 160 pounds. Likewise, fat increased 3.5 percent through the first 20 pound interval but only 1.6 percent through the final interval. Generally, studies with ewes and wethers have shown the opposite, that is, greater percentage decreases in lean and greater increases in fat at heavier live weights (Lambuth et al., 1970). However, other studies involving ram lambs have produced results similar to those of this work (Crouse et al., 1978; Campion et al., 1976). The continued lean and bone growth in rams and the failure of fat growth to increase more at heavier weights explains why the percentage changes for all tissues are less at the heavier weights than at the lighter weights.

An implication of the change in percent lean yield at a decreasing rate as live weight increases is that this indicates a different relationship than the yield grade changes indicated. As previously discussed, the apparent linear increase in yield grade indicates the percentage lean yield should decrease in a somewhat linear fashion. However, as shown in Table X, each 20 pound increase in live weight

TABLE X

ESTIMATED MEANS[a] FOR PERCENTAGE COMPOSITION OF CARCASSES FROM RAM LAMBS AT FOUR SLAUGHTER WEIGHTS

Carcass Tissue	Slaughter Weight (lbs.) 100	120	140	160
Lean[b,e]	61.6	59.0	57.2	55.9
Fat[c,e]	24.2	27.7	30.0	31.6
Bone[d,e]	13.4	12.3	11.6	11.0

[a]Tissue weight determined by regression analysis x2 ÷ cold carcass weight x 100

[b]Total carcass closely trimmed lean plus the bone and intermuscular fat of the rack and loin

[c]All trimmable fat plus kidney and pelvic fat

[d]Total bone except from rack and loin

[e]Failure of component percentages to total 100 attributed to cutting loss

between 100 and 160 pounds resulted in first a 2.6 then a 1.8 and finally a 1.3 percent decline in lean yield. Therefore, the trend for cutability changes among these ram lambs was not reflected by the changes in yield grade. This lack of agreement between yield grade and cutability changes in ram lambs is also evident in the data of Campion et al. (1976). The inability of yield grade to reflect cutability changes in all sexes was implied by Carpenter et al. (1969). They indicated that a separate prediction equation for each sex grouping should increase the precision of a prediction equation.

The 30.0 and 31.6 percent fat levels in the carcasses of the 140 and 160 pound lambs, respectively, appear substantial especially since they represent separable (not chemical) fat and that some intermuscular as well as intramuscular fat is not included (i.e. from the rack and loin). Crouse et al. (1978) developed a prediction equation for percent chemical fat from the data obtained from ram lambs slaughtered between 37 and 145 pounds. That equation predicts the percentage fat (excluding kidney fat) at 100 and 160 pounds to be 22.9 and 26.2 percent, respectively, which is somewhat less at the heavy weight than was observed for these lambs.

A large part of the ultimate value of a market animal is determined by the quality and proportion of lean meat in the animal. While the ram lambs in this study appeared quite fat at heavy weights, lean growth did continue and components other than fat are associated with the proportion of lean in a market animal. Two major factors are related to the proportion of lean: 1) the proportion of fat in the carcass and 2) the proportion of offal in the live animal. The influence which the offal items have in determining the proportion of lean in an animal is often only briefly considered or completely omitted from meat research studies. The data in Table XI indicate the significance of offal items in determining the proportion of lean produced from an animal. The 5.7 percent decline in lean composition on a carcass basis between 100 and 160 pounds live weight (Table X) corresponded to only a 1.2 percent decline on a live weight basis (Table XI). This relationship is depicted graphically in Figure 1.

One would expect the percentage change in lean to be less on a live weight basis simply because the percentage itself is smaller. However, the 1.2 percent decline on a live weight basis is disproportionately less than the 5.7 percent decline on a carcass basis. In fact, a proportional decrease in lean yield on a live weight basis would have required a 2.9 percent decline between the 100 to 160 pound rams.

As shown in Table XI, as live weight increased the percentage of offal and bone decreased while percentage fat increased and percentage lean changed the least in relation to its total. Changes in composition of a growing animal depend upon the relationship between the percentage composition of the animal and the composition of each unit of weight gain. Obviously, as live weight increases the percentage composition of the animal will shift towards the percentage composition of the gain. For example, the values in Table IX indicate that lean, fat, bone, and offal (slaughter weight-carcass weight) increased .28, .24, .04, and .44 pounds, respectively, with each one pound increase in live weight between 100 and 160 pounds. Therefore, each unit of liveweight gain consisted of 28 percent lean, 24 percent fat, 4 percent bone, and 44 percent offal. The percentage composition of the lamb at 100 pounds is presented in Table XI (30.9 percent lean, 12.2 percent fat, 6.7 percent bone, and 49.8 percent offal). Obviously, fat and offal are the

TABLE XI

ESTIMATED MEANS[a] FOR PERCENTAGE COMPOSITION OF RAM LAMBS AT FOUR SLAUGHTER WEIGHTS

	Slaughter Weight (lbs.)			
Component	100	120	140	160
Hot Carcass	50.2	51.6	52.5	53.2
Offal[b]	49.8	48.4	47.5	46.8
Lean[c,f]	30.9	30.4	30.0	29.7
Fat[d,f]	12.2	14.3	15.8	16.8
Bone[e,f]	6.7	6.3	6.1	5.9

[a]Weights determined by regression analysis then converted to a percentage

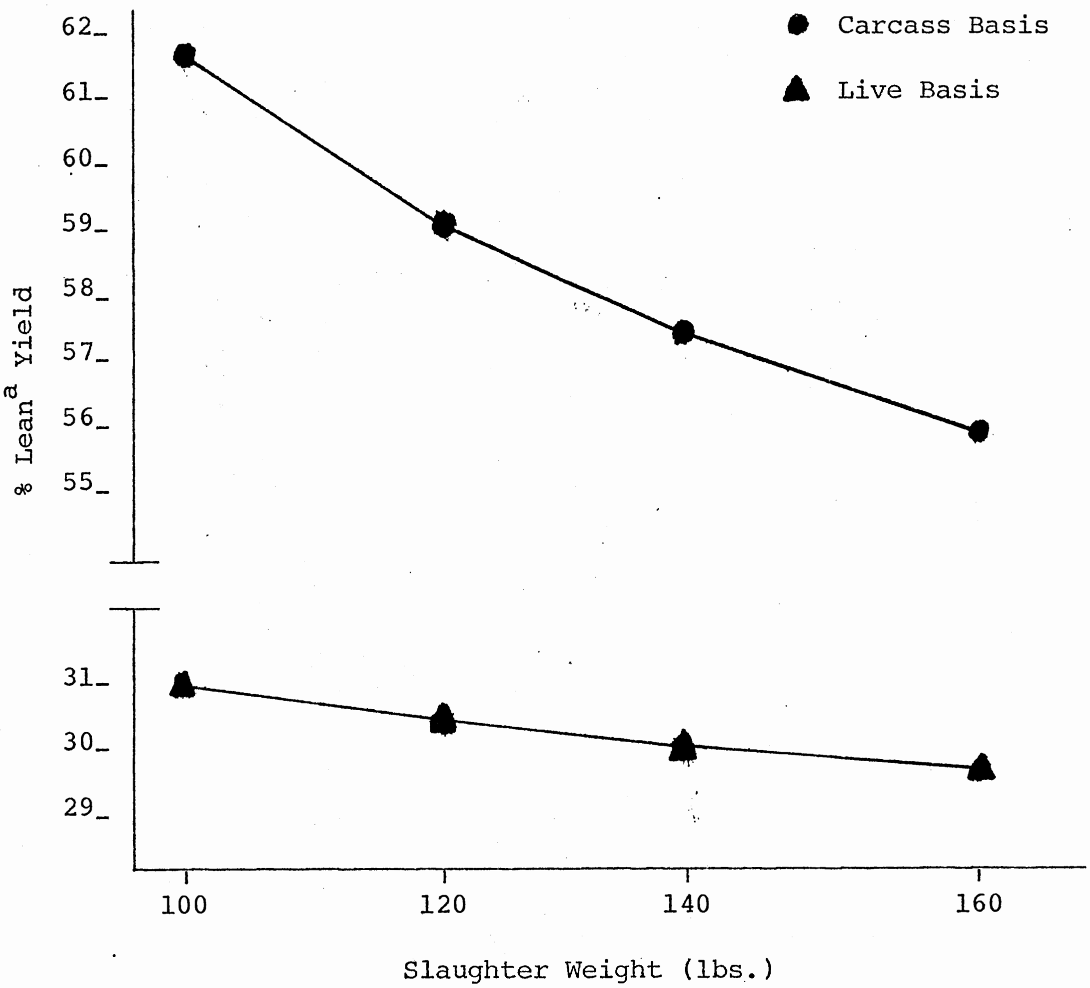
[b]100 - Dressing percent

[c]Includes the bone and intermuscular fat from rack and loin

[d]All trimmable fat plus kidney and pelvic fat

[e]All bone except from rack and loin

[f]% of cold carcass x dressing percent to correct for cooler shrinkage



[a]Includes bone and intermuscular fat of the rack and loin.

Figure 1. Lean Yield of Carcasses From Ram Lambs at Four Slaughter Weights

tissues that differed the most between their percentage composition of gain and their percentage composition of the carcass. Thus, these two tissues changed the most on a percentage basis as live weight increased (Table XI). In addition, fat was the only tissue that constituted a higher percentage of weight gain than it did of the carcass. Therefore, fat was the only tissue that increased as a proportion of the animal as live weight increased, while all other tissues decreased.

The reason for fat and offal tissues to change more on a percentage basis than the other components of a live animal is explained by the difference in maturation for these components. Palsson and Verges (1952) determined that offal components mature earlier than carcass tissues and that fat is the latest maturing of all tissues. Therefore, at heavier weights the proportion of early maturing offal will decrease while the late maturing fat will increase as a percentage of the live weight of the animal. Bone and lean are intermediate in maturation to offal items and fat (Palsson and Verges, 1952) and therefore change the least of these tissues on a percentage basis. In addition, lean is a later maturing tissue than bone (Palsson and Verges, 1952). Therefore, the decline in lean relative to its total will be less than the relative decline in bone as live weight increases. Moreover, since the major percentage composition changes essentially result in some "trade-off" of fat for offal, the changes in the percentage of lean in the growing animal appear to be relatively small. Tulloh (1964) reached a similar conclusion by noting that in beef cattle as live weight changed, muscle comprised almost a constant percentage of a market steer's live weight.

In this study, the largest change in lean content on a live weight basis occurred between 100 and 120 pounds, after which only small changes occurred. However, other data indicate that the most substantial changes in lean content usually occur at heavier weights. The data presented by Lambuth et al. (1970) indicate that the percent edible portion of live weight was 32.6, 32.7, and 31.0 for lambs slaughtered at live weights of 36, 45, and 54 kilograms, respectively. In their data, dressing percentage increased most (1.9 percent) between the first two weights. Therefore, edible portion as a percentage of live weight was similar between the lightest weights. However, it decreased at the heaviest weight because dressing percentage did not increase as much as at the lighter weights. Adams (1978) found that dressing percentage increased approximately 3.4 percent for ram lambs slaughtered at 125 pounds compared to 100 pound lambs, resulting in essentially no change in lean yield on a live weight basis.

The carcass and live composition analyses discussed to this point fail to indicate the importance of other edible products from ram lambs. Kemp et al. (1970) reported that testicle weights of ram lambs accounted for nearly .75 percent of live weight and that generally their price per pound was approximately twice that of the carcass. Testicle weights for the ram lambs in this study were recorded and regressed on live weight (analysis not shown). Testicle weight increased in an apparent linear manner with increasing live weight and while this weight decreased somewhat as a percentage of live weight (.79 percent for 100 pound rams to .73 percent for 160 pound rams), it averaged approximately .75 percent. Therefore, the testicles of ram lambs can be of significant economic importance.

The distribution of carcass weight among the wholesale cuts is an important consideration because of the differing value of these cuts. The weight distribution of wholesale cuts is presented in Table XII.

TABLE XII

ESTIMATED MEANS[a] FOR WHOLESALE CUT WEIGHTS OF CARCASSES FROM RAM LAMBS AT TWO SLAUGHTER WEIGHTS

	Slaughter Weight (lbs.)			
	100		160	
Wholesale Cut(s)	lbs.	% of carcass[b]	lbs.	% of carcass[b]
Leg	12.5	26.0	19.8	24.2
Loin	7.9	16.4	13.6	16.7
Rack	5.0	10.4	9.0	11.0
Shoulder	11.3	23.5	19.1	23.4
Rough Cuts	10.0	20.7	17.1	21.0
Kidney and Pelvic Fat	1.4	2.9	3.0	3.7

[a]Weights determined by regression analysis

[b]Total wholesale cut weight (cold)

Wholesale cut weights and percentages of carcasses from the 120 and 140 pound lambs were intermediate to those presented for the 100 and 160 pound lambs. All wholesale cut weights, except the rough cuts (flank, breast, shank, and neck), appeared to increase linearly with increasing live weight. The rough cut weight followed a quadratic curvature, increasing more at the heavier weights. This is thought to reflect at least some increase in fat deposition in these cuts. Still, the proportion of rough cuts in the carcass increased only slightly (.3 percent) between 100 and 160 pounds. The percentage of leg changed the most, declining 1.8 percent, while the percentage rack and kidney fat increased and percentage shoulder and loin changed only slightly. These changes are similar to those reported by Kemp et al. (1970) except that these workers found that the percentage of breast and flank increased more than any other cut and that the loin increased somewhat more than the rack as a percentage of the carcass. These changes reflect the different rates of maturation among the wholesale cuts previously reported by Palsson and Verges (1952) in that the leg matures relatively early while the rack and loin are later maturing regions.

The trends noted for the untrimmed wholesale cuts are also apparent in the lean weights of these cuts. The "lean" weight of each wholesale cut (presented in Table XIII) increased in an apparent linear manner as live weight increased. The percentage of total lean in the leg and shoulder declined as live weight increased but the percentage in the rack and rough cuts increased. Moreover, the percentage of lean in the loin remained approximately the same. The magnitude of fat deposition in the shoulder is evident by the shoulder's much larger decline as a percentage of lean weight (.6 percent decline) than as a percentage of the untrimmed wholesale cut weight (.1 percent decline).

TABLE XIII

ESTIMATED MEANS[a] FOR LEAN[b] WEIGHT DISTRIBUTION AMONG THE WHOLESALE CUTS OF CARCASSES FROM RAM LAMBS AT TWO SLAUGHTER WEIGHTS

	Slaughter Weight (lbs.)			
	100		160	
Wholesale Cut(s)	lbs.	% of lean	lbs.	% of lean
Leg	8.2	27.9	12.3	26.9
Loin	6.1	20.5	9.4	20.5
Rack	3.9	13.3	6.5	14.1
Shoulder	7.0	23.8	10.6	23.2
Rough Cuts	4.3	14.5	7.0	15.2

[a] Weights determined by regression analysis

[b] Boneless, closely trimmed leg, shoulder, and rough cuts. External fat closely trimmed, bone-in rack and loin.

The location of fat within the primal cuts (leg, loin, rack, and shoulder) can be determined from the data presented in Table XIV. The retail trim weight of the primal cuts decreased 3.7 percent between 100 and 160 pounds live weight. Obviously, this decrease is also a part of the 4.9 percent decrease in closely trimmed weight and of the 5.2 percent decrease observed for the lean weight. Therefore, the trim loss from the wholesale weight to the closely trimmed weight accounted for a major part of the decrease in lean yield between the 100 and 160 pound slaughter weights. This indicates that subcutaneous fat accumulated much more than the intermuscular fat and bone in the primal cuts as live weight increased from 100 to 160 pounds. This trend is in agreement with the well established order for fat development to progress from kidney fat to intermuscular fat and then to subcutaneous fat (Palsson, 1952).

Carcass Quality and Lean Tenderness

The quality score of these ram lamb carcasses did not change substantially throughout the weight range of this study (Table XV). However, while quality score only increased from high Choice to low Prime, feathering increased from typical Small to typical Modest and flank streaking from high Slight to low Modest. Obviously, these quality factors were offset by an increase in carcass maturity from youthful (A^-) to more mature (A^+), resulting in the small difference in quality scores at different weights.

The lean from two chops, one from the posterior end of the rack and the other from the anterior end of the loin, from each of the 36 lamb carcasses of the final season was evaluated for tenderness. The analysis indicated a significant linear effect between the shear values

TABLE XIV

ESTIMATED MEAN[a] DISTRIBUTION OF WEIGHT WITHIN THE PRIMAL CUTS[b] OF CARCASSES FROM RAM LAMBS AT TWO SLAUGHTER WEIGHTS

	Slaughter Weight (lbs.)			
	100		160	
Weight	lbs.	% of Wholesale	lbs.	% of Wholesale
Primal	36.8	100.0	61.4	100.0
Retail Trim[c]	34.5	93.6	54.7	89.9
Closely Trimmed	31.2	84.5	48.9	79.6
Lean[d]	25.2	68.5	38.9	63.3

[a]Weights determined by regression analysis

[b]Leg, loin, rack, and shoulder

[c]Maximum .2 in. external fat

[d]Leg and shoulder, boneless and closely trimmed of all fat. Bone-in rack and loin closely trimmed of all external fat.

TABLE XV

ESTIMATED MEANS[a] FOR QUALITY ATTRIBUTES OF CARCASSES FROM RAM LAMBS AT FOUR SLAUGHTER WEIGHTS

	n[b]	100	120	140	160
Quality Score[c,d]	140	11.8	12.2	12.6	13.0
Feathering[e]	140	13.9	15.0	16.2	17.4
Flank Streaking[e]	140	11.6	12.9	14.2	15.6
Maturity[f]	138	1.4	2.0	2.5	3.1
Shear Force (kg)	36	2.7	3.0	3.2	3.5

[a]Determined by regression analysis

[b]Some lambs were not quality graded

[c]Balance of feathering, flank streaking, and maturity

[d]Average Choice = 11, High Choice = 12, etc.

[e]Small$^-$ = 13, Modest$^-$ = 16, etc.

[f]$A^- = 1$, $A^0 = 2$, $A^+ = 3$, $B^- = 4$

and live weight. The data presented in Table XV indicate that the estimated shear force increased from 2.7 to 3.5 kilograms for the lean from 100 and 160 pound rams, respectively. The 3.5 kilogram estimate is under the 3.6 kilogram shear force considered acceptable for lamb (Field et al., 1967). However, the shear values obtained from these 36 lambs were extremely variable ($s_{y \cdot x}$=.83 kg) and therefore, definite conclusions cannot be drawn from these data. In addition, the values estimated by regression indicate a different trend for tenderness than that shown by the raw means (Table XVII, Appendix). The raw means for shear force changed the most between the 100 and 120 pound slaughter weights and remained almost constant at the heavier weights. The regression analysis did not identify this quadratic response for tenderness but this is not surprising when one considers the high variability of the data.

Shelton and Carpenter (1972) slaughtered lambs between 38 and 68 kilograms and Kemp et al. (1981) slaughtered lambs between 41 and 50 kilograms to evaluate lean tenderness. These studies involved ram, ewe, and wether lambs and the researchers in each study concluded that shear force did not differ significantly with changing live weight. However, Kemp et al. (1972) and Shelley et al. (1970) reported that tenderness improved as slaughter weight increased from 36 to 54 kilograms. However, none of these studies involved lambs as heavy as those in this work. Campion et al. (1976) evaluated tenderness in lean from heavy ram lambs (16 to 51 kilogram carcasses) and found that the lean became somewhat less tender as carcass weight increased.

The increasing shear values and quality scores presented in Table XV indicate a negative correlation between quality score and tenderness. Campion et al. (1976) reported a significant negative correlation for carcass quality and taste panel tenderness, juiciness, and overall acceptability. Those researchers concluded that the present U.S.D.A. quality grades apparently fail to reflect the palatability of the lean in ram lambs, especially at heavy weights. The results of this study tend to support that finding, although the lean tenderness of these ram lambs was considered acceptable at all weights.

CHAPTER V

SUMMARY

Feedlot performance and carcass data were obtained from 144 crossbred ram lambs fed to different slaughter weights. The lambs were fed in four groups (seasons) determined by year and time of birth (Summer, Fall, or Winter). When 12 lambs averaged 70 pounds, they were placed in a pen and started on the experiment. At average pen weights of 100, 120, and 140 pounds a stratified sample of three lambs was obtained for slaughter. The remaining three lambs in the pen were slaughtered at 160 pounds. Carcass measurements were obtained and detailed carcass cut-out data collected from the right side. Carcass data were analyzed by regression analyses of the various data on individual lamb live weights.

Seasonal influences were evident in the live performance analyses. The lambs in Season 2 generally performed unlike lambs in the other seasons, thought to be due in part to the health problems in Season 2. Across seasons, average daily gain decreased ($P<.05$) from .67 pounds for lambs fed from 70 to 100 pounds to .59 pounds for lambs fed from 140 to 160 pounds. The major part of that decrease appeared to occur in the 140 to 160 pound weight interval. Daily feed intake increased, reached a peak, and then decreased ($P<.01$). Daily feed intake was 4.2, 4.9, 5.3, and 4.9 pounds for lambs in the 70 to 100, 100 to 120, 120 to 140, and 140 to 160 pound weight intervals, respectively. The pounds of feed required to produce a pound of gain increased ($P<.01$) as live weight increased. Lambs in the 70 to 100, 100 to 120, 120 to 140, and 140 to 160 weight intervals required 6.4, 7.3, 8.5, and 8.5 pounds of feed per pound of gain, respectively. It appears that declining feed intake and declining daily gains in the 140 to 160 pound interval resulted in the similar feed to gain ratios for the last two intervals.

All carcass measurements and weights increased ($P<.0001$) as live weight increased. This appeared to be a linear increase for all parameters except for weight of the rough cuts. That weight increase appeared to follow a quadratic curvature, increasing more at the heavier weights than at the lighter weights. Loin eye area increased from 2.16 to 2.92 square inches, yield grade from 2.9 to 4.1, and twelfth rib fat thickness from .16 to .32 inches as live weight increased from 100 to 160 pounds.

The weight of lean increased from 29.5 to 45.8, fat from 11.6 to 25.9, and bone from 6.4 to 9.0 pounds, respectively, as live weight increased from 100 to 160 pounds. These data indicate that the ram lambs had not reached a stage in maturity of declining lean and increasing fat growth.

Lean as a percentage of carcass declined from 61.6 to 55.9 and bone from 13.4 to 11.0 while fat increased from 24.2 to 31.6 percent as live weight increased from 100 to 160 pounds. The percentage change in all tissues was less through the heavier growth intervals than it was through the lighter growth intervals. However, the changes in yield grade indicated a constant percentage decline in lean yield on a carcass basis as live weight increased. Therefore, yield grade changes did not accurately identify the trend for changes in ram carcass cutability.

As a percentage of live weight, fat increased and bone decreased as live weight increased while changes in percentage lean were relatively small, especially at the heavier weights. The decline in lean on a carcass basis was 5.7 percent while the decline on a live weight basis was 1.2 percent. Higher dressing percentages at the heavy weights largely offset the reduced cutability of heavy lambs. Apparently, as live weight increased, a substitute of fat for offal as a proportion of the live animal resulted in only small changes in the percentage lean.

Carcass weight distribution among the wholesale cuts changed only slightly as live weight increased. The largest change was a 1.8 percent decline for the leg between the 100 and 160 pound slaughter weights. The largest percentage increases were for the rack and kidney fat followed by the rough cuts while the shoulder and loin changed only slightly between the 100 and 160 pound live weights. Subcutaneous fat increased more than intermuscular fat in the primal cuts.

Carcass feathering and flank streaking increased although quality scores increased only slightly due to the offsetting effect of increased maturity. Warner-Bratzler Shear values from the 36 lambs in the final season increased significantly with increasing live weight. However, the mean shear values for the four average pen slaughter weights were within the range for acceptable tenderness.

These lamb composition and lean tenderness data indicate that price discrimination against heavy weight ram lambs is not always justified.

LITERATURE CITED

Adams, Robert Lee. 1978. Feed efficiency and carcass characteristics of ram and ewe lambs fed for two weight gain intervals and slaughtered at two live weights. M. S. Thesis. Oklahoma State University, Stillwater.

Antoniewicz, R. J. and A. L. Pope. 1967. Effects of age and weight on feed efficiency and carcass composition of lambs. J. Anim. Sci. 26:1487. (Abstr.).

Batcher, O. M., A. W. Brant, and M. S. Kunze. 1969. Sensory evaluation of lamb and yearling mutton flavors. J. Food Sci. 34:272.

Bradford, G. E. and G. M. Spurlock. 1964. Effects of castrating lambs on growth and body composition. Anim. Prod. 6:291.

Busboom, J. R., G. J. Miller, R. A. Field, J. D. Crouse, M. L. Riley, G. E. Nelms, and C. L. Ferrell. 1981. Characteristics of fat from heavy ram and wether lambs. J. Anim. Sci. 52:83.

Campion, D. R., R. A. Field, M. L. Riley, and Gerald M. Smith. 1976. Effect of weight on carcass merit of very heavy market ram lambs. J. Anim. Sci. 43:1218.

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

Craddock, B. F., R. A. Field, and M. L. Riley. 1973. Predicting composition from live and carcass measurements. J. Anim. Sci. 36:1194.

Crouse, J. D., R. A. Field, J. L. Chant, Jr., C. L. Ferrell, G. M. Smith, and V. L. Harrison. 1978. Effect of dietary energy intake on carcass composition and palatability of different weight carcasses from ewe and ram lambs. J. Anim. Sci. 47:1207.

Dinkel, C. A., L. L. Wilson, H. J. Tuma, and J. A. Minyard. 1965. Ratios and percents as measures of carcass traits. J. Anim. Sci. 24:425.

Field, R. A., K. E. Hoke, J. D. Kemp, G. T. King, and J. L. McBee, Jr. 1967. Guides for lamb carcass evaluation. Proceedings of the 20th Annual Reciprocal Meats Conference. Appendix.

Guenther, J. J., D. H. Bushman, L. S. Pope, and R. D. Morrison. 1965. Growth and development of the major carcass tissues in beef calves from weaning to slaughter with reference to the effects of plane of nutrition. J. Anim. Sci. 24:1184.

Harrison, V. L. and John D. Crouse. 1978. Can feedlot lambs be fed economically to heavier weights? U. S. Dept. Agr. Econ. Stat. and Coop. Serv. ESCS-15.

Jacobs, John A., Ray A. Field, M. P. Botkin, M. L. Riley, and G. P. Roehrkasse. 1972. Effects of weight and castration on lamb carcass composition and quality. J. Anim. Sci. 35:926.

Jeremiah, L. E., G. C. Smith, and Z. L. Carpenter. 1972. Ovine yield grades II. Palatability attributes within various quality grades. J. Anim. Sci. 34:196.

Johnston, D. D., W. E. Tyler, C. E. Murphey, E. F. Kimbrell, D. F. Manns, C. L. Strong, Z. L. Carpenter, and G. T. King. 1967. Estimating yields of retail cuts from lamb carcasses. J. Anim. Sci. 26:896. (Abstr.).

Kemp, J. D., J. D. Crouse, W. Deweese, and W. G. Moody. 1970. Effect of slaughter weight and castration on carcass characteristics of lambs. J. Anim. Sci. 30:348.

Kemp, James D., M. Mahyuddin, D. G. Ely, J. D. Fox, and W. G. Moody. 1981. Effect of feeding systems, slaughter weight and sex on organoleptic properties and fatty acid composition of lamb. J. Anim. Sci. 51:321.

Kemp, James D., J. M. Shelley, Jr., D. G. Ely, and W. G. Moody. 1972. Effects of castration and slaughter weight on fatness, cooking losses and palatability of lamb. J. Anim. Sci. 34:560.

Lambuth, T. R., J. D. Kemp, and H. A. Glimp. 1970. Effect of rate of gain and slaughter weight on lamb carcass composition. J. Anim. Sci. 30:27.

Lloyd, W. R., A. L. Slyter, W. J. Costello. 1981. Effect of breed, sex and final weight on feedlot performance, carcass characteristics and meat palatability of lambs. J. Anim. Sci. 51:316.

Luitingh, H. C. 1962. Developmental changes in beef steers as influenced by fattening, age and type of ration. J. Agri. Sci. 58:1.

Makarechian, M., J. V. Whiteman, L. E. Walters, and A. W. Munson. 1978. Relationships between growth rate, dressing percentage and carcass composition in lambs. J. Anim. Sci. 46:1610.

Marchello, J. A., D. A. Cramer, and L. G. Miller. 1967. Effects of ambient temperature on certain ovine fat characteristics. J. Anim. Sci. 26:294.

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

Mendenhall, V. T. and S. K. Ercanbrack. 1979. Influence of carcass weight, sex and breed on consumer acceptance of lamb. J. Food Sci. 44:1063.

Misock, J. P., D. R. Campion, R. A. Field, and M. L. Riley. 1976. Palatability of heavy ram lambs. J. Anim. Sci. 42:1440.

Palsson, H. 1955. Conformation and body composition. In Progress in Physiology of Farm Animals. J. Hammond (ed.). Butterworths Scientific Publ. London, Eng. 2:430.

Palsson, H. and Juan B. Verges. 1952. Effects of the plane of nutrition on growth and the development of carcass quality in lambs. J. Agr. Sci. 42:1.

Paul, Pauline C., Judith Torten, and Glenwood M. Spurlock. 1964. Eating quality of lamb. Food Technol. 18:1779.

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

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

SAS Users Guide. 1979. SAS Institute Inc. Raleigh, North Carolina.

Seebeck, R. M. 1968. Developmental studies of body composition. Anim. Breed. Abstr. 36:167.

Shelley, J. M., J. D. Kemp, W. Deweese, D. D. Kratzer, and D. G. Ely. 1970. Effect of castration, slaughter weight and testosterone on lamb carcass composition and palatability. J. Anim. Sci. 31:189. (Abstr.).

Shelton, Maurice, M. C. Calhoun, and Z. L. Carpenter. 1972. The problem of soft, oily lamb carcasses. Tx. Agr. Exp. Sta. PR 3025.

Shelton, Maurice and Z. L. Carpenter. 1972. Influence of sex, stilbestrol treatment and slaughter weight on performance and carcass traits of slaughter lambs. J. Anim. Sci. 34:203.

Smalling, J. Bruce, J. B. Fox, J. D. Kemp, and W. G. Moody. 1970. Lamb tenderness as determined by different methods and different times after cooking. J. Anim. Sci. 31:189. (Abstr.).

Smith, G. C., Z. L. Carpenter, G. T. King, and K. E. Hoke. 1970. Lamb carcass quality II. Palatability of rib, loin and sirloin chops. J. Anim. Sci. 31:310.

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

Stritzke, Debi J. 1980. A study of lamb growth performance traits: I. Effect of season of birth II. Transmitted effect of purebred vs. crossbred rams. M. S. Thesis. Oklahoma State University, Stillwater.

Tanner, J. M. 1949. Fallacy of per-weight and per-surface area standards, and their relation to spurious correlation. J. Applied Physiol. 2:1.

Tichenor, Doris A., James D. Kemp, J. D. Fox, W. G. Moody, and Winston Deweese. 1970. Effect of slaughter weight and castration on ovine adipose fatty acids. J. Anim. Sci. 31:671.

Tulloh, N. M. 1964. Comparative breed studies of beef cattle III. Carcass composition. Austr. J. Agr. Res. 15:333.

U.S.D.A. 1969. Official United States standards for grades of lamb, yearling mutton and mutton carcasses. Title 7, Ch. 1, Pt. 53, Sections 53.114-53.118.

Wellington, G. H. 1953. Recommended procedure for cutting beef. Proceedings of the 6th Annual Reciprocal Meats Conference. p. 73.

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

APPENDIXES

TABLE XVI

TESTS OF SIGNIFICANCE FOR SOURCES OF VARIATION IN LIVE PERFORMANCE CHARACTERISTICS

Source of Variation	Feed Intake	ADG	Feed Efficiency
Season	NS	NS	+
Weight Interval Linear	**	*	**
Weight Interval Quadratic	**	NS	NS
Season x Linear	*	*	NS
Season x Quadratic	NS	NS	NS

NS Not Significant (P>.10)

+ P<.10

* P<.05

** P<.01

TABLE XVII

RAW MEANS[a] AND PREDICTED VALUES[b] FOR SLAUGHTER WEIGHT AND CARCASS CHARACTERISTICS OF RAM LAMBS SLAUGHTERED AT FOUR AVERAGE PEN WEIGHTS

Item	Average Pen Weight (lbs.)							
	100		120		140		160	
	actual	predicted	actual	predicted	actual	predicted	actual	predicted
Number of lambs	36		36		36		36	
Live Weight[c]	100.4		121.6		144.3		161.9	
Loin eye area (in.)	2.2	2.2	2.4	2.4	2.7	2.7	3.0	2.9
Fat thickness (in.)	.16	.17	.22	.23	.26	.29	.34	.33
Yield Grade	2.8	2.9	3.4	3.3	3.7	3.8	4.3	4.1
Leg[d] (lbs.)	12.5	12.6	15.1	15.1	17.8	17.9	20.2	20.0
Loin[d] (lbs.)	7.8	8.0	10.0	10.0	12.1	12.1	13.9	13.7
Rack[d] (lbs.)	5.0	5.1	6.6	6.5	7.9	7.9	9.2	9.1
Shoulder[d] (lbs.)	11.4	11.4	14.0	14.1	16.7	17.0	19.8	19.3
Lean[e]	29.7	29.6	35.0	35.4	41.4	41.6	46.7	46.3
Fat[e]	11.2	11.7	17.4	16.8	21.7	22.2	26.8	26.4
Bone[e]	6.6	6.4	7.1	7.4	8.3	8.4	9.3	9.1
Shear Force (kg.)[f]	2.5	2.7	3.4	3.0	3.3	3.3	3.3	3.5

[a] All weights in pounds

[b] Determined for the actual live weights by regression analysis

[c] S.D. = 7.1, 11.3, 13.7, 9.8 for raw means at 100, 120, 140, 160 average pen weights, respectively

[d] Wholesale cut weight (untrimmed)

[e] Defined in text

[f] Represents data from nine lambs at each weight group

TABLE XVIII

REGRESSION COEFFICIENTS AND STANDARD ERRORS FOR CARCASS MEASUREMENTS REGRESSED ON LIVE WEIGHT[a]

Trait	b_0	S.E.	b_1[b]	S.E.	$s_{y \cdot x}$
Composition Measures					
Loin eye area (sq. in.)	.88	.128	.0127	.0010	.2917
USDA Yield Grade	.92	.240	.0198	.2399	.5457
Fat thickness (12th rib, in.)	-.09	.031	.0026	.0002	.0714
Body wall fat (in.)	-2.35	.065	.0059	.0005	.1478
Sacral fat (in.)	-.51	.166	.0093	.0012	.3736
Quality Measures[c]					
Quality score	-4.46	.288	.0273	.0021	.6496
Feathering	8.01	1.327	.0581	.0098	3.0000
Flank streaking	4.71	1.496	.0681	.0111	3.3790
Carcass maturity	-1.29	.288	.0273	.0021	.6495
Shear force (kg.)	1.38	.774	.0133	.0058	.8278

[a]Linear model, $Y = b_0 + b_1 X$, where b_0 is the intercept and b_1 is the slope

[b]Significant ($P<.001$)

[c]Coding scale for each trait the same as that used in text

TABLE XIX

MEANS AND PROBABILITY LEVELS FOR A QUADRATIC RESPONSE IN CARCASS MEASUREMENTS WITH RAM LIVE WEIGHT

Trait	Mean	Quadratic Effect[b] P value
Composition Measures		
Loin eye area (sq. in.)	2.56	.92
USDA Yield Grade	3.53	.89
Fat thickness (12th rib, in.)	.25	.57
Body wall fat (in.)	.62	.48
Sacral fat (in.)	.73	.20
Quality Measures[a]		
Quality score	12.5	.21
Feathering	15.8	.28
Flank streaking	13.7	.17
Carcass maturity	2.3	.60
Shear force (kg.)	3.12	.25

[a]Coding scale for each trait the same as that used in text

[b]Based upon the model $Y = b_0 + b_1X + b_2X^2$. P value for t-test that $b_2 = 0$ with 141 d.f.

TABLE XX

REGRESSION COEFFICIENTS AND STANDARD ERRORS FOR CARCASS WEIGHT AND RIGHT SIDE COMPONENTS REGRESSED ON LIVE WEIGHT[a]

Trait (lbs.)	b_0	S.E.	b_1[b]	S.E.	$s_{y \cdot x}$
Hot Carcass	-7.96	1.355	.5819	.0101	3.0818
Cold Carcass	-8.83	1.291	.5676	.0096	2.9357
Right Side Component Weight					
Lean	1.18	.607	.1358	.0045	1.3812
Fat	-6.11	.667	.1192	.0050	1.5163
Bone	1.02	.217	.0219	.0016	.4926
Leg (Untrimmed)	.25	.194	.0602	.0014	.4411
Leg (Bnls.Cl.Tr.)	.70	.233	.0342	.0017	.5302
Loin (Untr.)	-.74	.988	.0470	.0015	.4521
Loin (Cl.Tr.)	.24	.168	.0279	.0012	.3813
Rack (Untr.)	-.76	.166	.0328	.0012	.3771
Rack (Cl. Tr.)	-.15	.130	.0212	.0010	.2956
Shoulder (Untr.)	-.77	.259	.0644	.0019	.5886
Shoulder (Bnls.Cl.Tr.)	.48	.207	.0303	.0015	.4700
Rough Cuts (Untr.)[c]	3.06	.206	-.0060	.0320	.8137
Rough Cuts (Bnls.Cl. Tr.)	-.09	.219	.0224	.0017	.4985
Kidney and Pelvic Fat	-1.34	.273	.0272	.0020	.6216
Primal (Untr.)	-2.02	.495	.2045	.0037	1.1261
Primal (Rt. tr.)	.42	.490	.1682	.0036	1.1154
Primal (Cl. tr.)	.80	.459	.1477	.0034	1.0448
Primal lean	1.27	.475	.1135	.0035	1.0808

[a]Linear model, $Y = b_0 + b_1X$, where b_0 is the intercept and b_1 is the slope

[b]Each $b_1 = 0$ $P<.001$ except Rough Cuts (Untr.)

[c]Multiple regression model $Y = b_0 + b_1X + b_2X^2$. $b_2 = .0025$, S. E. = .00012, $b_2 = 0$ $P<.05$.

TABLE XXI

MEANS AND PROBABILITY LEVELS FOR A QUADRATIC RESPONSE IN CARCASS AND RIGHT SIDE COMPONENT WEIGHTS WITH RAM LIVE WEIGHT

Trait (lbs.)	Mean[a]	Quadratic Effect[b] P value
Hot Carcass	68.87	.47
Cold Carcass	66.10	.43
Right Side Component Weight		
Lean	19.10	.09
Fat	9.63	.82
Bone	3.91	.14
Leg (Untrimmed)	8.20	.32
Leg (Bnls. Cl. Tr.)	5.21	.21
Loin (Untrimmed)	5.47	.90
Loin (Cl. Tr.)	3.92	.39
Rack (Untrimmed)	3.57	.95
Rack (Cl. Tr.)	2.64	.54
Shoulder (Untr.)	7.73	.12
Shoulder (Bnls. Cl. Tr.)	4.48	.53
Rough Cuts (Untrimmed)	6.83	.04
Rough Cuts (Bnls. Cl. Tr.)	2.86	.09
Kidney and Pelvic Fat	2.26	.69
Primal (Untrimmed)	24.97	.26
Primal (Rt. tr.)	22.63	.15
Primal (Cl. tr.)	20.30	.05
Primal lean	16.25	.17

[a]Pounds

[b]Based upon the model $Y = b_0 + b_1X + b_2X^2$. P value for t-test that $b_2 = 0$ with 141 d.f.

VITA

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