A STUDY OF SOME LIVE AND CARCASS CHARACTERISTICS OF LAMBS

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INTRODUCTION

Lamb has historically been a minority meat in the American diet, yet it represents an important commodity on the market and a substantial source of income to numerous sheep producers. The surging United States population is rapidly outdistancing the domestic production of lamb meat and may in time relegate it to an even lesser position on the menu. Recognizing that lamb is a high priority meat with some ethnic groups and in certain sections of the nation and that it is a potentially higher-demand commodity, it is of particular importance that its availability and improvement be assured. Sheep numbers can be expanded to meet the demand. A subtle way to satisfy the current needs and also promote lamb as a regular menu item would be to improve its acceptability and image with the consuming public. This approach in time may be the salvation of the sheep industry in the United States in view of a declining wool demand and yet a need to maintain domestic wool production for strategic purposes. Meanwhile, the more valuable and perishable entity, lamb meat, requires ready utilization.

To improve and promote lamb entails further insight into the genetic, nutritional, and environmental factors that are inherent in the production of this foodstuff. One must fully appreciate the growth pattern of the lamb from conception to market. The influence of nutrition, sex, birth weight, type of rearing, season, milking ability of the dam, and numerous managemental practices are most influential in developing the lamb from birth to market weight as a high quality, economical, maximum yielding source of protein and satiable sustenance. Today's market demands a low-fat diet. The consumer is more fat-conscious presently than ever before in this nation's history and as a result avoids fatty, wasty, high-caloric meat in particular.

To counteract this fad or fact the red meat producer must provide a leaner commodity. The breeder must ultimately take the initiative in this sequence and recognize and produce the maximum of high quality, edible lamb that will reach market with a minimum of additional feed input and offer an optimum ratio of lean to fat and bone. To accomplish this the sheep producer must first recognize these attributes in his flock in order that he may better select for these traits. Secondly, he must have some means of ascertaining the acceptability of this product so that he may better govern his breeding program and eventual selection of replacement stock. Furthermore, he must have certain readily obtained and applied information and methods and be working with characteristics that have a reasonably high heritability in order to make genetic progress in his lifetime.

Concurrently, the sheep industry must utilize all the tools available towards the goal of making its product most acceptable. In the interest of economy and practicability it needs to be established at approximately what point in a lamb's growth pattern that muscle development ceases to be efficiently and economically made and fat becomes predominant. Weight and age become factors of interest along with this point of inflection.

The economy of producing muscle and its anatomical associates, fat and bone, needs further investigation. The amount and kind of feed required to produce optimum gains on market lambs is critical to the economics of this business and the ultimate acceptability of the carcass and its retail cuts.

Is it more desirable to produce heavier lambs than the market presently demands and revise our methods to merchandise these larger, possibly meatier retail cuts in the interest of consumer acceptance? Or does a heavier lamb cost more to produce and is its final carcass composition favorable to such a practice?

The problems thus become a series of interrelated factors, when isolated and investigated may shed some light on a rather nebulous situation. In that lamb per se is youthful it seldom presents a tenderness problem by the very nature of its immaturity. Recognizing that tenderness is perhaps the most important of the meat palatability factors with juiciness and flavor composing the other major palatability features and being generally inherent in lamb, one perhaps need not then stress the matter of palatability improvement as sharply but should concentrate more on matters quantitative. To that end, this study was undertaken to attempt to:

(1) Measure the efficiency of feed utilization in lambs from weaning to market;

(2) Determine the relative efficiency of producing lightweight lambs (80 pounds market weight) versus heavyweights (100 pounds market weight);

(3) Relate certain measurements of live and carcass lambs to the ultimate merit of the carcass and its cuts; and

(4) Recognize and record the features that comprise the meat-type lamb as it expressed itself within the scope of this treatise.

REVIEW OF LITERATURE

Man has from time immemorial been fascinated by and keenly interested in growth and its numerous ramifications. The relationship of form and function has many philosophical implications and has caused man to speculate about and investigate the very nature of the structure and performance of his own body as well as that of domestic animals in particular.

General Concepts

Centuries ago Galileo advanced a theory of similitude postulating that nature could not construct an animal beyond a certain size without changing its form, and thus large and small organisms could not remain geometrically similar and survive. Thompson (1917) considered rate of growth to be the phenomenon of velocity whose dimensions were space and time. This idea permeated much of the British school of thought relative to growth, which was considered not uniform in all directions, with parts which were capable of very different rates of increment. Hammond (1921) further developed this thinking and cited the differential growth rates of the various tissues with nervous tissue developing first, followed by bone, muscle, and finally fat in a very definite sequence. Comparing improved sheep with the wild Mouflon, Huxley (1932) observed that the chief advances in creating improved sheep breeds were the result of steepening growth gradients already existing in the wild ancestral forms.

Hankins and Titus (1939) described growth in domestic animals as essentially a storage of protein and water. They indicated that a point of inflection existed which marked the transition from an accelerating growth rate to a decelerated rate of growth. Brody (1945) prescribed to this thinking but further proposed that as an animal grows larger its maintenance requirements in relation to its weight gain increases until growth virtually ceases.

A further modification of the heterogonic growth pattern was demonstrated by several researchers who declared that not only was there a differential growth rate between tissues but these same tissues had a distinct pattern of maturity. McMeekan (1940) working with pigs, Callow (1948) with cattle, and Palsson and Verges (1952) with lambs all traced a pattern of growth gradients from the ground upwards on the appendages and from the anterior and posterior regions toward the rib and loin sections respectively. They all indicated the loin and the rib as the latest maturing regions for each tissue, namely bone, muscle, and fat. Augmenting this concept, Palsson (1940) and Hammond (1950) acknowledged that the early developing parts have a priority on available nutrients and thus satisfy the vital body parts first and penalize fat and muscle in the event of emergency, resulting in a priority of the partition of nutrients.

Factors Influencing Growth

Recognizing that growth actually commences in the fetal form, Joubert (1956b) determined that the longissimus dorsi was the earliest maturing of the embryonic muscles he studied. The increase in muscle weight he found to be caused primarily by hyperplasia during the initial two-thirds of prenatal development and that during the last one-third of the term the muscle increase was principally by hypertrophy. The rapid disappearance of myoblasts close to parturition was further substantiation of this. McMeekan (1940) had previously observed that there was no evidence of an increase in the number of muscle fibers post-natally and concluded muscle development must be due solely to hypertrophy.

Studying the post-natal development of the muscle fiber, Joubert (1956a) computed a 4.46 factor increase in diameter size from 11.31μ to 50.43μ from birth to maturity in sheep. A sequential investigation by Joubert (1956c) showed a high correlation between muscle fiber diameter and body weight ($r = 0.996$) and to carcass weight ($r = 0.946$). It was further observed that the <u>longissimus</u> <u>dorsi</u> muscle fiber was the smallest in diameter (9.09μ) of the several muscles sampled. Ritzman (1917) measured the relative annual growth pattern of lambs experimentally with 50 percent of that year's growth in the first 3 months, 20 percent in the next 3 months, 20 percent from 6 to 9 months of age, and the remainder in the last quarter of the year.

Average daily gain was shown to be correlated with birth weight by Kean and Henning (1949). Single lambs averaged 0.60 pound per day versus a 0.45 pound daily gain for twins. Ram lambs outgained ewe lambs by 0.03 pound per day in the same study. Type of birth and type of rearing were considered as major environmental influences on growth of lambs by Price <u>et</u> <u>al</u>. (1953). Lambs born of mature dams had heavier body weight and better type and condition scores than those born of 2 year old dams.

Burris and Baugus (1955) reported a correlation of 0.90 for early growth and milk production of the dam, based on data on single and twin Hampshire lambs. They estimated an increased average daily gain of 0.00143 pound for each 1 pound of milk consumed. Barnicoat et al. (1956) recognized the early influence of milk production of the ewe but calculated lower correlations between milk yields of ewes and weight gains of lambs as lactation approached its end.

Weaning weights increased from 2.50 pounds to 5.96 pounds for each 1 pound increase in birth weight according to DeBaca et al. (1956). These workers also noted that singletons were an average of 17 pounds heavier than twins and that rams were heavier than ewes at weaning. Some of the sex and type of rearing weaning weight advantages were also attributed to heavier birth weights.

Hunter (1956) reported that twin lambs received only 68 percent as much milk as singletons. His investigation also evidenced a 1.38 pounds heavier lamb with a 0.31 centimeter longer shank on lambs born to mature ewes as contrasted with progeny of young ewes. Concurring with the influence of type of birth and rearing on rate of gain in lambs was the work of Harrington et al. (1958). They stated that this effect became relatively less important as the lambs matured. Differences in the breed of the dam were not manifested by increased rate of gain. A 34 to 44 percent variation at 45 days of age lowered to a 23 to 33 percent variation by day 135 when birth weight alone was considered.

Brothers and Whiteman (1962) found birth weight a significant ($P<.01$) source of variation and credited it with about 20 percent of the total animal variation relative to rate of gain in lambs. The effect of sex as a source of variation increased significantly with the age of the dam, accounting for from 4 to 16 percent of the total variation in their data. In addition, these researchers noted that age of ewe and year effects were confounded in their study. In a three year trial, Garrigus et al. (1962) asserted that ram lambs significantly exceeded wether lambs and ewe lambs in both average daily live gain as well as average daily carcass gain. Their comparisons on a more stable, chilled carcass basis eliminated the variables of fill, fleece, and shrink.

A number of studies have demonstrated the application of the lactation curve of ewes to early weaning practices. Wallace (1948) proposed that 96 percent of the variation in weight gains of lambs from birth to 112 days of age was accounted for by the consumption of milk and supplements.

Barnicoat et al. (1956) observed no detrimental effects on the rate of gain of lambs weaned at 2 months of age. Comparing 6 weeks weaning with 9 weeks, Hinds et al. (1960) reported no difference in mortality rate between the two nor any measurable differences in average daily gain or feed efficiency.

Wardrop et al. (1960), weaning lambs at 7, 10, 13, and 18 weeks of age, found that the rumen was sufficiently developed to permit weaning by the earliest date. They noted no significant differences between the dressing percentages, carcass weights, or carcass grades of lambs from each of these treatments.

A 2 weeks post-weaning set-back was pronounced in the early-weaned lambs when compared to the conventially-weaned lambs studied by Brothers and Whiteman (1961) with a 0.03 to 0.04 pound daily gain advantage to the later-weaned lambs. These workers indicated that minimum weaning conditions of 70 days of age and 50 pounds of weight could be practiced. Working with Shropshire lambs weaned at 10, 15, and 20 weeks of age, Cameron and Hamilton (1961) observed no significant effects of age of weaning on carcass scores. The slight advantage in average daily gain to 140 days by the later-weaned lambs was practically nullified by 170 days of age.

Feeding Regimes

Randomizing lambs to treatment groups and basing the initial weight on a 12 to 24 hour fasted basis were recommended by Meyer (1962) as some means of removing sources of error in lamb feeding experiments. Long et al. (1955) established significantly ($P<.01$) higher average apparent digestion coefficients for pelleted lamb rations over similar ground ingredients, suggesting restored palatability to the pelleted ration, also. Lambs fed pelleted rations in the study of Esplin et al. (1957) required 0.4 pound less feed per pound of gain and outgained by 0.515 pound versus 0.445 pound per head per day lambs fed the same, but unpelleted ration. The work of Perry et al. (1959) showed that lambs on a 60 percent roughage, 40 percent concentrate pelleted ration grew significantly ($P<.01$) more rapidly than those on a 40:60 pelleted ration. The latter did yield substantially higher dressing percentages (52.1 versus 50.3 percent), however, in the carcass. Smaller pellets produced increased gains and had less tendency to crumble when compared to larger pellets in the lamb feeding experiment conducted by Church et al. (1961). These investigators realized maximum gains using 75 to 90 percent roughage in their ration.

Rhodes and Woods (1962) noted that multiple feeding had no advantage over twice daily feeding regardless of type of ration used, as measured by average daily gain or feed conversion efficiency. Feed consumption was improved by self-feeding their lambs.

Urinary calculi were promoted in lambs on a pelleted ration by supplementation with potassium phosphate by Lindley et al. (1953). An increased rate of water consumption and urine excretion was observed in the lots with the highest incidence of this condition. Elam et al. (1956) used potassium, beet pulp, and phosphorus to induce 19 cases of urolithiasis in 20 wethers on a complete pelleted ration. They succeeded in producing 36 cases in wethers in a 124-day test period.

Emerick and Embry (1963) reported that dietary calcium should equal or exceed the phosphorus level to avoid urinary calculi in feed lot lambs. This recommendation was based on a 73 percent incidence of the condition with 0.81 percent phosphorus in the ration, a 31 percent incidence with 0.62 percent phosphorus, and a marked reduction of urolithiasis with the increase of calcium in the same ration.

Live Animal Evaluation Techniques

Stockmen have always applied some method of appraising or selecting meat animals alive which hopefully yielded the maximum of both quality and quantity of red meat. Recently a number of workers have attempted to develop and utilize more objective measures to supplement the usual visual evaluation at the market place.

Bailey et al. (1961) found the liveweight of the lambs to be as accurate a predictor of the longissimus dorsi area as were any carcass measurements they explored on the uncut carcass. The use of antipyrine injected intravenously according to body weight was determined by Kraybill et al. (1951) to be a reliable estimator of body water which in turn was a suitable indicator of body fat.

Ultrasonic scanning of the rib and loin areas of lambs was shown by Campbell et al. (1959) to have a correlation of 0.62 with the actual rib eye tracings from these same lambs. Zobriskey et al. (1961) reported correlations of 0.72 and 0.80 for ultrasonic readings of the longissimus dorsi of the live lamb as compared to the actual measured depth and depth times length of that muscle in the carcass. They also recorded a significant correlation with the weight of the primal cuts.

Using live probe methods, Stouffer et al. (1958) were able to make reasonable estimates of fat cover and loin eye muscling on 34 lambs, reporting correlations of 0.616 for depth of loin muscle and fat on the live lamb with carcass rib eye width and 0.420 for live lamb rib eye estimate with carcass rib eye area. Knight et al. (1959) realized a correlation of 0.53 on 26 lambs probed alive as compared to their actual area of the longissimus dorsi at the twelfth rib in the carcass. Applying a similar method on 86 lambs, Matthews et al. (1959) noted correlations of 0.43 and 0.62 in two trials between probed depth and actual depth and 0.56 and 0.59 between probed depth and actual area of the longissimus dorsi at the second lumbar vertebra.

The use of naturally occuring potassium-40 in the body has been investigated by Kirton et al. (1961) using the facilities at Los Alamos, New Mexico on 10 shorn lambs. They found a significant but low correlation between live animal gamma activity and carcass composition. More recently Judge et al. (1963) noted highly significant K-40 measurements on live lambs when related to edible portion, external fat, and bone composition of the carcass.

Little work to date has been done with live biopsy techniques but that reported by Spurlock et al. (1962) using samples from the longissimus dorsi and semimembranosus muscles shows promise. The percentage fat in these live core samples was highly correlated with the percentage intramuscular fat in the muscles of origin as well as with the percentage fat in the other muscle studied.

Carcass Evaluation Techniques

More definite, but possibly no more meaningful, measurements may be made on the lamb carcass as methods of determining its composition of muscle, fat, and bone. Lush (1926) related the proportions of fat and bone in cattle to the percentage offal fat and found it a very reliable single indicator of carcass fatness. This, coupled with dressing percentage and percentage caul and ruffle fat became even more highly associated with body fatness.

Kraybill et al. (1954) noted that the weight of an organ such as the heart, kidney, or liver increased in a direct proportion to the weight of the fat-free body, with the liver being the most reliable indicator of lean body mass. Working with lamb carcasses, Palsson (1939) determined that the muscling in one leg or one leg and adjoining loin provided the best index of muscling in the whole carcass. Independently verifying this same approach, Barton and Kirton (1958a) reported correlation coefficients of 0.95, 0.90, and 0.92 between muscle, fat, and bone respectively of the leg and loin related to those same components of the whole carcass.

Callow (1947) explored the adipose deposition in lamb carcasses and found that the extra-chemical fat was partitioned unequally among the tissues, chiefly as subcutaneous fatty tissue. The classical complete physical separation of 64 lamb carcasses of varying weights, grades, and origin by Hankins (1947) focused attention on the rack as the most satisfactory predictor of lamb carcass composition. He calculated correlation coefficients of 0.54 to 0.94 with most of them over 0.90 for the relation of lean, fat, and bone in the rack to those components of the entire carcass. Callow (1949) credited the major anatomical and chemical differences of lamb carcasses to the level of fatness. He described the arch-type carcass as composed of 28 percent fat, 57 percent muscle, and 15 percent bone. Callow (1950) observed that with lambs fattening slowly, 38.5 percent of the carcass weight increase was due to chemical fat and 10.7 percent to protein. Clarke and McMeekan (1952a) acknowledged a general and orderly increase in all measurements with increasing weight and a decrease in proportion of bone and muscle and increase in proportion of fat in finishing lambs.

Barton and Kirton (1958b) proposed that carcass weight alone was a reliable predictor of carcass components and fat in particular. Their study, based on the dissection of 120 lamb carcasses, represented an extremely wide range of weight and grade. Hiner and Thornton (1961), studying 1,138 lambs over a 9 year period, found body width and carcass weight to be the two most indicative factors for estimating yields of primal cuts from the uncut carcass.

The research of Ament et al. (1962) showed a correlation of 0.86 for longissimus dorsi area to total lean in the carcass. They stated that total lean increased with weight in a linear manner while the longissimus dorsi area increased in a curvilinear fashion. With Columbia lambs it was noted that beyond 95 pounds liveweight any further increase in weight was due more to fat than to muscle.

Field et al. (1962) emphasized that the physical separation of the rack was the most accurate method of predicting fat, lean, and bone composition of the carcass if complete carcass separation were not feasible. They cited correlations of 0.89, 0.82, and 0.84 respectively for fat, lean, and bone of the seven-rib rack with those same carcass components. These researchers also proposed a prediction equation with a correlation of 0.75 for estimating the percentage of lean in the lamb carcass. Their equation was: Percentage lean in carcass = 33.27

+ 3.90 (longissimus dorsi area/45 lbs.)

- 0.46 (fat thickness over rib eye)

- 0.80 (percentage kidney and kidney fat)

+ 0.53 (percentage of carcass represented by the leg).

Following the physical separation of 30 lamb carcasses, Botkin et al. (1959) reported that the area of exposed lean on the leg cut was more highly correlated with meatiness than was the loin eye area. These workers concluded that the two measures combined were even more predictive of lean body mass. Relating selected muscle weights to weight of separable lean in lamb carcasses, Orme et al. (1962) calculated correlation coefficients of 0.78 for the longissimus dorsi, 0.76 for the semimembranosus, 0.75 for the biceps femoris, and 0.71 for the semitendinosus. The area of the longissimus dorsi plus the carcass length yielded a correlation of 0.71 to total lean.

Knight and Foote (1961) investigated the relationship between physical separation and chemical determinations of carcass components and found some lack of agreement between the two methods based on relatively low correlations. Protein to lean, ether extract to fat, and ash to bone correlations were in the order of 0.63 which was significant at the 5 percent level. Also determining composition by chemical means, Kirton et al. (1962) advised that the half-carcass was as reliable as the entire carcass for sampling for carcass composition. The only substantial increase in precision was realized by increasing the number of carcasses per group.

Stanley (1962) appraised 83 ram lambs of the Columbia, Rambouillet, and Targhee breeds for live and carcass predictors of meatiness in lambs and found live or carcass weight to be the best single criterion for such lambs that were not highly finished. Leg width had the highest correlations with meatiness indicators in this study, and leg weight was the most highly correlated (0.89) of the wholesale cuts with meatiness indicators.

Specific gravity determination as a tool for non-destructively estimating carcass composition has been applied to live animals as well as their carcasses. Based on Archimedes' principle of displacement of water by body volume, and the density of the body, this method has been employed by Rathbun and Pace (1945) on guinea pigs and Keys and Brozek (1953) with humans to detect body adipose deposition in particular. Considering pork carcasses, Brown et al. (1951) noted correlations of 0.84 with percentage lean cuts, -.78 with fat cuts, 0.95 with percentage protein, and -.95 with percentage ether extract to specific gravity.

Whiteman et al. (1953) cited possible sources of variation and offered practical considerations for making specific gravity determinations in studies of carcass composition. Kline et al. (1955) suggested making all specific gravity determinations at a uniform carcass chilling time, based on their study which showed the variations realized by different time lapses.

The relationship between specific gravity of the 9-10-11 rib cut of beef with that of the whole carcass produced a correlation of 0.95 for Kraybill et al. (1952). Experimenting with lamb carcasses, Stouffer (1955) reported correlations of 0.58 for specific gravity and U.S.D.A. grade and 0.66 for specific gravity and ether extract.

Barton and Kirton (1956) determined correlations of 0.852 for specific gravity and percentage dissectable fat of the leg and loin and 0.814 between specific gravity and percentage dissectable fat of the 9-10-11 rib cut of lamb. They listed specific gravity readings ranging from 1.009 to 1.049 with a mean of 1.029 for whole lamb carcasses.

Knight et al. (1959) found the specific gravity of the shoulder cut to be the most satisfactory indicator of the entire lamb carcass specific gravity, yielding a correlation of 0.87. The work of Cowan et al. (1961) significantly correlated ($P < .01$) the calories per pound of fresh carcass with the 9-10-11 rib section specific gravity as -.79 and calories per pound of fresh carcass with the half-carcass specific gravity as -.70. Clarke and McMeekan (1952b) described an increasing caloric content with increasing lamb carcass weight.

Kirton and Barton (1962) determined a 0.69 correlation between percentage protein and specific gravity of the lamb carcass and reported a specific gravity range of 1.008 to 1.048 with a mean of 1.028 for the 20 lamb carcasses they considered. This compared closely with a mean of 1.0317 and a standard deviation of 0.0086 cited by Field et al. (1963a), whose work further showed correlations of 0.47 for carcass specific gravity with percentage lean in the carcass and 0.62 for rack specific gravity and percentage carcass lean. Bray (1963) admonished that specific gravity determination assumes that bone does not vary sufficiently in quantity in animals that are similar in weight and further that the distribution of muscling is not accounted for through specific gravity techniques.

Lamb Quality Factors

Recognizing that quality in lamb is generally not a problem, only a limited amount of work has been undertaken in that specific area. Cover et al. (1944) studied the effects of fatness on tenderness and concluded that fatness did not influence tenderness in lamb to any marked extent. Ramsbottom et al. (1945) found raw and cooked shears positively correlated for a number of beef muscles. Organoleptic and histological ratings for these same beef muscles were also positively correlated with both the raw and the cooked shear values. Bratzler and Smith (1963), testing tenderness of 129 lamb loins of choice and prime grade, failed to obtain any strong relationship between raw press samples and panel scores of the cooked meat. Their cooked press and shear values produced good correlations with the sensory scores, however. Similarly, the analyses of Batcher et al. (1962) showed no good correlation between raw and cooked shears for tenderness evaluation.

They reported that as the percentage separable fat increased the raw shear values indicated greater tenderness. The longissimus dorsi proved to be more tender than the semitendinosus, biceps femoris, semimembranosus, or adductor muscles when compared by raw shears.

Weller et al. (1962) found that tenderness of lamb as measured either by number of chews or mechanical shear appeared unrelated to weight or age of the lamb. Roasts from lambs older than 6 months of age were scored as milder than those from younger lambs. The youngest and lightest lambs in their study received the least preference rating whereas the older, heavier lambs were most frequently considered to have "natural" lamb flavor.

Genetic Parameters

To make genetic progress in live and carcass merit of lambs it is essential to be able to select wisely based on indications of heritable traits. Although these may not be absolutely known, the relative amount of variation attributed to inheritance is helpful in evaluating the flock. Therefore, heritability estimates are desired for the various characteristics considered in the production and selection of lamb.

Chapman and Lush (1932) determined heritability estimates for birth weight of 0.25 to 0.30 based on 1,019 lambs. They considered tangible environmental effects to account for 30 to 35 percent of the variation and intangible environmental influences as contributing 40 to 45 percent of the variation. Using methods of half-sib correlation and intra-sire regression of offspring on dam, Hazel and Terrill

(1945) reported an average heritability estimate of 0.30 ± 0.04 for weaning weight. They stated that the maximum gain from selecting for weaning weight alone would be about 0.9 pound per year. These same researchers, Hazel and Terrill (1946), removed year effects by analysis of variance to arrive at a composite heritability estimate of 0.17 ± 0.05 for weaning weight for the Columbia, Corriedale, and Targhee breeds. They emphasized that characters vary in economic importance as well as in heritability and that the maximum progress would result from the proportionate product of heritability and economic value.

Nelson and Venkatachalam (1949) analyzed data from five breeds of sheep in computing heritability estimates by intra-sire regression of offspring on dam of 0.72 ± 0.10 for birth weight and 0.29 ± 0.14 for weaning weight. By paternal half-sib correlation methods they determined heritability estimates of 0.15 ± 0.17 for birth weight and 0.42 ± 0.21 for weaning weight. Their weighted average heritabilities of these two traits were 0.61 ± 0.09 for birth weight and 0.33 ± 0.12 for weaning weight.

Analyzing progeny data on Shropshire lambs, Karam _et al._ (1953) reported a heritability estimate for 155-day weight of 0.34. These investigators constructed a selection index employing two other heritability figures for wool staple length and face covering, as well.

Blackwell and Henderson (1955) considered breed differences, year effects, and age of dam as very significant influences in the weaning weights of lambs in determining heritability of weaning weight as 0.073 by intra-sire method. They also established the repeatability of this trait as 0.078 by intra-class correlation.

Feeding lambs individually over a 2 year period, Botkin (1955) observed little relationship between initial weight and gain, but found the larger lambs to be less efficient. He estimated heritability for rate of gain to be 0.84 and for feed per pound of gain as 0.15. Paternal half-sib analysis by Hundley and Carter (1956) of 943 lambs, sired by Hampshire and Southdown rams produced genetic correlations for daily gain and market grade of 0.46 for the Hampshire sired lambs.

Warwick and Cartwright (1957) indicated that direct selection for weaning weight in lambs would be effective, based on the relatively high heritabilities they determined of 0.55 by intra-sire correlation of progeny with dam and 0.77 by regression of average offspring on dam. Selection for daily gain alone was deemed most practical by Givens et al. (1960) and most rewarding in genetic terms for economic returns. They obtained heritability estimates of 0.067 ± 0.015 for 120-day weight, 0.181 ± 0.021 for daily gain, and 0.122 ± 0.018 for market grade.

Tallis (1960) reported that controllable errors generally do not bias estimates of genetic correlation but may impose a serious negative bias on heritability estimates. He proposed that controllable errors also tend to inflate the sampling variances of estimates of genetic correlation.

Comparing progeny of four Hampshire rams, Ross et al. (1961) found differences between sires for the untrimmed leg ($P<.005$), for the untrimmed shoulder ($P<.01$), and for the trimmed shoulder ($P<.025$). The longissimus dorsi area showed differences by sires at the 9 percent level of probability, as did efficiency of gain.

Heritability estimates of gains from birth to 50 pounds, 50 to 90 pounds, and birth to 90 pounds were determined by Harrington et al. (1962) to be 0.09 ± 0.07 to 0.13 ± 0.08; 0.38 ± 0.13; and 0.34 ± 0.12 to 0.36 ± 0.13. Birth weight and maternal influence effects were particularly noted in the earliest period measured.

Field et al. (1963b) found the faster gaining rams to be the sires of the lambs that produced the leaner carcasses. For each 0.10 pound increase in average daily gain of the sire the carcasses of its progeny yielded 1.88 percent more lean. Conversely, for each 0.10 pound decrease in average daily gain of the ram there was an accompanying 1 percent increase in carcass fat of its progeny.

MATERIALS AND METHODS

Live Animal Procedures

This study was conducted over a two and one-half year period using 128 ram, wether, and ewe lambs sired by six different rams from the purebred Dorset and Shropshire flocks of the University of Connecticut. In detail, this population consisted of 39 ram, 3 wether, and 14 ewe lambs sired by three different Dorset rams, and 27 rams, 13 wethers, and 32 ewes by three Shropshire rams.

Each lamb was weighed to the nearest one-tenth of a pound at birth. All lambs were allowed free access to a creep ration formulated as shown in Table I. The pelleted, complete ration was included in the creep mixture to accustom the lambs to this feed which was to be their sole ration once weaned. All lambs were drenched with liquid phenothiazine-lead arsenate, 7 to 10 days prior to weaning and at the same time received a vaccination with Clostridium perfringens, type D., as protection against enterotoxemia.

As each lamb reached 100 days of age it was weaned at approximately 10:00 a.m. of that morning, weighed to the nearest one-half pound, and assigned to a 6 foot slatted pen equipped with a self-feeder, water, and a mineralized salt lick. There were 8 such pens located inside an open shed allowing maximum daylight and air circulation. Each pen was bedded with shavings or sawdust to ensure that no litter would be consumed by these lambs.

Allocation to the pens and weight group was determined by random assignment based on the breed, the sire, and the sex of the lamb. Birth weight, type of rearing, and the age of the dam were randomized in so far as possible. The final weight groups were arbitrarily designated as 80 pounds finished weight for the lightweights and 100 pounds for the heavyweights. These weight distinctions were considered to be wide enough to be practical from a market standpoint and adequate to obviate differences in both live and carcass characteristics.

The lambs were fed a complete, pelleted ration as described in Table I and analyzed by the A.O.A.C. method of proximate analysis. Fresh feed was offered the lambs at all times, being added to the self-feeder in the approximate amounts that the lambs would consume daily. Fresh water was also provided daily and available continuously. Fecal samples were analyzed periodically to determine the incidence of internal parasite infestation. This was done with each series of lambs at least once during the feeding period.

Each Monday morning, starting at 8:00 a.m., the lambs were weighed. This weekly walk from their individual pens to the scales and back, a total distance of about 200 feet, afforded the only extensive exercise these lambs received. At that time the pens were freshly bedded, the weighback taken and recorded, and fresh feed placed in the self-feeders. Feed consumption per lamb was determined by dividing the total feed consumed per pen by the number of lambs in that pen for that week. Generally, there were two or three lambs per pen, never more than three, and occasionally only one. In any event, the pen mates were always progeny of the same sire, of the same sex and breed, and destined for the same finished weight.

TABLE I

INGREDIENTS AND ANALYSIS OF RATIONS

Creep ration for suckling lambs

	Pounds
Oats	400
Corn	200
Soybean oil meal (44 percent protein)	100
Bran	50
Molasses	40
Pelleted lamb feed	700

Complete, pelleted lamb ration for lambs on feed

	Pounds
Alfalfa meal	1080
Corn meal	790
Soya meal (50 percent protein)	100
Bone meal	20
Trace mineralized salt	10
Vitamins A and D; Aureomycin and Terramycin	

Proximate analysis of complete, pelleted lamb ration

	Percent
Crude protein	16.75
Moisture	9.29
Ash	7.15
Ether extract	4.09
Crude fiber	13.60
Nitrogen free extract	49.12

Any lightweight lamb scaling 80 pounds or more or any heavyweight attaining 100 pounds or more on a given weigh day was immediately taken off feed, but given free access to water, for 24 hours prior to slaughter. These lambs were reweighed previous to slaughter to determine the amount of pre-slaughter shrinkage occurring during the 24 hour fast. Just prior to slaughter the lambs were evaluated for grade, loin eye area, fat cover, percentage of preferred cuts, and percentage of leg and loin, all relative to the shrunk liveweight. This appraisal was principally for the author's enlightenment and no attempt was made to analyze these predictions other than for self-improvement.

During slaughter, weights were recorded of head, feet, pelt, viscera, pluck, heart, tongue, liver, genitalia, and blood and moisture losses. They are reported as means and percentages for lightweight and heavyweight lambs.

Carcass Procedures

All lambs were slaughtered according to acceptable processing procedures and the sternum was split to avoid air trapping during specific gravity determination. The washed carcass was dried of excess surface moisture and weighed to the nearest one-half pound. It was then placed in a cooler maintained at 34 to 36 degrees Fahrenheit and of constant humidity and air circulation. Following a 48 hour chill the lamb carcass was reweighed and scored for conformation, finish, feathering, flank streaking, and maturity in assessing final grade to the nearest one-third of a grade. Carcass grades were recorded numerically according to the following scale, to facilitate statistical computations:

High Prime 12	High Choice 9	High Good 6
Average Prime . . 11	Average Choice . . 8	Average Good . . . 5
Low Prime 10	Low Choice 7	Low Good 4

The entire carcass was then photographed. Carcass length was measured from the anterior epiphysis of the aitch bone (symphysis pubis) to the anterior surface of the first costal bone. Specific gravity was determined hydrostatically by weighing the chilled carcass in air to the nearest one-hundredth of a pound before immersing the carcass horizontally in a tank of water maintained at 42 degrees Fahrenheit and equipped with a stainless steel wire rack to suspend the carcass during weighing. The weight in water was determined to the nearest one-hundredth of a pound using the same scale. Due precautions were taken to obtain as precise measurements as possible as noted by Rathbun and Pace (1945), Keys and Brozek (1953), Brown et al. (1951), Whiteman et al. (1953), Kline et al. (1955), Kirton and Barton (1958), and Bray (1963). The carcass specific gravity was then computed from the formula:

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

The final procedures in this sequence were to rib the carcass between the twelfth and thirteenth ribs and to photograph the ribbed carcass, to trace both longissimus dorsi muscles and their fat coverings on transparent acetate paper, and to photograph the exposed rib eyes. The longissimus dorsi areas were measured by use of the compensating polar planimeter and the area reported as an average of the two muscles.

The carcasses were aged until 7 days post-slaughter before they were reweighed and cut according to the procedure recommended by the

Reciprocal Meat Conference (Galloway, 1953). Specific gravity determination was made on each primal cut before it was further prepared for retail sale. The seven-rib rack was cut by crowding the fifth rib anteriorly and the twelfth rib posteriorly. The rack was physically separated into its constituents of lean, fat, and bone and each of these components was recorded to the nearest one-hundredth of a pound. Both the left and right longissimus dorsi muscles were freezer wrapped, identified, and frozen at -20 degrees Fahrenheit for a period of 48 hours before transferring to a 0 degree Fahrenheit holding unit.

The right leg was also physically separated and its integral parts weighed and recorded. The semimembranosus, semitendinosus, and biceps femoris were individually isolated and frozen in the same manner as the longissimus dorsi muscles for future analysis.

The front cannon bones (metacarpals) and rear cannon bones (metatarsals) were measured in length from the proximal to the distal epiphyses. The circumference of these bones was determined at the narrowest portion of the diaphysis. An average of the measurements for each pair of bones was taken as representative of the bones. A length to circumference ratio was computed to better describe the bone conformation. The paired bones were weighed and recorded, also.

The left longissimus dorsi and the semitendinosus muscles were subjected to proximate analyses for protein, ether extract, moisture, and ash. The right longissimus dorsi and the semimembranosus muscles were tested by the Warner-Bratzler shear device for tenderness evaluation, after defrosting for 48 hours in a 36 degree Fahrenheit cooler. All shear values were from raw (uncooked) muscle made immediately after coring, at room temperature. The longissimus dorsi muscle was cut into equal portions in cross-section and a one-inch core sample taken longitudinally from each half.

Every effort was made to assure a uniform and representative sample by cupping the left hand firmly around the approximately 3 to 4 inch cut-section of the longissimus dorsi, without contorting it, and extracting the sample with a sharp coring tool. This method was devised in an effort to avoid shearing the sample in the same plane as the muscle fiber, recognizing that the sample should, ideally, be sheared across the fiber.

Two, one inch cores were made from the center of the semimembranosus. Each sample from each muscle was sheared three times, thus affording a total of six shears per muscle. These six readings were averaged to obtain a tenderness score for each muscle.

Statistical Procedures

These data were analyzed by the least-squares analysis of data with unequal subclass numbers as described by Harvey (1960). The mathematical model underlying the analysis of these data was:

$$Y_{ijkm} = \mu + S_i + G_j + R_k + W_m + \beta_1 X_1 + \beta_2 X_2 + e_{ijkm}$$

Where: Y_{ijkm} = the response measured,

μ = the theoretical population mean with equal subclass frequencies when the other effects are equal to zero,

S_i = the effect of sire,

G_j = the effect of sex (gender),

R_k = the effect of type of rearing,

W_m = the effect of weight group,

$\beta_1 X_1$ = the covariable for birth weight,

$\beta_2 X_2$ = the covariable for weaning weight, and

e_{ijkm} = random error.

The means, standard deviations of the difference of the means, analyses of variance, and correlations were computed by the IBM 650 data processing machine at Oklahoma State University. The means reported were adjusted for the independent variables and covariables.

The standard deviations of the difference of means were based on the premise that:

$$s_{\bar{X}i} - s_{\bar{X}j} = \sqrt{(C_{ii} + C_{jj} - 2C_{ij})\ (\text{Error})}$$

where C_{ij} is equal to the elements in the inverse of the normal equations. The adjusted means and the standard deviations of the difference of means were computed for weight categories, sexes, and types of rearing and are reported in the Results and Discussion section.

The analysis of variance was computed on the basis that the sums of squares associated with each source of variation, except the correction factor, was adjusted for all other sources of variation. The prototype of these analyses with the sources of variation and degrees of freedom follows:

Source	Specific gravities df	All other characteristics df
Total	123	128
Correction factor	1	1
Sires	5	5
Sex	1	1
Type of rearing	1	1
Weight group	1	1

Birth weight	1	1
Weaning weight	1	1
Residual (Error)	112	117

The mean square values for these analyses of variance are listed in Appendix Table XII. The specific gravity analyses of variance differ slightly from those of the remainder of the measurements because of missing values. The tests of significance of variance components were based on the F-tables presented by Snedecor (1956).

For computational purposes, the last element in each classification was deleted. Therefore, the effects of Sire 6, ewe, single, and heavyweight elements of their respective classifications were considered as zero.

The simple correlation coefficients reported were obtained by pooling the corrected sums of squares and cross-products for the lightweight lambs with those for the heavyweights. All correlations are reported in Appendix Tables XIII through XIX.

The partial regression coefficients, or Beta values for the covariables birth weight and weaning weight, are presented in Appendix Table XXI. They indicate the direction and magnitude of the regression of one covariable when the other covariable is held fixed.

RESULTS AND DISCUSSION

The most logical approach to the consideration of the several phases of this investigation would appear to be to treat each unit in sequence and finally to relate each segment to the whole. Therefore, these results and data are presented and discussed in the chronology in which they occurred.

Growth and Feed Efficiency

The population distribution with some unadjusted mean values is summarized in Table II. From this it may be noted that the Dorset lambs generally were lighter at birth (7.0 pounds) than the Shropshire lambs (8.2 pounds). Similarly, the Dorset lambs were slightly lighter at weaning time than were the Shropshires (62.0 pounds versus 64.8 pounds). It is to be reemphasized that all lambs were weaned at a constant age of 100 days rather than at a constant weight, so a variation in weaning weight did exist between the lambs. The influence of breed, sire, sex, birth weight, type of rearing, age, and milking ability of the dam are all reflected in these weaning weights.

The finished weights and days of age at slaughter for the two breeds compared very closely, with some sire groups showing earlier maturity or more rapid growth than others. It may also be noted in Table II that the liveweight per day of age and feed efficiency, in terms of pounds of feed per pound of gain, differed by sire progeny

TABLE II

UNADJUSTED MEAN VALUES FOR SOME LIVE CHARACTERISTICS
BY BREEDS AND BY SIRES

Sire and Breed	N	Birth Weight (lbs.)	Weaning Weight (lbs.)	Finished Weight (lbs.)	Days of Age @ Slau.	Weight Per Day of Age (lbs.)	Feed Per Pound Gain (lbs.)	Sex[a] M-F	Rearing Type[b] S-Tw	Weight Group[c] L-H
O.S.U.	25	6.7	59.7	92.0	176	0.522	6.05	17-8	9-16	12-13
U.N.H.	20	7.4	63.7	89.7	165	0.545	6.56	15-5	5-15	12-8
U. Conn.	11	6.9	69.5	89.5	153	0.586	6.39	10-1	7-4	7-4
All Dorsets	56	7.0	62.0	91.1	167	0.544	6.28	42-14	21-35	31-25
Triumph	43	8.4	64.0	90.4	173	0.521	7.46	22-21	9-34	24-19
Vahlsing	10	8.6	69.8	89.9	146	0.615	6.36	6-4	2-8	6-4
U.C. 5930	19	7.4	63.8	90.7	172	0.527	7.37	12-7	4-15	11-8
All Shropshires	72	8.2	64.8	90.4	169	0.534	7.31	40-32	15-57	41-31
All lambs	128	7.7	64.0	89.8	168	0.536	6.84	82-46	36-92	72-56

[a]M = Male, F = Female.
[b]S = Single, Tw = Twin.
[c]L = Lightweight, H = Heavyweight.

and by breeds. These unadjusted mean values were not tested for statistical significance but are here presented to better portray the population distribution and some of the sire and breed influences which are confounded within this study. Seasonal and year effects and the ratio of males to females and singles to twins within sires within breeds are additional interacting factors in this cursory comparison.

The data shown in Table III indicate highly significant differences between the lightweight and heavyweight lambs for finished weight. This was unavoidable in that final weight was imposed on these lambs, with approximately half of them being slaughtered at 80 pounds (lightweights) and the remainder at 100 pounds (heavyweights). This was also true of the factor of gain from weaning to slaughter, recognizing that the heavyweights had to gain some 20 pounds more in order to attain their designated finished weight. The lightweight lambs had a greater weight per day of age at slaughter than their counterparts (0.575 versus 0.531 pound liveweight per day of age). This difference of 0.044 pound per day was not great, yet when considered over some 168 days of age at slaughter was manifested as approximately 7.5 pounds liveweight. The lightweight lambs averaged 151 days of age at slaughter, whereas the heavyweights were 188 days of age at slaughter. The adjusted means did not evidence a real feed efficiency advantage for the lightweights over the heavyweights despite the 0.73 pound difference.

When the adjusted means were considered relative to sex differences it was observed (Table III) that the males were highly significantly ($P < .01$) more efficient than the females from the standpoint of both liveweight per day of age and feed efficiency. On the ration employed, the males required approximately 1.5 pounds less feed per pound of gain than did the ewe lambs.

TABLE III

ADJUSTED MEANS AND STANDARD DEVIATIONS
OF THE DIFFERENCE OF MEANS FOR
LIVE CHARACTERISTICS

Characteristic	Lightweights Pounds	Heavyweights Pounds	Standard Deviations[a]	Males Pounds	Females Pounds	Standard Deviations[a]
Birth weight[b]	7.63	7.63		7.67	7.67	
Weaning weight[c]	63.63	63.63		63.97	63.97	
Finished weight	80.57**	100.15	0.443	90.69	90.22	0.477
Weight per day of age	0.575**	0.531	0.0094	0.564**	0.514	0.0101
Gain, weaning to slaughter	17.02**	36.54	0.447	27.05*	26.25	0.481
Feed per pound gain	6.47	7.20	0.379	6.03**	7.66	0.408

[a]Standard deviation of the difference of means.
[b]Birth weight, a covariable, adjusted means are the same.
[c]Weaning weight, a covariable, adjusted means are the same.
*P<.05
**P<.01

Pooled correlations (Appendix Table XIII) of 0.55 for birth weight with weaning weight and 0.49 for birth weight with weight per day of age are in accord with the work of Kean and Henning (1949) and Brothers and Whiteman (1962), who reported that about 20 percent of the variation in rate of gain in lambs was attributable to birth weight. Weaning weight was highly correlated (r = 0.85) with weight per day of age. The negative correlations of finished weight (r = -.45) and weight per day of age (r = -.46) with feed efficiency denote a tendency for the more efficient lambs to finish heavier and more rapidly than the less efficient feeders regardless of weight classification. The high negative correlations of gain from weaning to slaughter, with birth weight (-.52), weaning weight (-.98), and weight per day of age (-.79) automatically reflect the fact that the heavier lambs had less weight to add to attain their final classification.

The post-weaning set-back of the lambs may be observed in Table IV. For the 128 lambs there was generally 1.4 pounds lost from weaning to first weigh-day, which was never more than one week apart. It is interesting to note that the total weight loss for all lambs from weaning to their first weigh day amounted to 180 pounds, an appreciable weight and financial loss. At twenty dollars per hundredweight on the present market this would amount to a thirty-six dollar loss. Some sire progeny groups were more disposed to this post-weaning set-back than others. The 43 lambs sired by Triumph required one week more than the others to regain or surpass their original weaning weight.

Generally, the lambs had attained or exceeded their weaning weight by the second weigh day. Some groups lost no weight at all, and others even showed a slight gain the first week. The post-weaning set-back

TABLE IV

POST-WEANING SET-BACK

Sire and Breed	N	Weaning Total	Weaning Mean	1st Weigh Day Total	1st Weigh Day Mean	1st Weigh Day Gain[a]	2nd Weigh Day Total	2nd Weigh Day Mean	2nd Weigh Day Gain[a]	2 Week Net Gain
		Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
O.S.U.	25	1493	59.7	1477	59.1	-0.6	1600	64.0	4.9	4.3
U.N.H.	20	1272	63.6	1258	62.9	-0.7	1328	66.4	3.5	2.8
U. Conn.	11	764	69.5	747	67.9	-1.6	797	72.5	4.6	3.0
All Dorsets	56	3529	63.0	3482	62.2	-0.8	3725	66.5	4.3	3.5
Triumph	43	2754	64.0	2612	60.7	-3.3	2732	63.5	2.8	-0.5
Vahlsing	10	698	69.8	704	70.4	+0.6	742	74.2	3.8	4.4
U.C. 5930	19	1213	63.8	1214	63.9	+0.1	1285	67.6	3.7	3.8
All Shropshires	72	4665	64.8	4530	62.9	-1.9	4759	66.1	3.2	1.3
All lambs	128	8194	64.0	8012	62.6	-1.4	8484	66.3	3.7	2.3

[a]Gain from previous weigh day.

resulted in a 1 to 2 pound weight loss the first week and then this was regained plus enough additional to produce a net gain of approximately 2 pounds per lamb for the immediate, post-weaning period. The weight losses may be attributed to the stress to which the lambs were subjected, namely: changes in environment, nutrition, exercise, and companionship, any one of which alone could influence the lambs' progress.

Seasonal influence as well as sire effects were represented in these differences. The Dorset lambs were weaned in the cold weather months of December, January, and February and generally more easily adapted to their new environment and ate more readily. The Shropshire lambs represented June and July weaning which usually was less conducive to efficient feeding and its accompanying growth gains. Thus, some differences may reasonably be attributed to season as well as to breed and sire. Additional confounding factors not readily isolated may be weaning weight, sex, type of rearing, milking ability of the dam, and gaining ability of the lamb.

Some incidental, but interesting facets of this phase of the study included pen-gnawing by some of the lambs. On several occasions wooden slats had to be replaced on some pens where the lambs had actually chewed their way through. This trait was observed in individuals of each breed. It was thought that this activity was caused by boredom and thus became an outlet compensating for lack of exercise, lack of normal activity, and possibly a craving for roughage. This latter point was most obvious when the lambs were driven out of their pens on weigh day. At that time they would nibble straw bedding, broom straws, and baled hay as they were driven to and from the scales.

A second noteworthy item was the appearance of five cases of urinary calculi during the first year of the study. All cases occurred in late July and early August and were confined exclusively to the Shropshire male lambs. Stones and gravel were evident in the kidneys, ureters, urinary bladder, and urethra of each of these afflicted lambs. In each of four cases the lamb's condition was recognized in time to salvage it. A fifth lamb was slaughtered but the carcass condemned for advanced edema. Catheterization was attempted, but unsuccessfully, on several of the early cases. No urolithiasis was observed in the second year of the trial.

The results of the fecal sample worm egg counts gave no evidence of internal parasite infestation. This was true of each year's and each season's feeding groups.

Other minor or temporary problems were treated as they appeared. Four cases of scours, all occurring the first year only, were treated by the oral administration of a 500 milligram oblet of crystalline tetracycline hydrochloride for each of two or three consecutive days. This readily terminated the problem which occurred in 2 Dorsets and 2 Shropshires. In each case these afflicted lambs gained from 2 to 4 pounds during the ensuing week.

One case of sore mouth was observed and treated on Dorset lamb 6120. This lamb gained 3 pounds the previous week, 1 pound the week of treatment, and 2 pounds and 3 pounds in the subsequent weeks. Any horns that gave evidence of growing into the head on Dorset lambs were cut back sufficiently to avoid this irritation and consequent decreased efficiency.

The influence of the weather on the gainability of the lambs was observed although not specifically measured. Extremely hot, humid days, especially those following a heavy rain, appeared to make the lambs more lethargic. A lowered feed intake accompanied by a greater water consumption was noticed. To relieve the Shropshire lambs and to prevent an accumulation of wet, matted fleece under the jaw, the wool was completely sheared from their heads to the rear of their ears. This operation was performed July 1 of each year, just prior to the onset of the hottest, most humid weather for that locality.

Slaughter Data

Although the weights of the components of the lambs at slaughter were not an expressed purpose of this study, it was of interest to observe their contribution to liveweight and to compare the relative percentage each determined when lightweight and heavyweight lambs were contrasted. These constituents are itemized in Table V by actual weight and percentage composition. The bar graph of Figure 1 more descriptively portrays the relative contribution of each part, by weight categories. The only noticeable differences appear to be in percentage pelt, percentage viscera, and blood and trim percentage. In general, the heavyweight lambs had less total loss at slaughter and therefore yielded a slightly higher warm dressing percentage (55.50 versus 54.22 percent). As has been demonstrated (Hammond, 1921), the organs, including the viscera, do represent a greater proportion of the lightweight individual than do those same parts of a heavier individual of the same species. The greater pelt weight of the heavyweight lambs was considered to be due primarily to longer wool staple. Although this

TABLE V

PERCENTAGE OF LIVEWEIGHT REPRESENTED BY VARIOUS ANATOMICAL COMPONENTS, BY LIGHTWEIGHT (80 POUNDS) AND HEAVYWEIGHT (100 POUNDS) LAMBS

Component	Lightweights		Heavyweights	
	Weight (Pounds)	Percent	Weight (Pounds)	Percent
Tongue	0.20	0.26	0.18	0.19
Heart	0.31	0.40	0.30	0.32
Genitalia[a]	0.41	0.54	0.61	0.64
Feet	0.54	0.72	0.62	0.65
Pluck[b]	1.29	1.67	1.60	1.69
Liver	1.40	1.84	1.56	1.65
Blood and trim[c]	3.58	4.70	4.02	4.24
Head	3.77	4.95	4.61	4.86
Pelt	8.99	11.82	11.48	12.12
Viscera	14.36	18.86	17.20	18.15
Total loss	34.85	45.78	42.18	44.50
Warm carcass	41.28	54.22	52.60	55.50
Liveweight (shrunk)	76.13	100.00	94.78	100.00

[a]Genitalia includes entire reproductive tract and organs from both sexes.

[b]Pluck includes trachea, esophogus and lungs; heart and liver were recorded separately.

[c]Blood and trim weight determined by difference: slaughter weight minus hot carcass, minus total all other components.

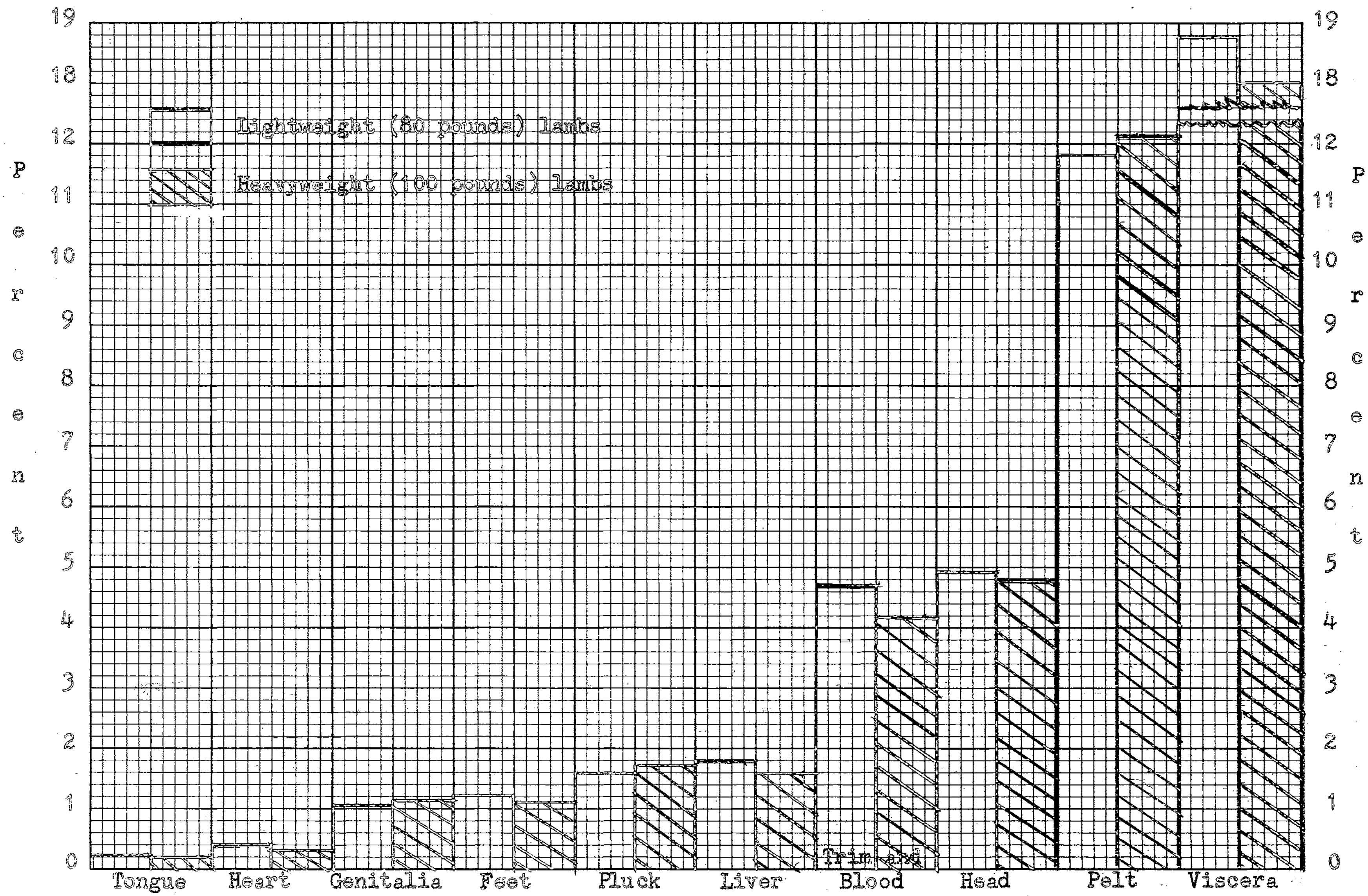


Figure 1. Percentage of Liveweight Represented by Various Anatomical Components

represented an actual difference of about 2.5 pounds, the difference on a percentage of body weight basis accounted for only 0.3 percent disparity between lightweight and heavyweight lambs.

Carcass Characteristics

Most carcass characteristics showed real differences when analyzed by sires, sex, and weight group. Birth weight, type of rearing, and weaning weight were generally not significant factors influencing the several carcass characteristics, except that weaning weight was highly significantly ($P < .01$) associated with carcass weight per day of age and carcass grade. The partial regression coefficients presented in Appendix Table XXI indicate that carcass weight per day of age tended to increase with increased weaning weight when birth weight was held constant. Similarly, carcass grade improved with increased weaning weight ($P < .01$), but lowered with increased birth weight ($P < .05$), when the respective covariables, birth weight and weaning weight, were held constant.

Sire, sex, and weight grouping were highly significant ($P < .01$) factors when chilled carcass weight, chilled dressing percentage, chilled carcass weight per day of age, carcass grade, and fat cover were considered. The analyses of variance for these characteristics are reported in Appendix Table XII. The extent of these differences is noted as adjusted means and standard deviations of the difference of means in Table VI. Sire differences and weight group differences were highly significant ($P < .01$) for carcass length. There was no significant sex difference for carcass length. Significant differences

TABLE VI

ADJUSTED MEANS AND STANDARD DEVIATIONS
OF THE DIFFERENCE OF MEANS FOR
CARCASS CHARACTERISTICS

Characteristic	Lightweights	Heavyweights	Standard Deviations[a]	Males	Females	Standard Deviations[a]
Chilled carcass weight	39.08 lbs.**	50.13 lbs.	0.418	44.09 lbs.**	45.43 lbs.	0.450
Chilled dressing percentage	52.33**	53.79	0.396	52.29**	54.83	0.426
Carcass weight per day of age	0.279 lbs.**	0.265 lbs.	0.0049	0.274 lbs.**	0.260 lbs.	0.0052
Carcass grade	8.63**	8.92	0.037	8.71**	8.98	0.037
Carcass length	22.75 in.**	24.32 in.	0.108	23.41 in.	23.25 in.	0.117
Area of longissimus dorsi	1.80 sq. in.*	1.90 sq. in.	0.044	1.92 sq. in.*	1.81 sq. in.	0.048
Fat cover at 12th rib	0.30 in.**	0.39 in.	0.016	0.29 in.**	0.40 in.	0.017

[a]Standard deviation of the difference of means.
*$P < .05$
**$P < .01$

($P<.05$) between weight groups and highly significant ($P<.01$) sire differences in rib eye area were noted.

The weight grouping automatically imposed a wide chilled carcass weight difference, thus providing approximately 40 pounds lightweight versus 50 pounds heavyweight carcasses. The chilled carcass weight per day of age disparity (0.014 pound) between the two weight groups does not appear to be great but the highly significant difference ($P<.01$) is realistic when one considers that it is multiplied by an average age of 168 days at slaughter.

The differences in dressing percentage and carcass grade were closely associated with fat covering differences. For example the heavyweight lambs, when compared to the lightweights, had an average of 0.09 inch more fat covering over the twelfth rib, graded slightly higher, and averaged 1.46 percent higher in chilled dressing percentage. These factors all appeared to be functions of fat deposition.

It was also noted (Table VI) that the ewe lambs were highly significantly ($P<.01$) fatter than the male lambs by 0.11 inch measured at the twelfth rib. This finding closely approximated the work of Kemp et al. (1962) who reported a similar difference when measured in millimeters. Carcass grade favored ($P<.01$) the ewe lambs. The male lambs exhibited a slightly larger ($P<.05$) longissimus dorsi area (1.92 versus 1.81 square inches). Garrigus et al. (1962) noted a larger longissimus dorsi area in rams (2.17 square inches) than in wethers (2.00 square inches) and in ewes (2.00 square inches). Kemp et al. (1962) found ram lambs to have about 0.07 square inch larger ($P<.05$) longissimus dorsi area than ewe lambs.

The difference in carcass length between lightweight and heavyweight lambs was not unexpected, for the heavyweight carcasses were generally observed to be somewhat longer by visual appraisal. This is verified by a difference ($P<.01$) of about 1.5 inches as measured from the anterior portion of the first costal bone to the proximal epiphysis of the aitch bone (symphysis pubis). The review of literature failed to reveal any measurements of length in lamb carcasses so comparison with other findings could not be made. This is not a critical measurement but rather one of interest and an attempt to establish a criteria for future reference and to verify certain postulations relative to growth patterns in lambs. It would appear that growth at this stage of development involved some lengthening of the vertebrae, or a widening of the intervertebral spaces, or both, to result in this difference in carcass length between lambs that differed in age by an average of 37 days and in weight by approximately 20 pounds.

Correlations of 0.87 between chilled dressing percentage and chilled weight and 0.47 and 0.49 for carcass grade with chilled carcass weight and chilled dressing percentage respectively are reported in Appendix Table XIV. Recognizing that an increase in carcass weight usually is associated with an increase in fat deposition and that in turn is generally accompanied by increases in dressing percentage and carcass grade, this finding was anticipated. Weight, yield, and grade were generally closely associated with finish or degree of fat in or on the carcass.

The correlation of -.39 between carcass length and carcass grade would imply that the shorter and usually somewhat blockier carcasses tended to grade higher than the other carcasses. This was in keeping with the current interpretation of the federal lamb carcass grading standards. The area of the <u>longissimus dorsi</u> was equally correlated with carcass weight and dressing percentage (0.41) indicating a larger rib eye accompanying the heavier, higher dressing lambs. Callow (1949) has described the early lengthening of the <u>longissimus dorsi</u> muscle and its later maturing depth development. Joubert (1956a) and McMeekan (1940) have both studied and reported the increase in muscle fiber size, especially in the <u>longissimus dorsi</u> muscle, with body weight increase.

Specific Gravity Measurements

Subjecting the entire carcass as well as the primal cuts to specific gravity determinations revealed some interesting relationships. The ewe lamb carcasses had lower ($P < .01$) specific gravity readings than the males, indicating an appreciable difference in fat deposition. Not only were the ewe lamb carcasses generally fatter where measured at the twelfth rib, but they also showed a greater deposition of fat over the rump and into the dock and leg crotch area. The usual pattern of specific gravity determinations relative to lean and fat held consistently true in this study. Table VII lists the means and standard deviations of the difference of means for lightweight and heavyweight carcass specific gravities. The mean specific gravity for all 128 lambs in this study was 1.0367 which was slightly higher than those reported by Kirton and Barton (1962) of 1.028 and Field <u>et al.</u> (1963a) of 1.0317 for Romney and Southdown lamb carcasses, respectively.

Specific gravity determinations of the primal cuts also evidenced (Table VII) some real differences when analyzed by sires, sex, and

TABLE VII

ADJUSTED MEANS AND STANDARD DEVIATIONS
OF THE DIFFERENCE OF MEANS FOR
SPECIFIC GRAVITY

Characteristic	Lightweights	Heavyweights	Standard Deviations[a]	Males	Females	Standard Deviations[a]
Carcass specific gravity	1.0390**	1.0344	0.0017	1.0402**	1.0331	0.00182
Leg specific gravity	1.0616**	1.0572	0.0016	1.0527*	1.0490	0.00169
Loin specific gravity	1.0431**	1.0343	0.0024	1.0342**	1.0264	0.00251
Rack specific gravity	1.0479*	1.0403	0.0030	1.0398**	1.0310	0.00317
Shoulder specific gravity	1.0526*	1.0482	0.0020	1.0461**	1.0375	0.00215

[a]Standard deviation of the difference of means.

*$P \leq .05$

**$P \leq .01$

weight group. In each case the cuts from the lightweight carcasses paralleled the higher reading of the carcass, hence the higher specific gravity of the carcass in its entirety. The leg had the highest specific gravity of all cuts. The relatively large proportion of muscle with a goodly amount of bone in this cut and only relatively small deposits of adipose tissue in the flanks, crotch, and dock areas precluded this cut as one of greatest density. The square-cut shoulder was the second most dense cut, again associating a less heavily fatted region with a higher specific gravity. The tendency for this cut to amass fat in the intermuscular seams was one reason for its slightly lower specific gravity when compared to the leg, however. The rack and loin ranked third and fourth respectively in these specific gravity determinations. Their greater external fat covering and relatively smaller degree of muscling in proportion to the total mass contributed to this fact. The high correlation ($r = 0.82$), noted in Appendix Table XV, between the loin and rack specific gravity further points up this close relationship.

Although specific gravity readings for the neck and breast are not listed, they were taken. In a number of cases it was not feasible to obtain weights of these cuts in water because they were too bouyant and thus floated and failed to register any weight. The heavy fat to lean ratio contributed to this condition in those areas. It was also impractical to obtain specific gravity readings for the kidney knobs under similar conditions.

During the initial stages of the experiment specific gravity determinations were made on each intact as well as ribbed carcass. Each carcass yielded an identical or nearly identical reading by both methods so in the interest of expediency only the intact carcasses were used thereafter. The chief reason for using the several methods was to eliminate all possible chances of trapped air falsifying the weight in water. All precautions having been taken, both methods yielded similar results.

Some interesting correlations between specific gravity and several of the other measurements are worthy of consideration. Correlation coefficients of -.43, -.37, and -.33 (Appendix Table XIV) for carcass specific gravity with carcass weight, dressing percentage, and fat thickness at the twelfth rib indicated that lower specific gravity was associated with heavier carcasses, higher dressing percentage, and greater fat covering as measured over the twelfth rib.

The lightweight carcasses and their respective cuts were highly significantly ($P<.01$) greater in specific gravity determinations than were the heavyweights for carcass, leg, and loin and significantly ($P<.05$) so for the rack and shoulder. Male carcasses and their primal cuts were highly significantly ($P<.01$) more dense than the ewe carcasses except for leg specific gravity which favored the males at the 5 percent level of statistical significance. Garrigus _et al_. (1962) found the ewe lamb carcasses to average 1.0396 and the males to average 1.0434 by specific gravity determination. This study compares closely with readings of 1.0331 and 1.0402 respectively. Generally, in keeping with the differences in fat deposition between the weight groups and the sexes, it was noted that greater fat accompanied lower specific gravity readings.

The specific gravity of the primal cuts accounted for about 36 percent of the variation in the carcass specific gravity, as noted from the correlation coefficients in Appendix Table XV. The carcass specific gravity was correlated with cannon bone weight in the magnitude of about 0.50. The primal cuts' specific gravity correlated with cannon bone weight to a lesser degree or about 0.40. If one accepted these bones (metacarpals and metatarsals) as representative of the general carcass bone character then these correlation coefficients would imply that about 16 to 25 percent of the specific gravity variation was accounted for by bone. Palsson (1939) has reported correlations of 0.95 for the weight of the left cannon bone with the weight of the entire skeleton and 0.96 for the weight of all 4 cannon bones with the skeletal weight.

Several correlations between carcass specific gravity and percentage lean, fat, and bone in the rack and leg, by physical separation, are worthy of notation (Appendix Table XV). Both rack fat and leg fat percentages are similar ($r = -.54$ and $r = -.56$, respectively) when correlated with carcass specific gravity. This association reemphasizes the influence of fat on specific gravity. The percentage lean in the rack and in the leg indicate lower, but like correlations with carcass specific gravity (0.40 and 0.44, respectively). Rack bone ($r = 0.52$) appeared to be more closely associated with carcass specific gravity than did the separable bone from the leg ($r = 0.34$).

Specific gravity of the carcass or of the primal cuts showed no notable association with tenderness as measured by the Warner-Bratzler device or with any of the proximate analyses determinations on the <u>longissimus dorsi</u> or <u>semitendinosus</u> muscles. The largest correlation coefficients for specific gravity and any of the proximate analyses determinations were with ether extract. These values ranged from -.10 to -.26.

Comparing these specific gravity findings with those of other workers provides some interesting considerations. Barton and Kirton (1956) reported a correlation of 0.814 between specific gravity and percentage dissectable fat of the 9-10-11 rib cut of lamb. This study dealt with the entire, 7-rib rack and had a comparable correlation of -.38. Knight *et al*. (1959) determined r = 0.87 between shoulder and carcass specific gravity. This study showed these two to be associated as r = 0.60 with the leg specific gravity being slightly higher with a correlation of 0.63.

The research of Stouffer (1955) cited a correlation coefficient of 0.58 for specific gravity and U.S.D.A. grade. This study notes a small but negative correlation between the two (r = -.14). This difference in sign and magnitude may be explained in part by the change in the federal lamb grading standards in the intervening period of time, with less emphasis on fat and more consideration for yield in the revised standards.

Cannon Bone Measurements

Several investigators have established relationships between the weights or linear measurements of the cannon bones (metacarpals and metatarsals) and muscular development of the carcass. An attempt was made in this study to determine if any strong relationship existed between these two components. In addition to the weights of the paired fore cannon bones (metacarpals) and the paired rear cannon bones (metatarsals) a ratio of the length of these bones to their respective circumferences was established to further characterize these bones. The weights alone appeared to be the better indicator of these bones relative to carcass merit.

Differences were pronounced ($P<.01$) between sexes for both fore and rear cannon bones. The cannon bones from the males were heavier than those from the ewe lambs by approximately 3 grams. The rear cannon bones were slightly heavier than the fore cannon bones (Table VIII).

The heavyweight lambs had appreciably heavier ($P<.01$) cannon bones, by approximately 7 grams, than the lightweight lambs. The rear cannon bones were generally about 2 to 3 grams heavier than the fore cannon bones. The fact that the length to circumference ratio of each weight group is practically identical for both fore and rear cannons causes one to speculate that probably bone growth is proportionate in length and width with increasing body weight at this stage of development. McMeekan (1940) and Palsson (1940) have both described a pattern of bone lengthening early in its development and bone thickening as a late maturing feature. The fore cannon weight generally had a higher correlation than rear cannon weight with birth weight, weaning weight, and live weight per day of age. All of these correlations were in the vicinity of 0.4 (Appendix Table XIII). A significant ($P<.01$) positive association was observed between birth weight and the weight of the rear cannon bones, when weaning weight was held constant (Appendix Table XXI).

The only other categories in which the cannon bone measurements showed any appreciable correlations were in the relationship with the physical separation of the rack where correlations of -.41 and -.31 were established for the weights of these two bones with the percentage of fat in the rack and 0.43 and 0.41 with percentage of bone in the rack. Correlations are reported in Appendix Table XVI of 0.51 and 0.47 between the fore and rear cannon bone ratios and the percentage

TABLE VIII

ADJUSTED MEANS AND STANDARD DEVIATIONS
OF THE DIFFERENCE OF MEANS FOR
CANNON BONE MEASUREMENTS

Characteristic	Lightweights	Heavyweights	Standard Deviations[a]	Males	Females	Standard Deviations[a]
Fore cannon weight	48.38 gms.**	55.29 gms.	0.811	53.29 gms.**	50.26 gms.	0.873
Fore cannon ratio[b]	1.91	1.93	0.024	1.85**	1.95	0.025
Rear cannon weight	50.30 gms.**	58.13 gms.	0.826	55.42 gms.**	52.73 gms.	0.890
Rear cannon ratio[b]	2.00	2.13	0.024	2.05**	2.15	0.020

[a]Standard deviation of the difference of means.

[b]Ratio of length to circumference of bone.

*$P < .05$

**$P < .01$

of fat in the rack and -.32 and -.30 correlations with the percentage of bone in the rack. It would appear that these cannon bone measurements were not very reliable predictors of carcass muscling based on the results of this study.

Physical Separations

The complete physical separation of each carcass into lean, fat, and bone would have been the ideal end point for this study. In that it was not feasible to do a complete carcass physical separation in this investigation, the physical separation of the rack and leg were selected as the alternatives based on indications of their predictive values of carcass composition cited by Hankins (1947) and Field et al. (1962).

There were no statistically significant differences for the percentage of lean in the rack in any category (Appendix Table XII). The mean differences by weight and by sex appeared sizeable (Table IX) but the standard deviations of the difference of means were large, also. When the percentage of lean in the leg was considered, however, real differences ($P < .01$) were observed for weight groups as well as sex comparisons.

The percentages of fat and bone in the rack and in the leg were highly significantly different ($P < .01$) between weight classifications as well as between sexes. In each case the lightweights had less fat and more bone in both racks and legs than did the heavyweights, and the males, likewise, had less fat and more bone than did the ewe lambs.

Type of rearing was a significant ($P < .05$) factor relative to percentage of fat in the rack. This was the only one of the 36 categories

TABLE IX

ADJUSTED MEANS AND STANDARD DEVIATIONS
OF THE DIFFERENCE OF MEANS FOR
PHYSICAL SEPARATIONS

Percentage of		Lightweights	Heavyweights	Standard Deviations[a]	Males	Females	Standard Deviations[a]
Rack as:	Lean	43.36	39.29	3.398	43.49	39.42	3.662
	Fat	35.05**	40.91	1.011	34.11**	40.74	1.089
	Bone	20.73**	18.85	0.482	20.81**	18.32	0.519
Leg as:	Lean	61.46**	59.11	0.664	61.11**	58.58	0.715
	Fat	22.33**	25.25	0.758	21.65**	25.59	0.816
	Bone	15.75*	15.01	0.349	15.93**	14.47	0.375

[a]Standard deviation of the difference of means.
*$P < .05$
**$P < .01$

studied in which rearing type indicated any statistically significant difference. Appendix Table XX indicates about 2.4 percent less separable fat in the 7-rib rack from twins than from singles. Kemp et al. (1962) observed 33.53 percent fat in the entire carcasses of twins versus 34.80 percent in singles.

The partial regression coefficient ($\hat{\beta}$) for weaning weight on percentage fat in the rack was negative and significantly ($P<.01$) different from zero (Appendix Table XXI). Thus, with birth weight held constant, increased weaning weight was accompanied by a lower percentage of fat in the rack. Callow (1949) noted that rapid fattening produced the same levels of fatness as slower fattening, but at lighter weights. Heavy weaning weight, however, does not necessarily imply fatness.

The high correlations ($r = -.90$) between separable rack lean and fat and between leg lean and leg fat ($r = -.86$) (Appendix Table XVII) lend credence to the strong negative association of these two major components of carcasses and primal cuts. The fat and bone relationships were negative in both the rack and leg and accounted for approximately 36 percent and 25 percent of the variation of fat or bone in the rack and leg respectively.

There was a highly significant ($P<.01$) difference between sires for percentage bone in the leg but not for bone in the rack (Appendix Table XII). When the cannon bones were considered there was a highly significant ($P<.01$) difference between sires relative to the rear cannon bones but not for the front cannon bones.

The lean, fat, and bone components of the rack and leg closely approximated each other when correlated with the carcass specific gravity (Appendix Table XV). Correlations of 0.40 and 0.44 for percentage lean, -.54 and -.56 for percentage fat, and 0.52 and 0.34 for percentage bone in the rack and leg respectively were noted with carcass specific gravity. Percentage fat in the rack or leg was most closely associated with carcass specific gravity.

Correlations of 0.50 and 0.44 for the relationship of the longissimus dorsi area to the percentage of lean in the rack and the leg respectively verify the rib eye area as a reasonable predictor of muscling in the carcass as represented by the rack and the leg as typifying lean content. This concurs to a lesser degree with the research of Ament et al. (1962) who established a correlation of 0.86 for the rib eye area with total carcass lean.

The correlations of -.61 and 0.65 for lean and fat in the rack with the fat thickness at the twelfth rib and coefficients of -.56 and 0.51 for lean and fat of the leg with this same measurement further validates the usefulness of the fat thickness at the twelfth rib as a reasonable indicator of carcass fatness. These correlations are reported in Appendix Table XIV.

Lean, fat, and bone percentages of the rack and leg were generally correlated as approximately ± .5 with one another. These relationships would imply that one may serve equally well as an indicator of the composition of the other. In that the leg was easier and faster to physically separate and yielded a more saleable product following this operation, it lends itself more readily as a reasonable predictor of lamb carcass composition.

Shear Values

The use of the Warner-Bratzler shear device as a method of determining tenderness yielded some real ($P<.01$) differences between sires and sexes for both the *longissimus dorsi* and the *semimembranosus* muscles. The statistical analyses of the shear values are presented in Table X and Appendix Table XII. An analysis of the differences in tenderness between the lightweight and heavyweight lambs showed no statistical significance. It has been recognized that tenderness is seldom a problem in young lamb. The heavyweight lambs were older (by 37 days) than the lightweights but they showed no less tenderness by this method of evaluation. Weller *et al.* (1962) support this observation, reporting that tenderness of lamb as measured either by number of chews or mechanical shear appeared to be unrelated to the weight or the age of the lamb.

A highly significant ($P<.01$) difference in tenderness of the *longissimus dorsi* and a significant ($P<.05$) difference for the *semimembranosus* was observed when the means for the two sexes were tested. These two muscles from the ewe lambs were more tender than were those from the males. It will be recalled that the ewe lamb carcasses were the fatter of the two sexes when evaluated by the thickness of fat at the twelfth rib, by specific gravity of the carcass and its primal cuts, and by physical separations of both the rack and the leg. If tenderness is a function of fat deposition then this could be a plausible explanation of the tenderness difference between the sexes when weight and age were similar.

TABLE X

ADJUSTED MEANS AND STANDARD DEVIATIONS
OF THE DIFFERENCE OF MEANS FOR
SHEAR VALUES

Characteristic	Lightweights	Heavyweights	Standard Deviations[a]	Males	Females	Standard Deviations[a]
Longissimus dorsi	14.30	14.70	0.433	16.21**	12.61	0.466
Semimembranosus	20.71	20.17	0.684	21.19*	19.36	0.737
Average	17.51	17.44	0.464	18.70**	15.99	0.500

[a]Standard deviation of the difference of means.
*$P < .05$
**$P \leq .01$

The correlation of -.44 (Appendix Table XVII) between the percentage of separable fat in the rack and the shear value of the longissimus dorsi further substantiates the association of fat with tenderness. A -.40 correlation of shear value of the longissimus dorsi and fat thickness at the twelfth rib, reported in Appendix Table XIV, closely parallels the previous statement and data. These findings are in accord with the research of Batcher et al. (1962) who reported that an increase in separable fat was accompanied by greater tenderness with raw shear values of lamb muscles. This, however, disagrees with the investigations of Cover et al. (1944) who concluded that fatness did not influence tenderness in lamb to any marked extent.

Carcass grade had somewhat smaller but positive correlations with the shear values of the longissimus dorsi (r = 0.26) and the semimembranosus (r = 0.37). This would indicate that the lamb carcasses tended to be less tender with increasing grade. However, it was also shown that carcass grade was not strongly associated with fatness. Although carcass grade was correlated with carcass weight and dressing percentage as 0.47 and 0.49 respectively, it was poorly correlated with the indicators of fatness as follows: fat thickness at twelfth rib, r = -.01; carcass specific gravity, r = -.14; percentage separable rack fat, r = 0.12; percentage separable leg fat, r = 0.27; ether extract of the longissimus dorsi, r = 0.20; ether extract of the semitendinosus, r = 0.19.

The longissimus dorsi was more tender than the semimembranosus muscle by approximately 6 pounds of shear force as measured by the Warner-Bratzler machine. This agrees with the work of Batcher et al. (1962) who observed the longissimus dorsi to be more tender than the semitendinosus, biceps femoris, semimembranosus, or adductor muscles when compared by raw shears.

The correlation (r = 0.58) of the shear value of the longissimus dorsi with that of the semimembranosus was not as high as might be anticipated, assuming a like degree of tenderness throughout the carcass. However, it should be emphasized that tenderness varies between muscles and between locations in the same muscle and would therefore not necessarily be strongly associated from muscle to muscle. The difference in location on the carcass of these two muscles and their use, greatly affects their ultimate tenderness.

Proximate Analyses

Statistical treatment of the results of chemical or proximate analyses of the longissimus dorsi and semitendinosus muscles, as representative of the carcass muscle chemical composition, produced few noteworthy differences among the characteristics studied. It should be emphasized that these samples were the by-product of the physical separations of the leg and the rack and thus were devoid of external fat when comminuted for analysis. Therefore, the ether extract content expressed is actually intramuscular fat or, in effect, marbling; all separable fat having been previously removed in the process of determining components by physical separation.

The greatest differences in chemical composition were manifested between the two weight groups, primarily for ether extract and moisture analyses (Table XI). Sire differences ($P < .01$) were expressed for the ash content of the longissimus dorsi and protein content of the

TABLE XI

ADJUSTED MEANS AND STANDARD DEVIATIONS
OF THE DIFFERENCE OF MEANS FOR
PROXIMATE ANALYSES

Characteristic	Lightweights	Heavyweights	Standard Deviations[a]	Males	Females	Standard Deviations[a]
Longissimus dorsi:						
Protein	21.07	21.27	0.231	20.87	21.14	0.248
Ether extract	5.11**	6.62	0.382	5.40	6.07	0.412
Moisture	72.35**	70.85	0.363	71.37	70.70	0.391
Ash	1.08	1.07	0.018	1.08	1.04	0.019
Semitendinosus:						
Protein	20.25*	20.71	0.212	20.09	20.18	0.229
Ether extract	5.81	6.36	0.307	5.88	6.09	0.331
Moisture	71.99*	71.48	0.243	70.80	69.46	0.261

[a]Standard deviation of the difference of means.
*$P < .05$
**$P < .01$

semitendinosus and to a lesser degree ($P<.05$) for moisture content of the semitendinosus.

The partial regression coefficients (Appendix Table XXI) indicate significant ($P<.01$) but negative association between weaning weight and ether extract content of the longissimus dorsi muscle. A significant ($P<.01$) and positive relationship between the moisture content of that muscle and weaning weight was also observed. These data lend further support to the earlier association between weaning weight and separable fat in the rack. No differences between sexes were noted for any of the proximate analyses of either the longissimus dorsi or the semitendinosus.

Several correlations between the proximate analysis constituents and the other characteristics studied evidenced some interesting relationships. In Appendix Table XIII it is noted that weaning weight, liveweight per day of age, and gain from weaning to slaughter have very similar magnitude when correlated with ether extract in the longissimus dorsi; namely -.37, -.38, and 0.36 respectively. These same factors are correlated almost identically with moisture percentage, but with sign changes, as 0.41, 0.42, and -.41 respectively. Although these r values are not large, they do indicate a pattern and do verify the fat:moisture relationship. A similar sequence is observed (Appendix Table XIV) between the carcass weight per day of age and longissimus dorsi ether extract ($r = -.35$) and moisture ($r = 0.41$).

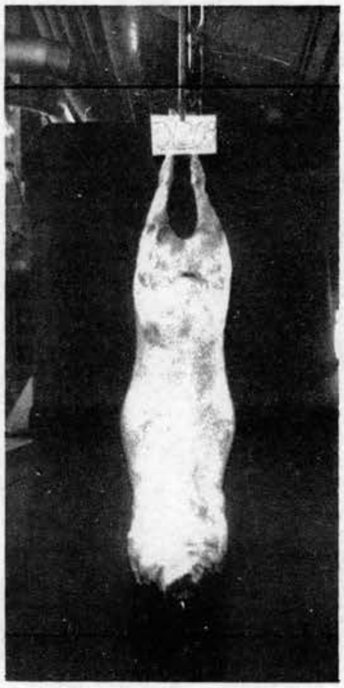
Correlations between the components of physical separations and proximate analyses are listed in Appendix Table XVII. Negative relationships between lean and fat and between fat and moisture are evident. However, one might expect that racks and legs which yielded high percentages of fat in physical separations would, by method of ether extract, analyze a high fat content and show strong correlations between external and internal fat. This was not the case, although an r value of -.26 between percentage lean in the rack and ether extract of the *longissimus dorsi* indicated a trend towards this association.

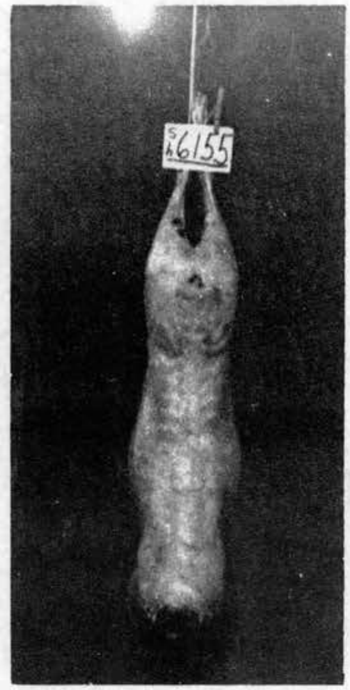
The correlations in Appendix Table XIX reaffirm the strong relationship between fat and moisture wherein r = -.86 for ether extract and percentage moisture in the *longissimus dorsi*. The comparable r value for these two factors in the *semitendinosus* is -.68. The relationships between the respective components of the *longissimus dorsi* and the *semitendinosus*, by proximate analysis, were 0.68 for percentage protein, 0.46 for ether extract, and 0.44 for percentage moisture. These correlations are not extremely high perhaps because the two muscles represent somewhat divergent regions of development. The *longissimus dorsi* muscle is late developing whereas the *semitendinosus* is earlier maturing as a muscle (Hammond, 1921; McMeekan, 1940; Joubert, 1956a).

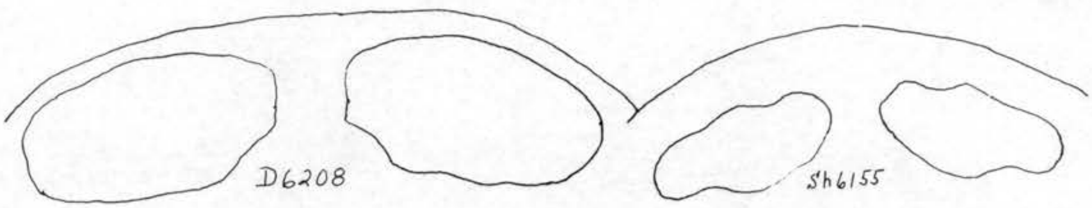
These analyses for protein, fat, moisture, and ash provided some interesting chemical or nutritive composition data as observed in Table XI. The protein content of the *longissimus dorsi* showed no significant difference when statistically compared between the two weight groups, being approximately 21 percent protein for each. These proximate analyses compared closely with those reported by Shorland *et al.* (1947). There was a highly significant difference ($P < .01$) however between the fat content, as determined by ether extract methods, with the heavyweight lambs averaging about 1.5 percent more fat than the lightweights. The general pattern of adipose deposition replacing or decreasing moisture held true in the proximate analysis of the *longissimus dorsi*. There was a highly significant difference ($P<.01$) between the two weight groups in moisture content in direct contrast to the ether extract. The lightweight group, with less fat, had about 1.5 percent more moisture than the fatter heavyweight lambs. The ash content was very similar in all samples, averaging about 1.07 percent. The _semitendinosus_ proximate analyses showed significant difference ($P<.05$) between the weight groups relative to protein content and moisture content although the ether extract did not indicate statistical difference. The greater protein and moisture content in the _semitendinosus_ of the lightweight lambs was in keeping with their greater percentage of lean and lower fat content in the leg when compared with the heavyweights.

Extreme Comparisons

Comparisons of some of the extreme individual differences for five of the characteristics measured are represented in Figures 2 through 6. These Figures portray the respective carcasses of the lambs with these extremes as well as their loin eye and fat covering tracings, which are reduced to 50 percent of their actual size to better fit the space arrangements. In addition, several other factors are compared on each of these lambs to point up the influence of some of these measurements on others. In Figure 2, the lamb with the largest _longissimus dorsi_ area (D6208) had a markedly higher specific gravity than did its counterpart (Sh6155) with the smallest _longissimus dorsi_ area. Considering that muscle has a relatively high specific gravity we would expect the carcass then to be of a higher specific gravity, in so far as the area of the _longissimus dorsi_ is an







D6208	Lamb number	Sh6155
2.86	Longissimus dorsi area (square inches)	1.18
0.22	Fat cover at 12th rib (inches)	0.44
High Choice	Carcass grade	High Choice
1.0441	Specific gravity	1.0253
0.252	Carcass weight per day of age (pounds)	0.266
7.73	Feed efficiency (pounds feed per pound gain)	5.27

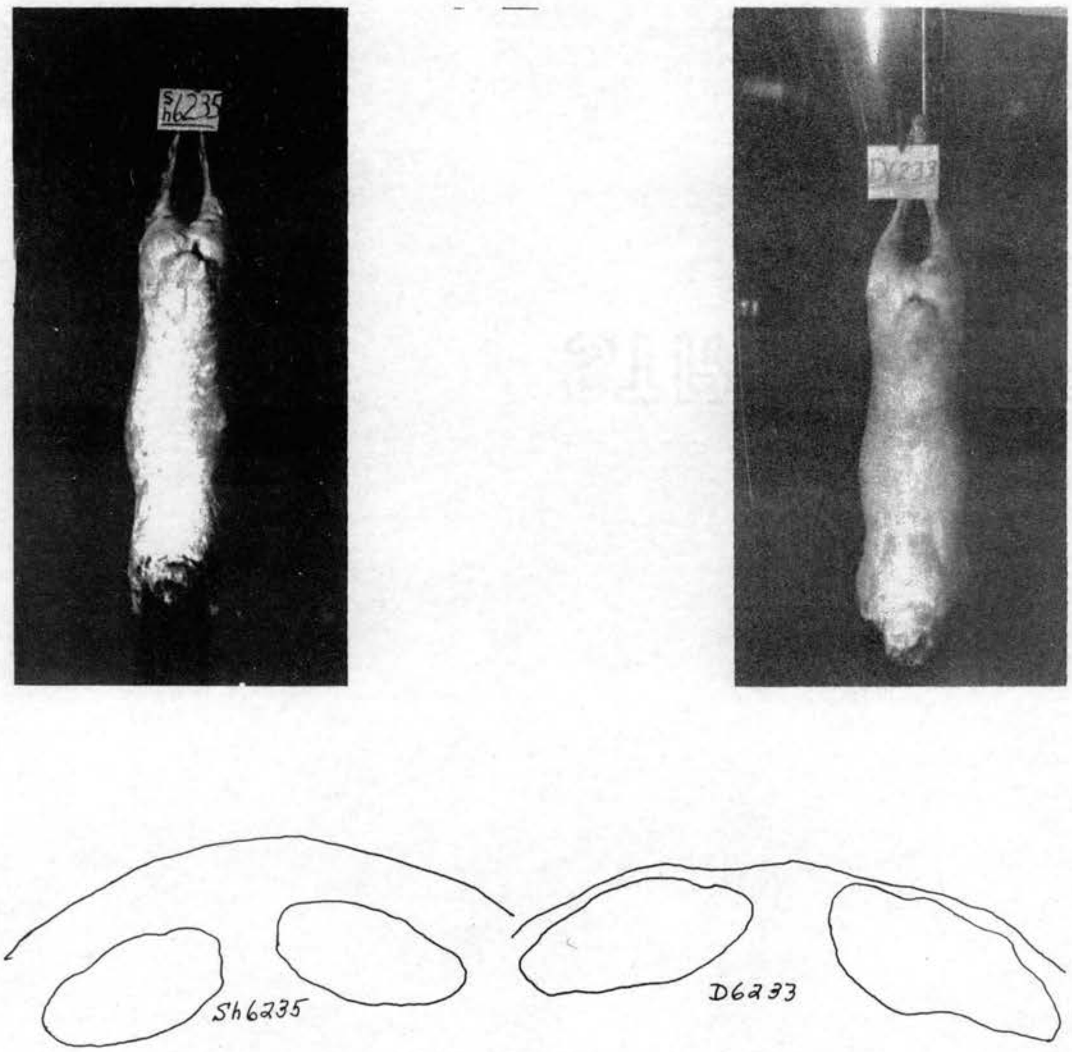
Figure 2. Largest and Smallest *Longissimus Dorsi* Areas

indicator of carcass muscling. In this instance, however, one can not be certain whether the higher specific gravity of D6208 was attributable to greater leanness or the fact that it had less fat covering as denoted by a 0.22 inch average fat thickness at the twelfth rib as compared to that of 0.44 inch for Sh6155. It is interesting to observe that in this comparison both carcasses were graded High Choice, but that the less desirable carcass, from a loin eye size and fat cover standpoint, was produced more efficiently. This was due in part to the fact that Sh6155 was a lightweight lamb whereas D6208 was a heavyweight and 65 days older.

In Figure 3, as one might predict, the carcass with the greatest fat covering had an appreciably lower specific gravity than the carcass with less fat. The extremely fat carcass (Sh6235) in this instance, did not grade as high as the much thinner carcass (D6233). Also, the less fat, better muscled carcass (D6233) was much more efficient to produce from both a weight of chilled carcass per day of age consideration as well as feed efficiency based on pounds of feed per pound of gain.

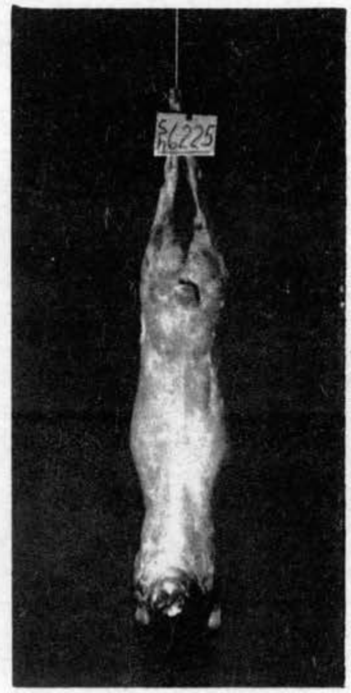
Contrasting the highest and lowest grading carcasses, it may be observed (Figure 4) that the Average Prime carcass of D6232 was larger in loin-eye area but somewhat fatter and lower in specific gravity than the Average Good carcass of Sh6225. Also D6232 was lighter per day of age and slightly less efficient than Sh6225.

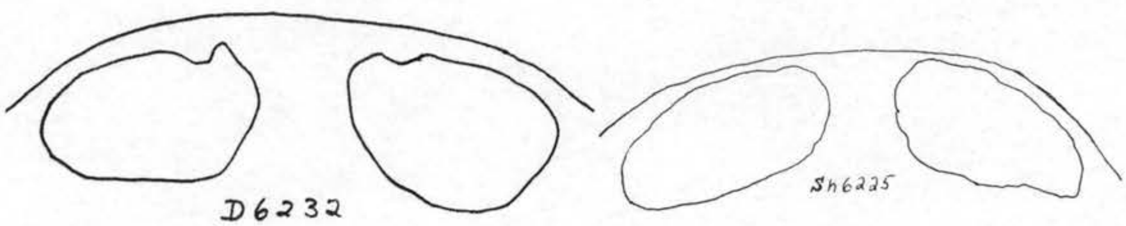
Figure 5 is a particularly interesting comparison of carcasses from the most and least efficient feeders. They were full-sib twins weighing 8.0 and 8.5 pounds respectively at birth, 55 and 58 pounds respectively at weaning, and both classified as lightweights. It



Sh6235	Lamb number	D6233
1.44	Longissimus dorsi area (square inches)	1.97
0.63	Fat cover at 12th rib (inches)	0.13
Average Choice	Carcass grade	High Choice
1.0250	Specific gravity	1.0418
0.189	Carcass weight per day of age (pounds)	0.323
6.30	Feed efficiency (pounds feed per pound gain)	4.17

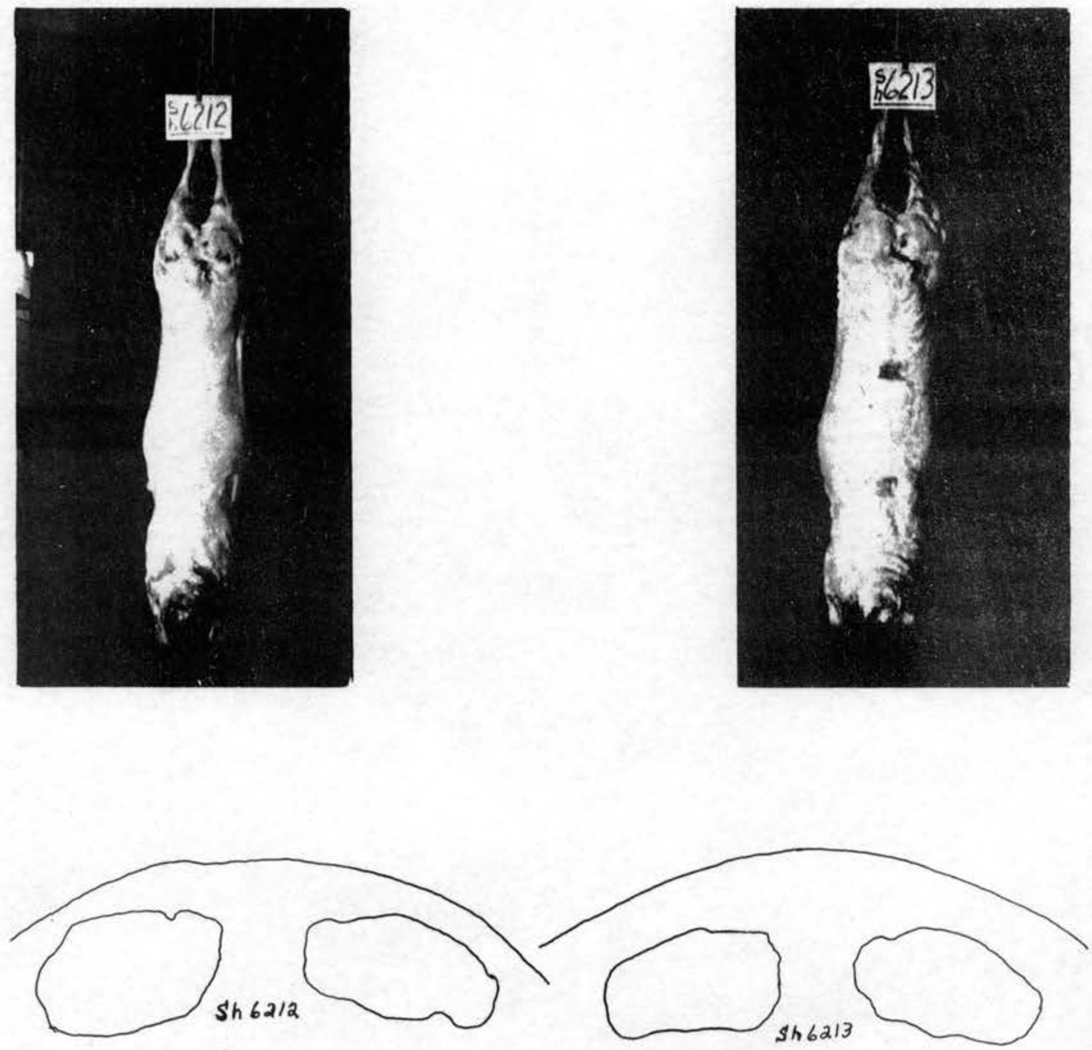
Figure 3. Greatest and Least Amounts of Fat Cover





D6232	Lamb number	Sh6225
2.51	*Longissimus dorsi* area (square inches)	1.83
0.25	Fat cover at 12th rib (inches)	0.13
Average Prime	Carcass grade	Average Good
1.0394	Specific gravity	1.0562
0.228	Carcass weight per day of age (pounds)	0.305
6.82	Feed efficiency (pounds feed per pound gain)	6.62

Figure 4. Highest and Lowest Grading Carcasses

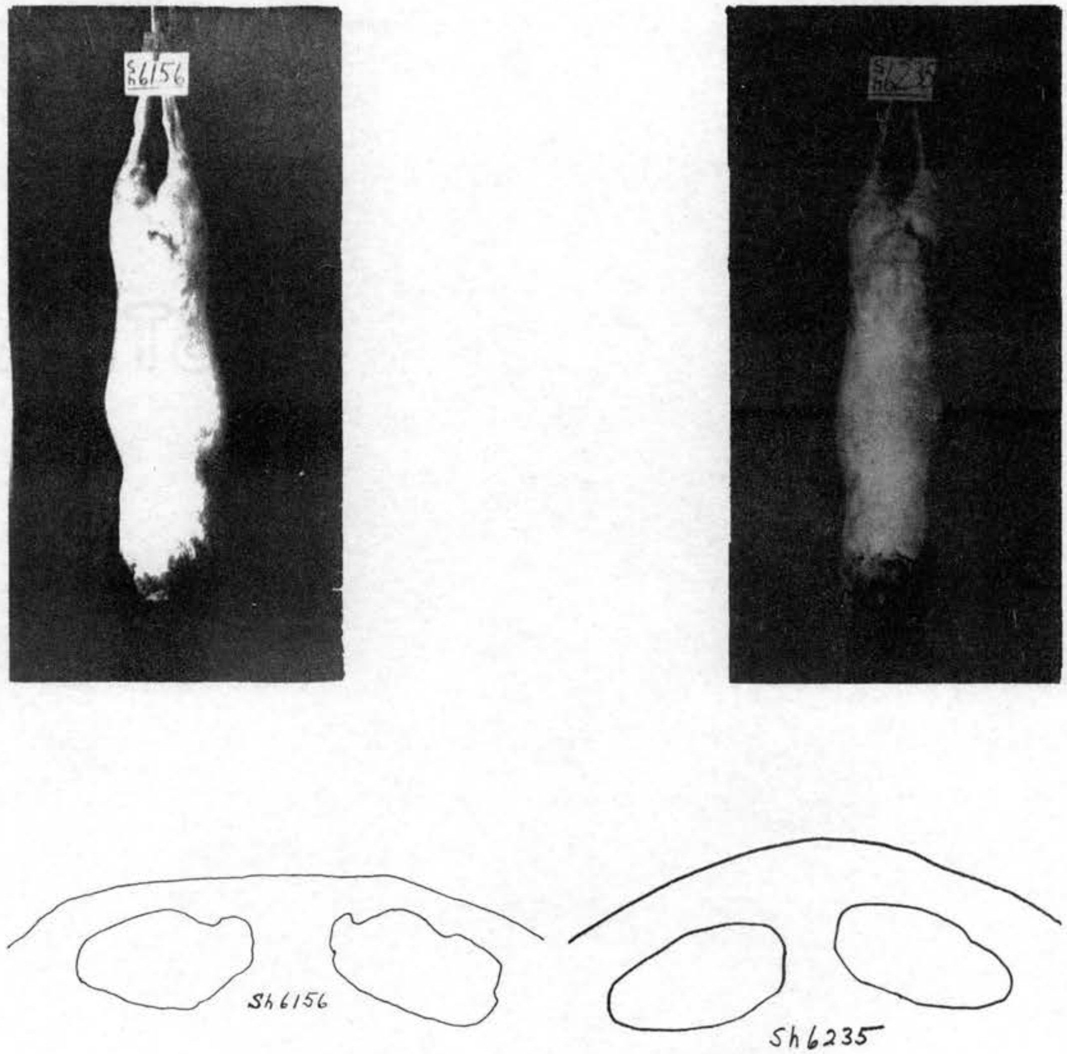


Sh6212	Lamb number	Sh6213
1.68	*Longissimus dorsi* area (square inches)	1.50
0.38	Fat cover at 12th rib (inches)	0.56
Low Choice	Carcass grade	Low Choice
1.0324	Specific gravity	1.0218
0.289	Carcass weight per day of age (pounds)	0.205
3.40	Feed efficiency (pounds feed per pound gain)	12.04

Figure 5. Most and Least Efficient Feeders

required about 5 weeks post-weaning time for Sh6212 to make its finished weight of 80 pounds whereas Sh6213 required 16 weeks post-weaning time to attain a similar weight. This is reflected to a pronounced degree in the relative feed efficiency of each lamb (3.40 versus 12.04 pounds of feed per pound of gain). It should also be noted that although the two lambs graded identically, the more efficient lamb had measureably less fat and a larger longissimus dorsi area. Sh6212 was a ram lamb and Sh6213 a ewe lamb, which tends to verify the greater efficiency of growth and superior feed efficiency of the male versus the female of this species.

The heaviest and lightest chilled carcass weights per day of age contrasted in Figure 6 indicate that it is possible to produce a Prime lamb, immediately off its dam and creep, at weaning time. In that this lamb (Sh6156) was assigned to the light weight group and weaned in excess of 80 pounds it was not placed on feed at all but slaughtered the day following weaning, thus having no measureable post-weaning evaluation for feed efficiency. Sh6156 was but 101 days of age and weighed 91 pounds at slaughter so it had the extremely high chilled carcass weight per day of age of 0.426 pound compared with 0.189 pound for Sh6235 which required 15 weeks post-weaning to attain its 80 pounds finished weight. There were several variables reflected in these differences but the final chilled carcass weight per day of age was the basis for this particular comparison. It is of interest to note that the heaviest carcass per day of age (Sh6156) was the higher grading of the two extremes, had less fat cover at the 12th rib, and was slightly higher in specific gravity.



Sh6156	Lamb number	Sh6235
1.33	*Longissimus dorsi* area (square inches)	1.44
0.38	Fat cover at 12th rib (inches)	0.63
Low Prime	Carcass grade	Average Choice
1.0261	Specific gravity	1.0250
0.426	Carcass weight per day of age (pounds)	0.189
0.00	Feed efficiency (pounds feed per pound gain)	6.30

Figure 6. Heaviest and Lightest Carcass Weights Per Day of Age

It is to be emphasized that these comparisons represent only the extremes for the various factors indicated and are not necessarily representative of the differences between groups or classifications within the population from which they were drawn. They do depict some of the characteristics measured and demonstrate some of the variation noted.

SUMMARY AND CONCLUSIONS

This study included 128 lambs representing the Dorset and Shropshire breeds in the University of Connecticut sheep flocks. These lambs were sired by three Dorset rams and three Shropshire rams over a period of two years from 1959-1961. All lambs were weaned at 100 days of age and randomly assigned to either a lightweight (80 pounds) or heavyweight (100 pounds) finished group. These lambs received a completely pelleted ration as their sole feed source. Records were kept and measurements made for 36 different live and carcass characteristics. All lambs were slaughtered when they attained their assigned finished weight.

Significant differences were noted for certain growth characteristics. There were significant differences ($P<.01$) between sexes for liveweight per day of age and feed efficiency as well as for gain ($P<.05$), with male lambs being heavier at birth and weaning and showing a greater feed efficiency than ewe lambs. Between weight groups, the lightweight lambs exhibited significantly ($P<.01$) more liveweight per day of age. The average daily gain, from weaning to slaughter, of the 128 lambs studied was 0.391 pound, the liveweight per day of age was 0.536 pound, and the pounds of feed required per pound of gain on this ration was 6.84 pounds, pooling all breeds, sires, sexes, type of rearing, birth weight, and weaning weight. A post-weaning setback or weight loss averaging 1.4 pounds per lamb was observed the first week following weaning. Some pen-gnawing and five cases of urolithiasis were encountered under the confinement management of this study.

All live components were recorded at slaughter time and it was noted that the heavyweight lambs yielded higher dressing percentages than the lightweight lambs. Significant differences ($P<.01$) in chilled carcass weight, dressing percentage, carcass weight per day of age, carcass grade, and fat cover were noted between sires, between sexes, and between weight groups, with the heavyweight lambs generally having the higher percentage or measurement. Male lambs were superior to ewe lambs in these characteristics with the exception of dressing percentage and carcass grade. There were sire and weight differences ($P<.01$) in carcass length, favoring the heavyweight carcasses. A highly significant difference ($P<.01$) existed between sires for the rib eye or longissimus dorsi area and the heavy lambs and male lambs also demonstrated larger ($P<.05$) rib eye measurements than their counterparts. A correlation of 0.87 was determined between finished weight and dressing percentage, indicating greater fat as well in the higher dressing lambs. Ewe lamb carcasses generally graded higher ($P<.05$) than those from male lambs, were significantly fatter ($P<.01$) at the twelfth rib, and dressed higher ($P<.01$). An r value of -.52 was observed to be the correlation of rib eye area with fat cover.

Relative to carcass specific gravity, it was demonstrated that the lightweight carcasses were higher ($P<.01$) than the heavyweights, implying a greater lean:bone versus fat composition. It was further noted that the ewe lamb carcasses had lower ($P<.05$) specific gravities than the males. No differences were noted in specific gravity readings between ribbed and unribbed carcasses subjected to specific gravity determination when due precautions were taken to avoid trapping air in the process. The highest correlation between a primal cut specific gravity with carcass specific gravity was that for the leg ($r = 0.63$).

Cannon bone (metacarpals and metatarsals) measurements showed little promise of predicting carcass merit, although the fore cannon (metacarpals) length to width ratio was correlated with percent fat in the rack, by physical separation, as 0.51. There were highly significant ($P<.01$) differences in cannon bone weight, with those from males and heavyweights being the heavier when compared with their counterparts.

Physical separation of the leg and the rack evidenced real differences ($P<.01$) in percentage of fat in each with the heavyweight lambs having the greater degree of fat, but with much less ($P<.01$) bone in the rack and somewhat less ($P<.05$) bone in the leg. Sex differences were also noted in these analyses with the ewe lamb carcasses having appreciably more ($P<.01$) fat in both the rack and leg than did the males. The males had a highly significantly ($P<.01$) greater percentage of bone in both rack and leg than did the ewes. Several correlations of interest in this phase of the study included coefficients of -.60 for percentage of lean in the rack with fat thickness at the twelfth rib, 0.65 for percentage of fat in the rack with fat thickness at the twelfth rib, 0.50 for area of *longissimus dorsi* and percentage of lean in the rack, and -.90 for percentage of lean to percentage of fat in the rack. The percentage of lean and bone in the leg was significantly ($P<.01$) greater in the lightweight lambs while the fat percentage was noticeably ($P<.01$) less than that of the heavyweights.

The correlation of -.56 for percentage of fat in the leg with carcass specific gravity plus the ease and practicality of physically separating the leg make this one primal cut of some value as a predictor of carcass composition. This region is also the most readily evaluated portion of the live animal and thus probably the most valuable single criterion for both live and carcass evaluation in lambs.

The raw shear values showed no measurable differences between weight groups but when analyzed by sexes it was found that the ewe lambs generally were more tender ($P < .01$) by the Warner-Bratzler shear device when the <u>longissimus dorsi</u> and <u>semimembranosus</u> muscles were sampled. It was observed furthermore that the <u>longissimus dorsi</u> samples required less shear force than those from the <u>semimembranosus</u>.

Proximate analyses indicated differences for fat and moisture in the <u>longissimus dorsi</u> when weight groups were compared. The lightweight lambs had significantly less ($P < .01$) fat and more moisture than did the heavyweights. Weaning weight was a significant ($P < .01$) factor relative to both fat and moisture content of the <u>longissimus dorsi</u> according to this analysis. The reciprocity of fat and moisture in muscle is emphasized by the correlation coefficients of -.86 for the <u>longissimus dorsi</u> and -.68 for the <u>semitendinosus</u>.

From this study it was shown that birth weight and type of rearing had little or no direct effect on the various live and carcass characteristics measured. Weaning weight was of little consequence except where it was closely associated with some live characteristics. Sire effects, which were admittedly confounded with breed effects were pronounced in some categories, but showed no significance in the live categories, interestingly enough. The two major variables that dominated the study were the effects of weight and of sex differences. These two factors were manifested in both live and carcass measurements and usually to a high degree of significance. Generally, the heavy-weight lambs and the ewe lambs were measurably fatter as determined by fat cover at the twelfth rib, by specific gravity, and by physical separation. This greater degree of fat content in turn influenced the dressing percentage, the carcass grade, and possibly shear value in the case of the ewe lambs.

The indications from this study, under these expressed conditions, were that it was more efficient to raise and market lambs at the lighter weight selected here and that these lambs yielded acceptable weight and quality carcasses. These lighter carcasses in turn gave evidence of yielding a higher percentage of edible meat with less waste than did the heavier weight lambs of similar breeding and sex under this established environment. Furthermore, it was observed that increasing live and carcass weight had a parallel and proportionate increase in adipose deposition regardless of sex or breed differences. An increase in longissimus dorsi area accompanied an increase in carcass weight. However, a decrease in percentage lean and an increase in percentage fat was noted from the physical separation of the leg and the rack to be associated with increased carcass weight.

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APPENDIX

TABLE XII

MEAN SQUARES AND SIGNIFICANCE FROM
ANALYSES OF VARIANCE FOR
LIVE AND CARCASS
MEASUREMENTS

Characteristic	Source: df:	Sires 5	Sex 1	Type of Rearing 1	Weight Group 1	Birth Weight 1	Weaning Weight 1	Residual (Error) 117
Finished weight		3.488	14.529	2.230	10,887**	4.346	1.341	5.577
Weight per day of age		0.005*	0.059**	0.009	0.552**	0.006	0.501**	0.003
Gain		3.265	15.877*	2.803	10,819**	3.997	8,212**	5.676
Feed per pound gain		7.100	64.707**	1.698	15.304	13.514	9.261	4.074
Carcass weight		45.164**	43.818**	3.445	3,465**	1.868	4.973	4.964
Dressing percentage		63.999**	157.201**	5.797	60.830**	8.549	0.027	4.449
Carcass weight per day of age		0.005**	0.005**	0.000	0.006**	0.000	0.133**	0.001
Carcass grade		13.802**	1.721**	0.086	2.286**	0.170*	0.828**	0.034
Carcass length		3.055**	0.663	0.000	70.324**	0.142	0.049	0.334
Area of L. D.[a]		1.143**	0.273*	0.000	0.268*	0.065	0.210	0.056
Fat cover at 12th rib		0.024**	0.280**	0.000	0.248**	0.015	0.026	0.007
Cannon bone:								
Fore weight		33.337	224.124**	29.577	1318.163**	53.475	114.080*	18.654
Fore ratio		0.010	0.267**	0.006	0.015	0.006	0.046	0.016
Rear weight		95.392**	177.831**	1.765	1739.206**	189.158**	0.013	19.386
Rear ratio		0.016	0.232**	0.006	0.033	0.007	0.026	0.017
Percentage:								
Rack lean		84.125	404.780	49.424	471.271	6.038	270.245	328.365
Rack fat		39.309	1075.324**	127.973*	974.045**	1.700	216.597**	29.038
Rack bone		9.648	151.336**	10.974	99.936**	2.786	1.094	6.592

TABLE XII (Continued)

Characteristic	Source:	Sires	Sex	Type of Rearing	Weight Group	Birth Weight	Weaning Weight	Residual (Error)
	df:	5	1	1	1	1	1	117
Leg lean		12.117	156.211**	0.005	157.142**	15.922	14.002	12.519
Leg fat		13.632	380.349**	3.250	243.212**	0.104	0.649	16.333
Leg bone		25.175**	51.963**	0.087	15.270*	12.777	16.061*	3.450
Shear value:								
L. D.[a]		54.357**	317.068**	5.384	4.679	0.010	7.450	5.320
S. M.[b]		156.276**	81.856*	1.533	8.413	15.960	0.238	13.300
Average		95.885**	180.176**	3.153	0.144	3.723	1.233	6.117
Percentage:								
L. D.[a] protein		2.493	1.809	0.234	1.210	0.006	0.434	1.510
L. D. ether extract		2.521	11.050	1.978	65.138**	1.363	31.351**	4.147
L. D. moisture		5.666	11.032	14.121	64.412**	0.086	28.138**	3.748
L. D. ash		0.035**	0.028	0.000	0.002	0.000	0.000	0.009
S. T.[c] protein		7.806**	0.167	0.471	5.891*	0.046	0.418	1.279
S. T. ether extract		4.950	1.082	2.238	8.572	4.548	3.565	2.680
S. T. moisture		4.600*	2.974	2.822	7.470*	7.252*	1.614	1.672
Specific gravity:[d]								
Carcass		0.00011	0.00123**	0.00001	0.00057**	0.00000	0.00006	0.00008
Leg		0.00021*	0.00034*	0.00004	0.00053**	0.00014	0.00048*	0.00007
Loin		0.00087**	0.00150**	0.00000	0.00208**	0.00000	0.00012	0.00015
Rack		0.00160**	0.00192**	0.00007	0.00157*	0.00005	0.00000	0.00025
Shoulder		0.00035*	0.00184**	0.00003	0.00053*	0.00000	0.00015	0.00011

[a]L. D. = <u>Longissimus dorsi</u>. *$P<.05$

[b]S. M. = Semimembranosus. **$P<.01$

[c]S. T. = Semitendinosus.

[d]The residual (error) for specific gravity has 112 degrees of freedom.

TABLE XIII

POOLED CORRELATIONS FOR LIVE MEASUREMENTS WITH LIVE AND CARCASS MEASUREMENTS

Characteristic	Birth Weight	Weaning Weight	Finished Weight	Weight Per Day of Age	Gain	Feed Per Pound Gain
Birth weight		0.55	0.14	0.49	-.52	-.09
Weaning weight	0.55		0.13	0.85	-.98	-.02
Finished weight	0.14	0.13		0.28	0.08	-.45
Weight per day of age	0.49	0.85	0.28		-.79	-.46
Gain	-.52	-.98	0.08	-.79		-.07
Feed per pound gain	-.09	-.02	-.45	-.46	-.07	
Carcass weight	-.28	-.08	0.34	-.10	0.16	-.03
Dressing percentage	-.40	-.23	-.01	-.27	0.23	0.13
Carcass weight per day of age	0.38	0.82	0.26	0.95	-.76	-.43
Carcass grade	-.19	-.10	0.06	-.04	0.11	-.14
Carcass length	0.32	0.22	0.18	0.11	-.18	0.08
Area of *longissimus dorsi*	-.25	0.07	0.02	0.19	-.07	-.21
Fat cover at 12th rib	0.05	-.17	0.07	-.31	0.19	0.23
Carcass specific gravity	0.19	0.23	-.06	0.31	-.24	-.11
Leg specific gravity	0.17	-.09	-.15	-.03	0.06	0.00
Loin specific gravity	0.24	0.17	-.02	0.20	-.18	-.04
Rack specific gravity	0.14	0.06	-.05	0.11	-.07	-.02
Shoulder specific gravity	0.10	-.02	-.02	0.12	0.01	-.18
Cannon bone: Fore weight	0.46	0.39	0.11	0.44	-.36	-.14

TABLE XIII (Continued)

Characteristic	Birth Weight	Weaning Weight	Finished Weight	Weight Per Day of Age	Gain	Feed Per Pound Gain
Fore ratio[a]	-.17	-.30	-.04	-.42	0.29	0.24
Rear weight	0.50	0.27	0.07	0.27	-.25	-.05
Rear ratio[a]	-.11	-.21	-.03	-.33	0.21	0.25
Percentage:						
Rack lean	0.09	0.34	-.09	0.40	-.37	-.17
Rack fat	-.18	-.35	0.11	-.43	0.38	0.22
Rack bone	0.21	0.15	-.11	0.26	-.18	-.18
Leg lean	-.05	0.14	-.10	0.22	-.16	-.18
Leg fat	-.13	-.16	0.12	-.25	0.19	0.21
Leg bone	0.34	0.10	-.10	0.12	-.12	-.09
Shear values:						
L. D.[b]	-.05	0.03	0.09	0.18	-.01	-.25
S. M.[c]	0.02	0.10	-.01	0.15	-.10	-.13
Average	-.01	0.08	0.04	0.19	-.07	-.20
Percentage						
L. D.[b] protein	0.15	0.06	0.04	-.01	-.05	0.09
L. D. ether extract	-.26	-.37	-.04	-.38	0.36	0.11
L. D. moisture	0.22	0.41	0.03	0.42	-.41	-.10
L. D. ash	0.03	0.07	0.01	0.01	-.07	0.13
S. T.[d] protein	0.11	0.05	0.10	0.01	-.03	0.05
S. T. ether extract	-.21	-.23	-.05	-.20	0.22	0.03
S. T. moisture	0.18	0.24	0.08	0.27	-.22	-.21

[a]Cannon bone: ratio = length to circumference.
[b]L. D. = *Longissimus dorsi*.
[c]S. M. = *Semimembranosus*.
[d]S. T. = *Semitendinosus*.

TABLE XIV

POOLED CORRELATIONS FOR CARCASS MEASUREMENTS
WITH CARCASS MEASUREMENTS

Characteristic	Carcass Weight	Dressing Percentage	Carcass Weight Per Day of Age	Carcass Grade	Carcass Length	Area of L. D.[a]	Fat Cover at 12th Rib
Carcass weight		0.87	0.18	0.47	-.13	0.41	0.08
Dressing percentage	0.87		0.01	0.49	-.28	0.41	0.09
Carcass weight per day of age	0.18	0.01		0.11	0.05	0.32	-.29
Carcass grade	0.47	0.49	0.11		-.39	0.20	-.02
Carcass length	-.13	-.28	0.05	-.39		-.37	0.13
Area of longissimus dorsi	0.41	0.41	0.32	0.20	-.37		-.52
Fat cover at 12th rib	0.08	0.09	-.29	-.02	0.13	-.52	
Carcass specific gravity	-.43	-.37	0.19	-.14	0.11	0.06	-.33
Leg specific gravity	-.58	-.47	-.19	-.32	0.11	-.16	-.11
Loin specific gravity	-.39	-.42	0.08	-.25	0.14	-.09	-.23
Rack specific gravity	-.40	-.35	-.01	-.21	0.11	-.06	-.27
Shoulder specific gravity	-.35	-.30	0.01	-.19	0.01	-.03	-.27
Cannon bone:							
Fore weight	-.30	-.42	0.34	-.21	0.31	-.09	-.25
Fore ratio[b]	0.24	0.31	-.34	0.05	0.05	-.22	0.30
Rear weight	-.33	-.41	0.16	-.24	0.45	-.26	-.19
Rear ratio[b]	0.15	0.18	-.28	-.06	0.08	-.25	0.33

TABLE XIV (Continued)

Characteristic	Carcass Weight	Dressing Percentage	Carcass Weight Per Day of Age	Carcass Grade	Carcass Length	Area of L. D.[a]	Fat Cover at 12th Rib
Percentage:							
Rack lean	-.17	-.18	0.35	-.05	-.10	0.50	-.61
Rack fat	0.33	0.35	-.33	0.12	0.02	-.38	0.65
Rack bone	-.49	-.48	0.10	-.24	0.09	-.02	-.45
Leg lean	-.10	-.06	0.21	-.09	-.04	0.44	-.56
Leg fat	0.40	0.36	-.14	0.27	-.11	-.21	0.51
Leg bone	-.63	-.64	-.07	-.41	0.28	-.32	-.09
Shear values:							
L. D.[a]	0.07	-.01	0.20	0.26	-.15	0.25	-.40
S. M.[b]	0.22	0.16	0.24	0.37	-.19	0.24	-.15
Average	0.18	0.10	0.25	0.36	-.19	0.28	-.28
Percentage:							
L. D.[a] protein	-.14	-.13	-.05	-.16	0.21	-.20	0.09
L. D. ether extract	0.10	0.19	-.35	0.20	-.18	-.08	0.12
L. D. moisture	-.05	-.18	0.41	-.18	0.19	0.15	-.15
L. D. ash	-.07	-.08	-.01	-.10	0.13	-.09	0.16
S. T.[c] protein	-.22	-.25	-.07	-.24	0.19	-.13	0.13
S. T. ether extract	0.12	0.13	-.16	0.19	-.11	0.00	0.05
S. T. moisture	0.03	-.02	0.28	-.08	0.00	0.11	-.08

[a]L. D. = Longissimus dorsi.

[b]S. M. = Semimembranosus.

[c]S. T. = Semitendinosus.

TABLE XV

POOLED CORRELATIONS FOR SPECIFIC GRAVITY MEASUREMENTS WITH CARCASS MEASUREMENTS

Characteristic	Carcass	Specific Gravity of the: Leg	Loin	Rack	Shoulder
Carcass specific gravity		0.63	0.56	0.61	0.60
Leg specific gravity	0.63		0.49	0.59	0.59
Loin specific gravity	0.56	0.49		0.82	0.61
Rack specific gravity	0.61	0.59	0.82		0.64
Shoulder specific gravity	0.60	0.59	0.61	0.64	
Cannon bone:					
Fore weight	0.54	0.34	0.44	0.41	0.30
Fore ratio[a]	-.41	-.23	-.22	-.16	-.25
Rear weight	0.47	0.41	0.39	0.43	0.27
Rear ratio[a]	-.32	-.14	-.16	-.14	-.20
Percentage:					
Rack lean	0.40	0.18	0.23	0.27	0.25
Rack fat	-.54	-.34	-.36	-.38	-.37
Rack bone	0.52	0.44	0.43	0.44	0.39
Leg lean	0.44	0.33	0.17	0.29	0.26
Leg fat	-.56	-.55	-.27	-.36	-.41
Leg bone	0.34	0.51	0.26	0.21	0.38
Shear value:					
L. D.[b]	0.26	0.07	0.06	0.12	0.16
S. M.[c]	0.07	-.02	-.02	-.06	0.07
Average	0.17	0.02	0.01	0.02	0.12

TABLE XV (Continued)

Characteristic	Carcass	Specific Gravity of the: Leg	Loin	Rack	Shoulder
Percentage:					
L. D.[b] protein	0.10	0.11	0.09	0.07	0.16
L. D. ether extract	-.21	-.13	-.12	-.10	-.25
L. D. moisture	0.14	0.03	0.03	-.03	0.10
L. D. ash	-.16	-.10	-.17	-.19	-.18
S. T.[d] protein	0.13	0.18	0.21	0.12	0.19
S. T. ether extract	-.18	-.13	-.22	-.14	-.26
S. T. moisture	0.02	-.05	0.00	-.14	0.04

[a]Cannon bone: ratio = length to circumference.
[b]L. D. = Longissimus dorsi.
[c]S. M. = Semimembranosus.
[d]S. T. = Semitendinosus.

TABLE XVI

POOLED CORRELATIONS FOR CANNON BONE MEASUREMENTS WITH SOME CARCASS MEASUREMENTS

Characteristic	Cannon bone Fore weight	Fore ratio[a]	Rear weight	Rear ratio[a]
Cannon bone:				
Fore weight		-.36	0.87	-.24
Fore ratio[a]	-.36		-.11	0.79
Rear weight	0.87	-.11		-.10
Rear ratio[a]	-.24	0.79	-.10	
Percentage:				
Rack lean	0.24	-.40	0.13	-.37
Rack fat	-.41	0.51	-.31	0.47
Rack bone	0.43	-.32	0.41	-.30
Leg lean	0.19	-.29	0.16	-.27
Leg fat	-.31	0.36	-.31	0.30
Leg bone	0.28	-.21	0.33	-.12
Shear value:				
L. D.[b]	0.16	-.35	0.07	-.26
S. M.[c]	0.01	-.17	-.01	-.14
Average	0.08	-.28	0.03	-.21
Percentage:				
L. D.[b] protein	0.16	0.00	0.17	-.01
L. D. ether extract	-.24	0.26	-.17	0.13
L. D. moisture	0.25	-.31	0.15	-.18
L. D. ash	0.05	0.05	0.03	0.04
S. T.[d] protein	0.05	-.06	0.04	0.00
S. T. ether extract	-.06	0.08	-.04	0.05
S. T. ash	0.05	-.13	0.01	-.12

[a]Cannon bone: ratio = length to circumference.
[b]L. D. = *Longissimus dorsi*.
[c]S. M. = *Semimembranosus*.
[d]S. T. = *Semitendinosus*.

TABLE XVII

POOLED CORRELATIONS FOR PHYSICAL SEPARATIONS WITH SOME CARCASS MEASUREMENTS

	Percentage of					
	Rack			Leg		
Characteristic	Lean	Fat	Bone	Lean	Fat	Bone
Percentage:						
Rack lean		-.90	0.27	0.51	-.50	0.12
Rack fat	-.90		-.60	-.52	0.60	-.30
Rack bone	0.27	-.60		0.31	-.50	0.47
Leg lean	0.51	-.52	0.31		-.86	0.02
Leg fat	-.50	0.60	-.50	-.86		-.50
Leg bone	0.12	-.30	0.47	0.02	-.50	
Shear value:						
L. D.[a]	0.39	-.44	0.21	0.23	-.21	0.03
S. M.[b]	0.19	-.21	-.02	0.12	-.05	-.06
Average	0.31	-.35	0.09	0.18	-.13	-.03
Percentage:						
L. D.[a] protein	-.19	0.13	-.04	-.17	0.06	0.16
L. D. ether extract	-.26	0.28	-.14	-.16	0.20	-.19
L. D. moisture	0.30	-.30	0.11	0.14	-.14	0.13
L. D. ash	-.08	0.11	-.20	-.11	0.17	-.13
S. T.[c] protein	-.16	0.08	0.07	-.08	-.06	0.26
S. T. ether extract	-.14	0.18	-.10	-.20	0.24	-.16
S. T. moisture	0.17	-.18	0.02	0.17	-.14	0.02

[a]L. D. = *Longissimus dorsi*.
[b]S. M. = *Semimembranosus*.
[c]S. T. = *Semitendinosus*.

TABLE XVIII

POOLED CORRELATIONS FOR SHEAR VALUES AND PROXIMATE ANALYSES

Characteristic	Shear Value of L. D.[a]	S. M.[b]	Average
Shear value:			
L. D.[a]		0.58	0.85
S. M.[b]	0.58		0.93
Average	0.85	0.93	
Percentage:			
L. D.[a] protein	-.18	-.12	-.17
L. D. ether extract	-.11	-.02	-.07
L. D. moisture	0.20	0.12	0.17
L. D. ash	-.18	-.05	-.11
S. T.[c] protein	-.21	-.21	-.23
S. T. ether extract	0.05	0.09	0.08
S. T. moisture	0.12	0.10	0.12

[a]L. D. = Longissimus dorsi.
[b]S. M. = Semimembranosus.
[c]S. T. = Semitendinosus.

TABLE XIX

POOLED CORRELATIONS FOR PROXIMATE ANALYSES
WITH PROXIMATE ANALYSES

	Percentage						
Characteristic	L. D.[a] Protein	L. D. Ether Extract	L. D. Moisture	L. D. Ash	S. T.[b] Protein	S. T. Ether Extract	S. T. Moisture
Percentage:							
L. D.[a] protein		-.34	0.05	0.36	0.68	-.31	-.04
L. D. ether extract	-.34		-.86	-.22	-.22	0.46	-.41
L. D. moisture	0.05	-.86		0.20	-.04	-.25	0.44
L. D. ash	0.36	-.22	0.20		0.23	0.00	0.06
S. T.[b] protein	0.68	-.22	-.04	0.23		-.42	0.00
S. T. ether extract	-.31	0.46	-.25	0.00	-.42		-.68
S. T. moisture	-.04	-.41	0.44	0.06	0.00	-.68	

[a]L. D. = Longissimus dorsi.
[b]S. T. = Semitendinosus.

TABLE XX

ADJUSTED MEANS AND STANDARD DEVIATIONS
OF THE DIFFERENCE OF MEANS
FOR TYPE OF REARING

Characteristic	Singles	Twins	Standard Deviations[a]
Finished weight	89.45	90.76	0.495
Weight per day of age	0.533	0.539	0.0105
Gain	26.21	26.56	0.499
Feed per pound gain	6.98	6.71	0.424
Carcass weight	44.95	44.57	0.467
Dressing percentage	53.81	53.31	0.442
Carcass weight per day of age	0.268	0.266	0.0053
Carcass grade	8.88	8.81	0.039
Carcass length	23.33	23.33	0.121
Area of L. D.[b]	1.87	1.87	0.050
Fat cover at 12th rib	0.34	0.34	0.018
Specific gravity:			
Carcass	1.0363	1.0364	0.00193
Leg	1.0507	1.0509	0.00180
Loin	1.0304	1.0302	0.00265
Rack	1.0363	1.0345	0.01058
Shoulder	1.0424	1.0412	0.00227
Cannon bone:			
Fore weight	51.20	52.34	0.905
Fore ratio[c]	1.90	1.90	0.026
Rear weight	53.93	54.21	0.923
Rear ratio[c]	2.10	2.09	0.270

TABLE XX (Continued)

Characteristic	Singles	Twins	Standard Deviations[a]
Percentage:			
Rack lean	40.72	42.19	3.796
Rack fat	38.61*	36.24	1.125
Rack bone	19.22	19.91	0.538
Leg lean	59.84	59.85	0.741
Leg fat	23.43	23.81	0.847
Leg bone	15.23	15.17	0.389
Shear values:			
L. D.[b]	14.17	14.66	0.483
S. M.[d]	20.14	20.40	0.764
Average	17.16	17.53	0.518
Percentage:			
L. D.[b] protein	21.95	20.05	0.258
L. D. ether extract	5.88	5.59	0.429
L. D. moisture	70.64	71.43	0.406
L. D. ash	1.059	1.057	0.020
S. T.[e] protein	20.21	20.06	0.237
S. T. ether extract	6.14	5.83	0.343
S. T. moisture	70.45	70.81	0.271

[a]Standard deviations of the difference of means.
[b]L. D. = Longissimus dorsi.
[c]Ratio of length to circumference of bone.
[d]S. M. = Semimembranosus.
[e]S. T. = Semitendinosus.
*$P < .05$

TABLE XXI

PARTIAL REGRESSION COEFFICIENTS FOR ALL CHARACTERISTICS FOR THE COVARIABLES BIRTH WEIGHT AND WEANING WEIGHT

Characteristic	Birth Weight	Weaning Weight
Finished weight	0.0140	0.01263
Weight per day of age	0.0005	0.0077**
Gain	0.0134	-0.9884**
Feed per pound gain	-0.0247	0.0332
Carcass weight	-0.0092	0.0243
Dressing percentage	-0.0196	-0.0017
Carcass weight per day of age	0.0008	0.0040**
Carcass grade	-0.0027*	0.0099**
Carcass length	0.0025	0.0024
Area of L. D.[a]	-0.0017	0.0049
Fat cover at 12th rib	0.0008	-0.0018
Specific gravity[b]:		
Carcass	-0.0165	0.8911
Leg	0.7988	-2.4475*
Loin	0.0963	1.2461
Rack	-0.5026	0.1560
Shoulder	-0.1131	-0.1388
Cannon bone:		
Fore weight	0.0491	0.1165*
Fore ratio[c]	-0.0005	-0.0023
Rear weight	0.0925**	0.0013
Rear ratio[c]	-0.0006	-0.0017

TABLE XXI (Continued)

Characteristic	Birth Weight	Weaning Weight
Percentage:		
Rack lean	-0.0165	0.1793
Rack fat	-0.0088	-0.1605**
Rack bone	0.0112	-0.0114
Leg lean	-0.0268	0.0408
Leg fat	0.0022	0.0088
Leg bone	0.0240	-0.0437*
Shear values:		
L. D.[a]	-0.0007	-0.0298
S. M.[d]	0.0269	0.0053
Average	0.0130	-0.0121
Percentage:		
L. D.[a] protein	0.0005	0.0072
L. D. ether extract	-0.0079	-0.0611**
L. D. moisture	0.0020	0.0579**
L. D. ash	0.0000	0.0002
S. T.[e] protein	-0.0014	-0.0071
S. T. ether extract	-0.0143	-0.0206
S. T. moisture	0.0181*	0.0139

[a]L. D. = _Longissimus_ _dorsi_.
[b]Specific gravity values coded 10^4 to show significant figures.
[c]Ratio of length to circumference of bone.
[d]S. M. = _Semimembranosus_.
[e]S. T. = _Semitendinosus_.
*P<.05
**P<.01

VITA

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Doctor of Philosophy

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