CHANGES IN CARCASS COMPOSITION FROM 9 TO 18 MONTHS IN HEIFERS FED A FATTENING RATION

By

LOUIS ALONZO MALKUS

Bachelor of Science
University of Maryland
College Park, Maryland
1958

Master of Science
University of Connecticut
Storrs, Connecticut
1961

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the Oklahoma State University of Agriculture and
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Thesis Adviser

Dean of the Graduate School

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INTRODUCTION

The proportions of fat, lean and bone in the carcass are important to the producer, packer, retailer and particularly the consumer. Current trends in consumer demands reflect emphasis on smaller, leaner cuts of beef.

To meet the demand for retail cuts which possess an absolute minimum of external fat, the producer has commenced to market cattle at an earlier age. This practice appears to be economically sound since during the early stages of growth, feed is utilized more efficiently in terms of weight gained and is primarily converted into muscle tissue (Hammond, 1960). Older animals are inclined to deposit relatively more fat than lean tissue in the carcass.

Because of the aversion to excessive amounts of external fat, it becomes increasingly more important to obtain fundamental information concerning the growth and development of major carcass tissues. The ultimate goal would be to establish a point during the growing cycle when maximum muscle development and a minimum of fat deposition in the carcass is obtained. At the same time, the quality of the beef must be acceptable to the consumer.

Information regarding the influence of animal age on the development and growth of bovine animals, especially heifers, is limited. Much of the data previously collected originated from experiments involving animals which varied considerably in weight, breed, age and sex.

This study represents a portion of a beef maturity project being conducted at the Oklahoma Agricultural Experiment Station. The primary objective of this portion was to evaluate the influence of age on the physical and chemical composition of the beef carcass.

REVIEW OF LITERATURE

The topics reviewed here will consider some of the work relative to: (1) quantitative measures of carcass composition and (2) changes in carcass composition as maturity progresses.

Quantitative Measures of Carcass Composition

Much controversy exists today about our present system of evaluating beef carcasses. The primary objective of carcass evaluation is to identify qualitative and quantitative differences that exist between carcasses. In the past, grading has been used to segregate beef carcasses according to their qualitative and quantitative merits. However, many researchers believe that grading does not adequately evaluate the relative proportions of fat, lean and bone in the beef carcass. Hence, efforts have been directed towards the development of indices to predict carcass composition. The following discussion is concerned with the measurements used to estimate the composition of the carcass. This section has been divided into four parts consisting of (1) carcass measurements, (2) carcass cut-out, (3) physical separation and (4) other techniques.

Carcass Measurements

In an attempt to predict carcass components, various carcass measurements have been used. An index of muscle and fat development can be obtained from the exposed cut surface at specific anatomical regions. The *longissimus dorsi* muscle area and the fat external to it have been studied extensively, particularly at the 12th rib.

The conventional method for obtaining the cross-sectional area involves tracing the outline of the longissimus dorsi muscle on acetate paper. A compensating polar planimeter is then employed to compute the area in square inches. Cahill et al. (1956) reported a highly significant correlation (r = 0.85) between the edible portion of the carcass and the area of the longissimus dorsi muscle obtained between the 12th and 13th rib. Yet, Cole et al. (1960) in a study which included 99 carcasses found that the longissimus dorsi area accounted for only 18% of the variation in total separable carcass lean.

These results concur with the findings of Kline and Hazel (1955) and Price et al. (1957) which indicated that a low relationship existed between the area of the longissimus dorsi and muscling in the pork carcass. These data suggest that the value of this measurement as an index to carcass lean is questionable. However, it is still being used rather extensively, particularly in regard to beef cattle performance testing programs and carcass contests.

Another approach involves the use of width and length of the longissimus dorsi muscle. Palsson (1939) and McMeekan (1941) concluded that individual length or width measurements of loin eye area were not related significantly to total carcass muscling.

In recent years, photographic techniques have been developed to measure the longissimus dorsi area. Schoonover and Stratton (1957) found that a photographic measurement of the loin eye area at the 12th rib was highly associated with the proportion of lean from the 9-10-11th rib which was determined by specific gravity. Deans et al. (1959) indicated that when a comparison was made between the actual measurements (hand tracing measured with a planimeter) and photographic measurements, less variability was obtained by the photographic method.

Fat thickness at the 12th rib provides another measure for carcass evaluation. The procedure for obtaining this measurement is described by Naumann (1952). Bracklesberg (1963) demonstrated that an average of a three fat depth measurement was highly associated with the percent fat in the carcass (r = 0.82). Ramsey _et al._ (1961, 1962) found that a single fat measurement obtained at a distance of two-thirds the length of the _longissimus dorsi_ muscle, as measured from the chine bone, was indicative of the separable fat in the carcass. Gottsch _et al._ (1961) working with beef carcasses reported correlations between fat trim and the average of the three measurements and a single measurement were 0.57 and 0.58, respectively.

A procedure for measuring the area of the external fat at the 12th rib was described by Wuthier and Stratton (1957). Malkus _et al._ (1961) found there was no advantage in using the fat area measurement over the average of three fat thickness measurements in predicting percent fat in the carcass determined by the 9-10-11th rib separation.

Orme _et al._ (1959) obtained repeatability estimates regarding circumference, depth, length and width measurements of the carcass. They concluded that the more repeatable estimates were closely related to the ease of defining the reference points from which the measurements were taken. In general, the repeatability of measurements was high; however, they found that the carcass measurements which included carcass length, depth of body at the 5th rib, width of shoulder, width of round and circumference of the round were not closely related to percent yield of primal cuts or rib eye area. Malkus _et al._ (1963) indicated that carcass measurements, such as discussed above, were unrelated to percent or weight of lean in the carcass. Similar conclusions were reported by Christians (1962) and Hendrickson (1962).

Specific gravity has been used to estimate carcass composition. Behnke et al. (1942) found that specific gravity could be used to estimate the percentage of fat in the human body. Rathburn and Pace (1945) developed formulas for calculating percent fat and moisture based on the concept that if the animal body is made up of two major tissues, lean body mass of high density (approximately 1.10), and fat of low density (approximately 0.89), the specific gravity of the whole body would be an expression of the relative amount of these components.

Kraybill et al. (1952) determined the specific gravity of eviscerated cattle by hydrostatic weighing. These workers found the specific gravity of the 9-10-11th rib was highly correlated to that of the carcass (r = 0.95). They also reported correlation coefficients of -0.96 and 0.98 between specific gravity of the carcass and carcass fat and moisture content, respectively. Using the equation derived by Kraybill and co-workers, Meyer (1960) found a high relationship between the specific gravity of the carcass and percent carcass fat. Using the regression equations of Hankins and Howe (1946), Hendrickson (1962) reported that simple correlations between percent fat, lean and bone of the carcass and specific gravity of the wholesale rib cut were -0.90, 0.80 and 0.70, respectively. Bushman (1963) indicated that the specific gravity of the rump was more highly related to percent lean and fat in the carcass than twelve other cuts studied. Several other authors have reported relationships between the specific gravity of various portions of the carcass and carcass composition (Whiteman et al., 1953; Bieber et al., 1961 and Bowman, 1962).

Carcass Cut-Out

In recent years, the consumer preference for retail cuts with a minimum of external finish has led to investigations concerning the identity of beef carcasses with high yields of preferred wholesale and retail cuts. Pierce (1957) demonstrated that superior conformation and a high degree of finish had opposite effects on the overall yield of the edible portion of the beef carcass. From the evaluation of 459 carcasses ranging in grade from prime to canner, it was concluded that finish was considerably more important than conformation in estimating yield of closely trimmed retail cuts from the chuck, loin, rib and round. Similar conclusions were reached by Goll et al. (1961).

In an investigation designed to develop a method for predicting the yield of retail cuts, Murphey et al. (1960) reported the following equation to be most useful: Percent boneless retail cuts from the round, loin, rib and chuck = 51.34 - (5.78 x single fat measurement over the rib eye, inches) - (0.462 x percent kidney fat) + (0.740 x area of rib eye, square inches) - (0.0093 x carcass weight, pounds). Utilizing subjective evaluations for exterior and kidney fat, a simple correlation coefficient of 0.92 between the estimated and actual yields of bone-in retail cuts was obtained. Ramsey et al. (1962) reported simple correlation coefficients between yield grade (as proposed by Murphey et al. 1960) and percent separable lean and fat were 0.82 and -0.80, respectively.

Brungardt and Bray (1963) studied the relationships between various linear measurements of beef carcasses and wholesale cuts with the yield of closely trimmed retail cuts from the round, loin, rib and chuck. The physical composition of 99 sides of beef was estimated from the equations of Hankins and Howe (1946). Their results indicated that carcass weight was a poor indicator of the edible portion of the carcass. The study also indicated that untrimmed wholesale cuts were not reliable predictors of the yield of trimmed retail cuts or carcass lean. The trimmed round was found to be the most reliable measure of the yield of trimmed retail cuts and carcass lean.

Iwanaga and Cobb (1963) indicated that the yield of trimmed retail cuts was highly related to the specific gravity of the whole carcass (r = 0.74) and the percent waste from the carcass (r = 0.89). Carcass weight, fat thickness over the rib eye and rib eye area were found not to be highly related to yield of trimmed retail cuts in this study. Stringer et al. (1963) reported a multiple correlation coefficient of 0.91 between percent retail cuts and fat thickness, percent kidney knob, area of longissimus dorsi per hundredweight and percent retail yield of the flank.

Physical Separation

A combination of dressing percent and the percentage of offal fat based on live weight was found by Lush (1926) to provide a reliable indicator of carcass fatness in cattle. Lush also reported that the percentage of fat in the wholesale rib was a more accurate indicator of the degree of fatness in the entire carcass than other wholesale cuts.

Hopper (1944) found that the composition of the wholesale rib and the 9-10-11th rib cut were highly correlated with the composition of the carcass. Later, Hankins and Howe (1946) concluded that the composition of the 9-10-11th rib cut was closely related to carcass composition. Based on data from 120 carcasses, they obtained correlation coefficients of 0.93, 0.85 and 0.83 between fat, lean and bone of the 9-10-11th rib cut and the corresponding components of the carcass, respectively. Although regression equations computed from this data have been used extensively to determine carcass composition, the large variation in the population studied and the sizeable standard errors make the application of these equations of questionable value, particularly with regard to uniform groups of carcasses.

Guenther (1953) reported a highly significant relationship between the percentages of lean, fat and bone in the 12th rib cut and the 9-10-11th rib cut. These results were based on information collected from 53 steer carcasses. A later investigation, by Crown and Damon (1960) found that correlation coefficients for percentages lean, fat and bone of the 12th rib cut with the percentages of lean, fat and bone of the carcass were 0.82, 0.96 and 0.73, respectively. The correlation coefficients between the lean, fat and bone of the 9-10-11th rib cut and the corresponding separable components of the carcass were 0.94, 0.98 and 0.73, respectively.

In an experiment based on a group of twenty-four steer carcasses, representing the Hereford, Milking Shorthorn and Holstein-Friesian breeds, Callow (1962) reported that the weight of the lean in the foreshin was highly related to the lean in the carcass ($r = 0.90$). Callow also studied the use of the thorax, 12th rib cut and the loin as a possible index of total separable fat in the carcass. The separable fat in the loin was more indicative of fatness in the carcass than was the thorax or 12th rib cut.

Cole *et al.* (1960) demonstrated that the weight of separable lean in several wholesale cuts was a more reliable indicator of carcass leanness than the area of the *longissimus dorsi*. Correlation coefficients between separable lean in various wholesale cuts and carcass lean were 0.95 with round, 0.93 with chuck, 0.81 with foreshank and 0.80 with the sirloin.

The validity of using the weight of an individual muscle or a group of muscles to predict total carcass lean was investigated by Orme *et al.*

(1960). The following simple correlation coefficients between the weight of total carcass lean and weights of certain muscle groups were obtained: biceps femoris 0.96; sirloin tip muscles 0.93; longissimus dorsi 0.92; and the inside round muscles 0.92. Orme and co-workers concluded that their results justified the use of certain entire muscles for the determination of the muscling in the carcass.

Bracklesberg (1963) conducted a study which involved 20 steer carcasses, ranging from 471 to 531 pounds chilled carcass weight, to determine the relationships between the fat, lean and bone of sub-sections of the side or wholesale cuts and the composition of the beef carcass. He reported that simple correlation coefficients between the percent round and the percent of lean and fat in the side were 0.88 and -0.87, respectively. According to Bracklesberg, the lean and fat content of most of the sub-sections of the side yielded highly significant relationships when they were correlated to carcass lean or fat content. Often, the fat of a particular section was more highly related to the lean content of the side than it was to the separable fat in the side.

The relationship of bone to muscle in beef carcasses has been studied extensively. Hammond (1932), Palsson (1939) and McMeekan (1941) found a high relationship between the bone of each animal they dissected and the weight of lean tissue. According to McMeekan (1956) "The weight of muscle can be determined within one percent, if the weights of cannon bones are known".

Bone data collected from 132 steers, indicated that cannon bone weight, area, weight/length ratio and specific gravity were highly related to the area of the longissimus dorsi and wholesale cut weight (Orts, 1959). Orme et al. (1959) reported that the weight/length ratio, width and thickness of the metacarpus and metatarsus of the beef carcass were related to the weight of carcass lean, but the authors concluded the relationships were not high enough for predictive purposes.

Wythe et al. (1961) reported a significant positive relationship existed between bone thickness (weight/length ratio) and muscling. Bracklesberg (1963) demonstrated that the weight/length ratio of the cannon bone, the cross sectional area of the bone plus the marrow cavity and the cross sectional area of the bone minus the marrow cavity were significantly correlated to carcass lean and fat content.

Other Techniques

Carcass composition has also been estimated by chemical analysis. Moulton et al. (1922b) established that the tissues of the carcass vary in their content of water, protein, fat and ash. Changes in weight or age may influence this variation.

A close relationship between the ether extract and the separable fat of any wholesale cut in the beef carcass was reported by Chatfield (1926). Hopper (1944) used 92 carcasses to determine if the chemical components of the wholesale rib cut could be used for the prediction of the chemical composition of the carcass and the edible portion of the carcass. He concluded that the chemical composition of the wholesale rib cut and the edible portion thereof was highly correlated with the chemical composition of the carcass and the edible portion of the carcass.

Hankins and Howe (1946) studied the relationships between the separable lean and fat of the 9-10-11th rib cut and the chemical composition of the beef carcass. Correlation coefficients between the separable fat and lean of the 9-10-11th rib cut and the ether extract and protein content were 0.93 and 0.82, respectively. Malkus et al. (1963) found that the percent protein in the 9-10-11th rib cut was associated with 85 percent of the variation in the percent protein of the side. Physical-chemical relationships have also been studied in swine carcasses (Judge et al., 1960; Henry et al., 1963) and in lamb carcasses (Barton and Kirton, 1960; Ulyatt and Kirton, 1963).

In recent years, the composition of meat cuts has been estimated on the basis of emission of gamma rays of potassium-40. The principles which apply to potassium-40 detection are dependent on the constant proportions of potassium in the lean tissues and on the constant ratios of potassium-40 in the naturally occurring potassium (Kulwick, 1961).

Kulwick et al. (1960) reported a high correlation between the separable lean of the ham and its potassium-40 activity. A study of the relationship between gamma-ray emission and lean and fat content of 16 beef rounds revealed highly significant correlations between the percent separable fat and lean and the disintegrations per minute from potassium-40 per round of intact round (Kulwick et al., 1961). They were -0.86 and 0.80, respectively. Judge et al. (1963) reported that potassium-40 measurements were closely related to the edible portion, excess fat and bone composition of lamb carcasses.

Lush (1928) stated, "Linear measurements should be regarded as supplementary to other means of description rather than a substitute for those other means". In a symposium on feeds and meats terminology, Bray (1963) indicated that the tremendous biological variations in carcass traits makes it difficult to use linear measurements to accurately estimate carcass composition. It should be emphasized that the present methods of evaluating quantitative differences in carcasses are not impeccable. The need for greater precision and refinement in technique presents a challenge to future investigations in the area of meat carcass evaluation.

Effect of Age on Carcass Composition

While age and plane of nutrition are of fundamental importance in determining the relative proportions of fat, lean and bone in the carcass, such factors as breed, sex and exercise may also influence the amount and distribution of the major tissue components of the carcass. However, only the aspect of age and its influence on the chemical and physical development of the carcass will be discussed here.

As early as 1849, Lawes and Gilbert, as reported by Lush (1926), found that the chemical analysis of a fat calf (9 or 10 weeks old), a half fat ox (4 years old) and a moderately fat ox (4 years old) indicated an inverse relationship between the fat and water content. The fat content was considered to be the most variable constituent in the body. The composition of the animal body was divided into two portions by Murray (1922) and included fat and non-fatty matter. The latter consisted primarily of water, protein and ash. Percent water in the animal's body varied inversely with age, but the protein/ash ratio was not altered by the age of the animal.

Based on a comprehensive review of the literature, Moulton (1923) indicated that in general the following changes occur in mammals as age progresses: (1) a decrease in the content of water and fluid constituents beginning with the development of the embryo and continuing into the early growth period; (2) an increase in the solid organic material which occurs at the greatest rate during a period immediately after birth; (3) a rapid increase in ash content during the period of prenatal life and then proceeding more slowly. According to Moulton, chemical maturity is reached when the concentration of water, proteins and salts become relatively constant on a fat free basis. Moulton <u>et al</u>. (1922b) pointed out that chemical maturity was reached about 5 months after birth in cattle. The carcasses of

30 Hereford-Shorthorn crossbred steers were analyzed to form the basis of their conclusion.

The dissection technique is the primary method used in measuring developmental changes in body components. The total carcass is separated into either wholesale cuts or major tissues (fat, lean and bone) and these are expressed as a percentage of the total carcass weight. Other methods which are sometimes used to study body development are: the weight of a tissue compared with a standard tissue; the weight of the tissue at different ages compared with the same tissue at a standard age, such as birth; the rate of gain in weight of a tissue estimated per unit of time; and the weight of the tissue of different treatment groups at a given age expressed as a percent of the weight of the same tissue of one of the treatment groups at the same age (Hafez, 1963).

Most of the investigations concerning the influence of age on carcass composition have been conducted with sheep or swine. Using the dissection technique, Hammond (1932) demonstrated that the percentage bone in the dressed sheep carcass decreased from more than 30 percent at birth to less than 10 percent in the mature carcass. The percentage of muscle increased slightly, ranging from 50 to 60 percent of the total carcass weight from birth to maturity. Fat increased from less than 5 percent of the total carcass weight at birth to approximately 30 percent in the mature carcass. Later results from sheep and swine investigations proved to be analogous with Hammond's work (McMeekan, 1940, 1941; Wallace, 1948; Palsson and Verges, 1952). In essence they concluded that bone was the first major tissue to develop in the body and this was followed by muscle. Fat was the last tissue to develop.

Since considerable time and expense is involved in a detailed beef carcass analysis, information is rather limited. However, there are several interesting studies concerned with the influence of age upon dressing percent and the percent of the various wholesale cuts.

The results of early beef carcass investigations concerned with age were not consistent (Gramlick and Thalman, 1924; Foster, 1928; Lush, 1928; Hankins and Titus, 1938; and Loeffel and Thalman, 1942). It was generally observed that gains made by older animals consisted largely of fat while younger cattle increased in their skeletal and muscular tissues. Furthermore, it was noted that dressing percent increased with advancing maturity and data pertaining to the development of the carcass (based on percentage figures from the wholesale cuts) were not in agreement. It can be surmised that many of the differences appearing in the literature at this time were due to procedures used to collect data rather than inherent differences in the carcasses. Often the experiments were conducted under diverse conditions, thus valid comparisons could not be made.

In a series of classical experiments, Callow (1944, 1947, 1948, 1949 and 1950) studied the changes in the chemical and physical constituents of carcasses in relation to growth and fattening. According to Callow, the proportion of muscle tissue decreased as live weight increased. He observed that in carcasses with 10 percent fatty tissue, there was nearly three times as much muscle as bone. When the fatty tissue in the carcass increased two-fold (20 percent), there was approximately four times as much muscle as bone. At this point on a percent basis fat represented slightly more of the total carcass than bone. In extremely fat carcasses (40 percent) there was nearly five times as much muscle as bone and four times as much fat as bone.

The influence of age on the body conformation and carcass composition of Afrikaner cattle was studied by Joubert (1959). Of the 12 animals used, 6 were approximately 2 years old and the others were 13 years old. All animals received similar nutritional treatment 60 days prior to slaughter. The average dressing percent for the younger animals was 53.8, while that of the more mature cattle was 55.0. Concerning the aspect of carcass measurements, Joubert recorded the following relative differences between the two age groups: depth of thorax (27.4 percent); length of side (25.5 percent); buttock length (12.6 percent); eye muscle width (8.1 percent); and depth of eye muscle (3.3 percent). The percent hindquarter in the younger animals was 2.8 percent greater than the aged cattle. Joubert pointed out that previous work indicated that the maximum development of the hindquarter occurred at approximately 8 months of age. At this time the hindquarter represented 52.2 percent of the carcass weight and it was observed that the percent hindquarter decreased progressively as age increased. Joubert concluded from his investigation that the final stages of development in the Afrikaner cattle occurs in the forequarter, particularly the thoracic region. This is contrary to the view supported by Hammond (1960). His observations concluded that a wave of growth begins at the head, spreads down the trunk, and secondary waves, which start at the extremities of limbs, pass upwards. These all converge at the junction of the loin with the last rib and hence this area represents the last part of the body to develop.

The developmental patterns during the short term fattening of beef steers of different ages (8, 20 and 32 months old) were investigated by Luitingh (1962) to ascertain what changes in the proportions of the various body parts, offal, organs and tissues occurred. One hundred and four steers were fed on rations differing in the ratio of concentrates to roughage. At the initiation of the experiment, 36 control steers representing the three age groups were slaughtered. Results of this investigation revealed the following observations: the percentage of the various wholesale cuts was relatively constant between the three age groups; the percentage of hindquarter decreased with age; and as the steers matured, the growth rate became intense in the forequarters, especially in the regions of the brisket, neck and plate.

Zinn et al. (1963a) placed 100 steers and 100 heifers on identical growing-fattening rations. Ten steers and 10 heifers were randomly selected and slaughtered as controls at the beginning of the experiment. Thereafter 10 steers and 10 heifers were slaughtered every 30 days. After 270 days on feed, the weights of the fat trim (external fat trimmed to an average of $\frac{1}{4}$ of an inch), edible lean and bone were 681, 114 and 71 percent, higher than the weights of the respective components in the controls. Almost one-half the increase in fat trim occurred between 90 and 150 days on feed. Samples of the semimembranosus, longissimus dorsi and triceps muscles from 50 steers and 50 heifers were obtained and chemically analyzed for moisture, ether extract, crude ash and crude protein. The results indicated that a significant ($P < .05$) decrease in moisture was accompanied by a significant ($P < .05$) increase in crude protein, ether extract and crude ash in the semimembranosus, longissimus dorsi and triceps muscles as the length of time on feed increased (Zinn et al., 1963b).

Much of the work cited relative to the influence of age on carcass composition is subject to criticism. General conclusions were often based on data from only a few animals. The procedures used to measure carcass composition were not usually standardized, hence the results of the investigations could not be compared. In addition, much of the information regarding age was a by-product of experiments designed to study the effects of the plane of nutrition on the development of the carcass. Consequently, it is believed that further investigations in this area will enhance our present knowledge regarding the influence of age on carcass composition.

EXPERIMENTAL PROCEDURE

Materials

The data reported were collected from 24 heifers. The experimental animals were sired by purebred Hereford bulls and out of grade Hereford dams. The heifers were calved during the Fall (October 15 to November 29) of 1961 and were creep fed while nursing their dams until they were weaned in early July. At weaning the heifers were allotted to 4 groups of 6 animals each (Table I).

TABLE I

SLAUGHTER SEQUENCE FOR INDIVIDUAL ANIMALS AND GROUPS

	Groups			
	A	B	C	D
Animal Number	105	443	138	453
	405	127	406	146
	407	134	409	145
	305	463	420	163
	112	199	452	197
	159	103	473	140
Slaughter Order	3	2	1	4
Date	Jan., 1963	Oct., 1962	July, 1962	May, 1963
Age	15 Months	12 Months	9 Months	18 Months

At 9 months of age, the 12, 15 and 18 month old heifers were transported by truck a distance of approximately 100 miles, (Lake Carl Blackwell to Fort Reno), and then placed on feed. The 9 month old heifers were slaughtered immediately after weaning. During the feeding period from 9 to 18 months, the heifers received a fattening ration, ad libitum, until they attained the appropriate slaughter age (Table II).

TABLE II

FATTENING RATION

350 lbs.	ground ear corn
200 lbs.	cottonseed hulls
100 lbs.	chopped alfalfa hay
100 lbs.	whole oats
100 lbs.	cottonseed oil meal
50 lbs.	blackstrap molasses

Methods

Slaughter Procedure

The experimental animals were delivered to the Oklahoma State University abattoir on the afternoon preceeding the day of slaughter. The heifers were allowed free access to water, but no feed.

The cattle were slaughtered according to the procedure outlined by Deans (1951). At the time of slaughter the weight of the head, hide, liver, pluck, heart, internal fat, full and empty reticulum, full omasum and abomasum and full intestines were recorded. The metacarpals and metatarsals were removed from each carcass, cleaned, weighed and subjected to selected measurements described by Orme and Pearson (1959).

Carcass Measurements

Immediately after slaughter and dressing, the carcasses were placed in a 34-36°F. cooler to chill for 48 hours. All carcasses were split 24 hours after slaughter. Care was taken to ensure a uniform split so that either side would be representative of the entire carcass. The carcasses were weighed and the following measurements were obtained according to the procedure described by Naumann (1952): length of leg, loin and carcass; thickness of round and chuck; and depth of body. Shortly after ribbing the carcasses, the area of the longissimus dorsi muscle and fat cover was traced at the 12th thoracic vertebra. Tracings of the cross sectional area of the longissimus dorsi muscle were made at the 6th and 9th thoracic vertebrae after the carcass was divided into cuts. A compensating planimeter was used to compute the area in square inches.

Two qualified personnel visually appraised each carcass with respect to conformation, quality, finish and maturity. From the overall evaluation a grade was determined according to the U.S.D.A. standards (1956).

Cutting Procedure

The right side of each carcass was divided into wholesale cuts according to the procedure described by Wellington (1953). The wholesale round was further divided into the cushion round and the hind shank by disjointing the femur and tibia on a line parallel to the round face. The wholesale rib was subdivided into the 6-7-8th rib, 9-10-11th rib and 12th rib sections. This was accomplished by cutting on the posterior edges of the 8th and 11th ribs. A total of 13 cuts was made from the right side as illustrated by Figure 1.

Each cut was weighed, wrapped in aluminum foil and quick-frozen at -10°F. in an air blast freezer. The cuts were stored at 0°F. until they were thawed for separation.

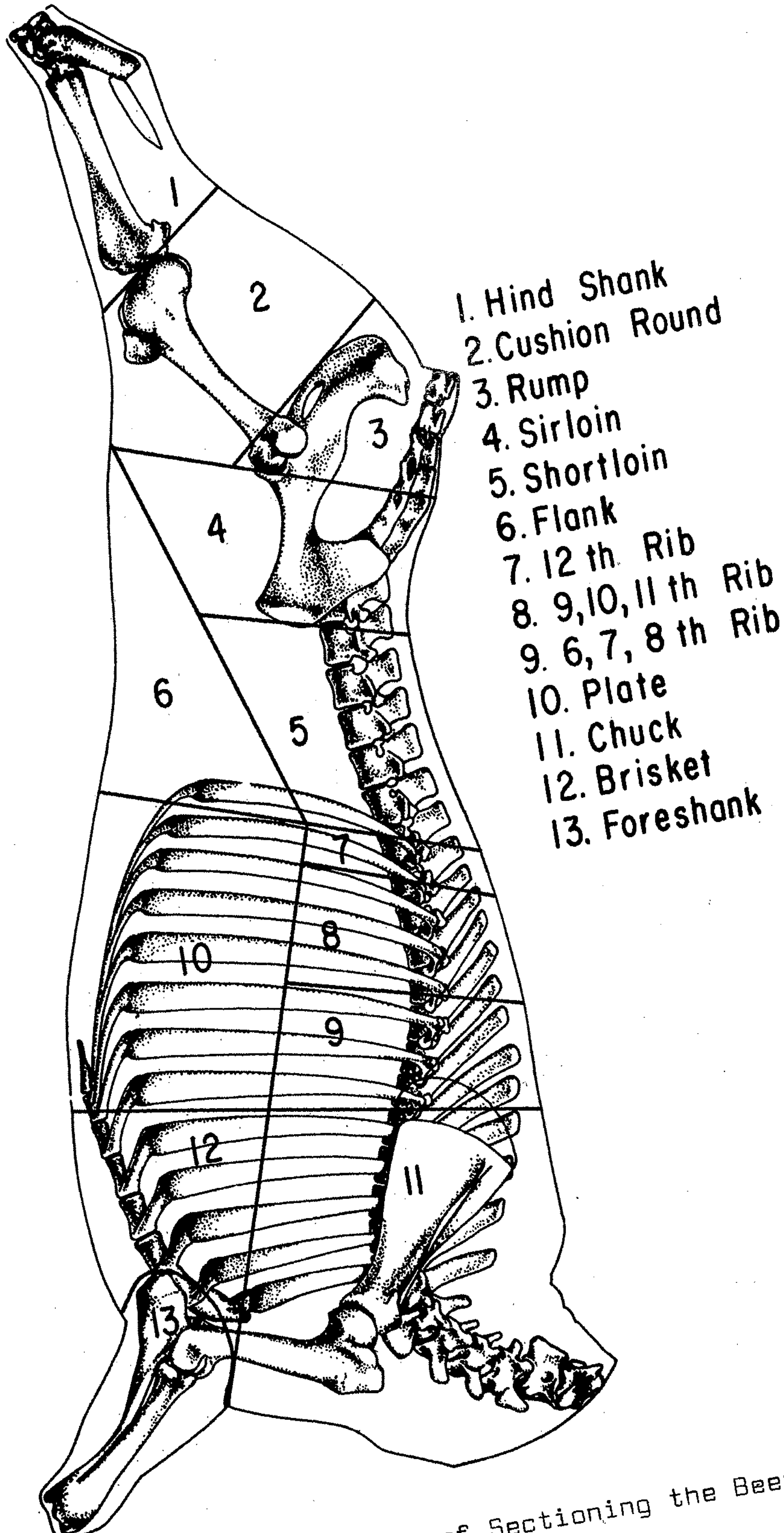

FIGURE 1 - Method of Sectioning the Beef Side.

Physical Separation

Prior to the physical separation, the cuts were removed from the freezer and permitted to temper at 35°F. After a weight was recorded, each cut was manually separated into lean, fat and bone. The dense connective tissue, ligaments and tendons were considered as part of the bone. Evaporation losses were restricted by conducting the physical separation in a high humidity (80%), 40°F. cooler. Weight losses incurred during the separation were added to the weight of the lean tissue. It was believed that a majority of the loss would come from this tissue rather than fat or bone. The weight of each component was recorded to the nearest 0.1 of a pound and the percentage of lean, fat and bone was determined for each cut. The percentage lean, fat and bone was also calculated for the forequarter, hindquarter and side.

Chemical Analysis

After physically separating each cut, samples of approximately 100 grams were secured for proximate analysis from the separable lean and fat in the following manner. A mixture of the boneless portion of each cut was ground through a 3/8 inch plate, hand blended and reground through a 1/8 inch plate. The ground meat was then uniformly distributed in a container and sampled randomly at several locations. The samples were placed in jars and frozen at 0°F. Later, they were removed from storage and the ground tissue was blended into a homogenous paste. Duplicate analyses for moisture, ash, ether extract, and protein were made for each cut. The proximate analysis was conducted according to the procedures outlined by the Association of Official Agricultural Chemists (1955).

The percentage of moisture, ash, ether extract and protein from the side was computed in the following manner: (1) the percentage of the chemical constituent of each cut was multiplied by the corresponding weight of the boneless portion of that cut; (2) the products thus obtained were summed; (3) this sum was divided by the boneless weight of the side.

Analysis of Data

The methods described by Snedecor (1956) were used to analyze the data. Mean values and standard deviations of the means were determined for all pertinent data. The analysis of variance was utilized to study the influence of age on the various factors concerning carcass composition.

Two methods were used to study developmental changes in body components. The weight of different organs, tissues and wholesale cuts was expressed as a percentage of the slaughter or carcass weight. In addition, the weights and measurements of various carcass parts at 12, 15 and 18 months of age were expressed as a percentage of the corresponding weights and measurements at 9 months of age.

RESULTS AND DISCUSSION

The results reported herein include a discussion of the effect of age on: offal parts, carcass measurements, yields of wholesale cuts, physical composition and chemical composition.

Slaughter Data

The effects of age on slaughter weight, chilled carcass weight, dressing percentage and various offal products are summarized in Table III. The wide variation in slaughter and carcass weight within an age group is indicated by the large standard deviations. This variation was also present between age groups. Individual animals within a more youthful age group sometimes weighed more than animals from an older age group. Individual carcass data may be found in the Appendix, Table XVIII.

The initial weights at 9 months of age for calves assigned to the 9, 12, 15 and 18 month old age groups were 480.8, 414.2, 417.5 and 446.7 pounds, respectively (Table III). The fact that the average initial weight of the 9 month old calves was 66.6 pounds more than the average weight of the calves assigned to the 12 month age group, will partially explain the small increases between 9 and 12 months of age with respect to various measures reported. The average slaughter weights were 451.8, 519.7, 712.2 and 844.3 pounds for the 9, 12, 15 and 18 month age groups, respectively. From 9 to 12 months of age there was an average increase of 67.9 pounds. Corresponding increases from 12 to 15 and 15 to 18 months of age were 192.5 and 132.1 pounds, respectively.

TABLE III

INFLUENCE OF AGE ON SLAUGHTER WEIGHT, CARCASS WEIGHT AND YIELD OF OFFAL PARTS

		9 Month		12 Month		15 Month		18 Month	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Initial Weight	lbs.	480.8	39.93	414.2	51.62	417.5	43.56	446.7	46.87
Slaughter Weight	lbs.	451.8	31.36	519.7	61.54	712.2	77.82	844.3	79.46
Carcass Weight	lbs.	257.2	26.48	305.4	42.32	440.9	50.58	549.3	53.64
Yield (%)		56.80	2.32	58.65	1.30	61.89	.94	65.05	1.23
Percent[a]									
Head		3.75	.28	3.48	.16	3.12	.19	2.82	.23
Hide		9.42	1.20	8.26	.52	8.25	.57	7.08	.92
Heart		.42	.03	.40	.02	.45	.07	.34	.02
Liver		1.41	.03	1.64	.02	1.30	.07	1.14	.08
Pluck		1.95	.14	2.02	.13	2.01	.18	1.73	.14
Feet		1.99	.20	1.99	.09	1.67	.10	1.46	.19
Fill		6.60	.68	6.14	1.11	4.28	.24	3.48	.79
Visceral Fat		.77	.15	1.21	.39	1.91	.49	2.99	.63

[a]Based on slaughter weight.

Dressing percentage or yield based on a 48 hour carcass weight increased as maturity advanced. There was an increase of 8.25 percent in yield between the 9 and 18 month old age groups. This was expected since other investigators (Gramlick and Thalman, 1924; Hankins and Titus, 1939; Callow, 1944; and Joubert, 1959) reported similar observations. The major increase in the proportion of the dressed carcass as the animal becomes older was attributed to increases in the weight of carcass fat.

A marked increase was observed in the percentage of visceral fat (Table III). There was approximately four times more internal fat present in the 18 month old age group than was present in the 9 month age group. This agrees with the work of Moulton _et al_. (1922a) who reported that as cattle become older, they tend to deposit more fat around the internal organs.

In general, the percentages of head, hide, heart, liver, pluck and feet tended to decrease with advancing age. Since these parts mature early (Palsson, 1955), their growth is not proportional to the growth of other carcass components. Thus, the major offal parts tend to decrease with age (from 9 to 18 months) when expressed as a percentage of the slaughter weight. Percent fill also declined as the animal age increased.

The average relative growth rates for the various offal parts of the 12, 15 and 18 month old groups, based on the corresponding offal parts of the 9 month old age group, are shown in Table IV. These data indicate the relative increase in the weight of the offal parts as age advances. It is interesting to compare the relative increase of the visceral fat with the increase of other offal parts. From 9 to 18 months of age there was a 629 percent increase in the weight of internal fat. During the same period, the percent weight increase ranged from 40 to 66 percent for the other

TABLE IV

AVERAGE PERCENTAGE INCREASE IN WEIGHT OF OFFAL PARTS[a]

	Age (Months)			
	9	12	15	18
Head	100	112	131	140
Hide	100	101	138	140
Heart	100	111	168	153
Liver	100	133	145	150
Pluck	100	118	164	166
Feet	100	114	132	142
Visceral Fat	100	180	417	729

[a]Average weight at 12, 15 and 18 months of age is expressed as a percentage of the corresponding weight at 9 months of age.

offal items. These figures verify the generally recognized fact that the offal items, with the exception of visceral fat, represent parts of the body which mature early in life. Thus the offal parts would not be expected to increase at the same rate of development as adipose tissue, which is deposited in greater quantities as the animal becomes older.

Carcass Measurements

Several measurements which illustrate the effect of age on skeletal development are presented in Table V.

Carcass length, length of loin, length of leg and depth of carcass, all reflecting skeletal growth, increased slightly as age progressed. The average percentage increase in these measurements for the 12, 15 and 18 month age groups as compared to the 9 month old group is shown in Table VI. From 9 to 18 months of age, there was only a 15 to 16 percent increase in the length of these various carcass measurements. This indicates that most of the bone growth occurred prior to the time the animals were placed

TABLE V

INFLUENCE OF ANIMAL AGE ON SKELETAL DEVELOPMENT

		9 Month		12 Month		15 Month[a]		18 Month	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Measurement									
Carcass length	in.	38.60	.36	39.90	1.57	43.00	1.16	44.90	1.52
Loin length	in.	20.80	.36	21.50	.65	22.90	.69	23.90	.62
Leg length	in.	24.30	.54	25.40	1.14	26.80	.96	28.00	.83
Chuck width	in.	6.40	.39	5.80	.51	7.40	.58	8.20	.66
Round width	in.	7.10	.42	7.20	.45	8.60	.70	9.00	.61
Carcass depth	in.	12.70	.70	13.20	.43	14.00	.43	14.60	.45
Metacarpal									
area	sq. in.	.89	.06	1.03	.01	1.09	.13	1.09	.10
length	in.	6.80	.15	7.20	.17	----	----	7.50	.17
weight	lbs.	.49	.02	.58	.08	.61	.10	1.02	.02
width	in.	1.28	.04	1.37	.08	1.30	.13	1.50	.10
Metatarsal									
area	sq. in.	.91	.06	1.04	.10	1.18	.09	1.18	.01
length	in.	7.90	.12	8.40	.17	----	----	8.50	.07
weight	lbs.	.57	.03	.67	.08	.70	.09	1.08	.02
width	in.	1.11	.02	1.19	.01	1.23	.07	1.30	.01

[a]The lengths of the metacarpal and metatarsal for 15 month age group were not available.

TABLE VI

AVERAGE PERCENTAGE INCREASE IN DIFFERENT CARCASS MEASUREMENTS[a]

	Age (Months)			
	9	12	15	18
Carcass length	100	103	111	116
Loin length	100	103	110	115
Leg length	100	105	110	115
Chuck width	100	91	116	126
Round width	100	101	121	126
Carcass depth	100	104	110	115

[a]All measurements at 12, 15 and 18 months of age are expressed as a percentage of the corresponding measurements at 9 months of age.

on the experiment and substantiates the observations made by Hammond (1932) that the skeletal portions of the carcass make a greater proportion of their growth early in life. Width of chuck and round do not necessarily provide meaningful estimates of skeletal growth. The former measures the horizontal distance from the center of the first vertebra to the exterior surface of the chuck perpendicular to the dorsal-ventral midline; the latter measures the distance from the center of the pubic bone to the exterior surface of the round, perpendicular to the dorsal-ventral midline. These measurements include changes in dimensions resulting from the development of muscle and fat. This accounts for the greater average percentage increase in the width of chuck and round from 9 to 18 months.

Cross-sectional area, length, weight, and width of the metacarpal and metatarsal bones are also shown in Table V. The rate of bone growth, expressed as the percentage increase in the various measurements at 12, 15 and 18 months of age above the corresponding measurements at 9 months of age, is shown in Table VII. The length measurements increased at a slower

TABLE VII

AVERAGE PERCENTAGE INCREASE IN VARIOUS MEASUREMENTS OF THE METACARPAL AND METATARSAL BONES[a]

	Age (Months)			
	9	12	15[b]	18
Metacarpal				
area	100	116	122	122
length	100	106	----	110
weight	100	118	125	208
width	100	108	102	117
Metatarsal				
area	100	114	129	129
length	100	106	----	108
weight	100	118	123	189
width	100	107	111	117

[a]All measurements at 12, 15 and 18 months of age are expressed as a percentage of the corresponding measurement at 9 months of age.

[b]The lenghts of the metacarpal and metatarsal for 15 months of age were not available.

rate than measurements concerning width or thickness as the animal matured. Palsson and Verges (1952) indicated that the maximum growth rate in length of bones occurs at an earlier age than growth rate in thickness. The weights of the metacarpal and metatarsal increased 108 and 89 percent, respectively, from 9 to 18 months of age.

The means and standard deviations concerning some of the common measurements used to evaluate quantitative differences in beef carcasses are found in Table VIII. As age advanced from 9 to 18 months, the area of the longissimus dorsi muscle increased 2.00, 2.12 and 3.56 square inches at the 6th, 9th and 12th vertebrae, respectively. The maximum increase in muscle area at all three positions occurred during the 12 to 15 month age interval, but the area increase was not as pronounced for the two anterior lo-

TABLE VIII

INFLUENCE OF AGE ON SOME MEASURES OF MUSCLE AND FAT

	9 Month		12 Month		15 Month		18 Month	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Longissimus dorsi area[a]								
6th Vertebra	2.90	.35	3.01	.26	4.30	.51	4.90	.82
9th Vertebra	3.97	.55	4.64	.60	5.93	.32	6.09	.69
12th Vertebra	6.13	.55	6.57	.95	8.48	1.21	9.69	.67
Fat area (12th Vertebra)[a]	1.33	.47	1.78	.24	2.80	.48	4.46	.94
Fat width (12th Vertebra)[b]	.24	.14	.37	.14	.63	.17	.91	.14

[a]Measured in square inches.

[b]Measured in inches.

cations from 15 to 18 months of age. At the 12th thoracic vertebra, the area of the longissimus dorsi increased 1.21 square inches from 15 to 18 months of age as compared to 0.60 and 0.16 square inches at the 6th and 9th vertebrae, respectively. This indicates that the rate of muscle development was greater at the 12th thoracic vertebra as age advanced than at the 6th or 9th thoracic vertebra. This would support the conclusions of Joubert (1959) that the final stages of carcass development occur near the junction of the thoracic and lumbar vertebrae and that this region is the last part of the carcass to attain its maximum growth rate.

From 9 to 18 months, the fat area increased 3.13 square inches. Approximately 53 percent of this increase occurred from 15 to 18 months of age. Since fat is the later maturing tissue in the animal (Palsson, 1955), the rate of development is expected to be greater as the animal advances in age. At 9 months of age, the muscle area at the 12th thoracic vertebra was 4.6 times greater than the fat area. The muscle area was only 2.2 times greater than the fat area at 18 months of age. This points out that the fat development is occurring at a much faster rate than muscle as the animal matures. Width of fat followed the same trend as fat area, in that it increased as age advanced.

Carcass Cut-Out

Table IX depicts the effect of age on the development of the wholesale cuts which comprise the beef side. With advancing age, the percentage of major cuts, which included the chuck, rib, loin, rump and cushion round, showed a highly significant decrease. The cushion round was the only cut in this group that was significantly influenced by age. The percentage of minor cuts, including the kidney knob, flank, brisket, plate, fore shank and hind shank increased as maturity progressed. Most of this increase was

TABLE IX

PERCENTAGES OF DIFFERENT WHOLESALE CUTS AS INFLUENCED BY AGE

	9 Month		12 Month		15 Month		18 Month		
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	"F" Test
Major Cuts[a]	68.04	1.69	66.93	.88	65.89	1.43	64.00	1.45	10.05**
Minor Cuts[b]	31.95	1.69	33.06	.28	34.10	1.43	35.99	1.45	10.32**
Wasty Cuts[c]	22.49	2.05	23.56	.44	26.18	1.35	28.44	2.39	18.25**
Forequarter	49.54	.81	49.20	.58	49.77	.81	49.86	.93	.83
Chuck	24.87	.69	24.15	.90	24.00	.62	23.34	1.52	2.79
Rib	7.86	.50	7.73	.49	8.22	.31	8.36	.57	2.35
Fore Shank	4.62	.27	4.78	.24	3.77	.33	3.57	.26	28.36**
Brisket	4.98	.31	5.22	.74	5.17	.34	5.07	.58	.27
Plate	7.23	.81	7.38	.44	8.62	.94	9.50	.90	1.10
Hindquarter	50.46	.79	50.80	.58	50.23	.81	50.15	.91	.82
Loin	14.20	.55	14.33	.45	14.19	.55	14.47	.66	.33
Rump	5.33	.47	5.74	.61	6.08	.45	5.43	.31	3.08
Round[d]	20.63	1.23	19.78	1.03	17.57	.55	16.38	.73	26.83**
Cushion Round	15.79	1.03	15.07	.88	13.41	.40	12.40	.57	24.50**
Hind Shank	4.84	.30	4.71	.16	4.16	.18	3.98	.26	18.57**
Flank	6.91	.86	7.37	.64	8.27	.75	8.88	.59	9.06**
Kidney Knob	3.37	.68	3.57	.52	4.11	.39	4.98	.54	10.78**

[a]Major cuts consist of chuck, rib, loin, rump and cushion round.
[b]Minor cuts consist of fore shank, hind shank, brisket, plate, flank and kidney knob.
[c]Wasty cuts consist of brisket, plate, flank and kidney knob.
[d]Round = cushion round and hind shank.
**$P < .01$

contributed by the flank and kidney knob, since the brisket and plate were not significantly influenced by animal age (Table IX). Furthermore, there was a significant decrease ($P < .01$) in the percentage of fore and hind shanks as animal age advanced. Since the shanks represent portions of the carcass which mature early in life (Palsson, 1955), it would be expected that they would represent a smaller percentage of the side as the animal grows older.

Age did not significantly influence the percentage of forequarter (Table IX). There was a slight increase in the percentage of rib and plate, but a small decrease in the percentage of chuck as age advanced. However, these differences were not statistically significant.

Although the data in Table IX indicate that animal age did not influence the percentage of total hindquarter, several changes occurred in the wholesale cuts which comprise this quarter. The percentage of round declined with increasing animal age. From 9 to 18 months of age, there was more than a 4 percent decrease in the round. Joubert (1959), Blackmon (1960) and Luitingh (1962) also found that the percentage of round decreased as age advanced. The percentage of kidney knob and flank became significantly larger ($P < .01$) as maturity advanced.

Palsson and Verges (1952) reported that different regions of the sheep carcass develop in a definite order of increasing growth rate from head and feet to the loin region. A similar trend was found in the beef animal as seen in these data (Table X).

The extremities of the carcass had a much slower growth rate than those regions near the center of the carcass. This suggests that central parts of the carcass are later maturing than those of the limbs. Furthermore, it is apparent that as the animal grows older and fatter, the average percentage increase in weight of the ventral portions of the carcass becomes larger than the dorsal regions. Luitingh (1962) reported similar results.

TABLE X

AVERAGE PERCENTAGE INCREASE IN WEIGHT OF WHOLESALE CUTS[a]

	Age (Months)			
	9	12	15	18
Fore Shank	100	122	139	164
Chuck	100	114	166	199
Brisket	100	125	175	214
Rib	100	115	179	227
Plate	100	119	203	281
Shortloin	100	117	173	216
Sirloin	100	121	170	217
Flank	100	123	204	270
Kidney Knob	100	125	209	319
Rump	100	126	196	214
Cushion Round	100	113	148	168
Hind Shank	100	114	147	174

[a]The weights of each wholesale cut at 12, 15 and 18 months of age are expressed as a percentage of the weight of the corresponding cut at 9 months of age.

The average percentage increase in the weight of the kidney knob was larger than other wholesale cuts (Table X). This would be expected since fat was the primary tissue responsible for the increase in the weight of the kidney knob as age advanced. The plate and flank increased 181 and 170 percent in weight, respectively, from 9 to 18 months of age, indicating that these regions mature later than others.

Physical Composition

The results of the physical separation of the side, expressed as the average weights and percentages of lean, fat and bone for the 9, 12, 15 and 18 month age groups are shown in Table XI. Corresponding data for individual animals may be found in the Appendix Table XIX.

TABLE XI

INFLUENCE OF ANIMAL AGE ON THE PHYSICAL COMPOSITION OF THE SIDE

		9 Month		12 Month		15 Month		18 Month	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Bone	lbs.	24.5	1.3	26.9	2.0	41.2	5.3	45.8	1.7
	%	19.3	2.0	18.0	2.0	18.7	1.4	16.9	1.6
Lean	lbs.	71.0	6.3	80.0	1.2	104.1	11.5	124.6	5.6
	%	55.7	3.5	53.1	1.2	47.3	1.3	45.9	3.0
Fat	lbs.	32.5	8.9	43.8	8.3	74.8	10.0	102.6	21.1
	%	25.0	5.2	28.9	1.8	34.0	2.3	37.3	4.2
Side	lbs.	128.0	13.9	150.7	21.3	220.1	24.5	273.0	27.3

TABLE XII

ANALYSIS OF VARIANCE SHOWING THE MEAN SQUARES FOR THE PERCENT BONE, LEAN AND FAT OF THE SIDE

Source	df	Bone M.S.	Lean M.S.	Fat M.S.
Total	23			
Age	3	6.2	130.7**	175.9**
Error	20	3.1	6.1	13.1

**P < .01

As reflected by Figure 2, bone increased at a slower rate than lean or fat as the age of the animal increased. From 9 to 18 months of age, the bone increased 21.3 pounds as compared to 53.6 and 70.1 pounds for lean and fat, respectively. A similar pattern of carcass development was found by Hammond (1932) and McMeekan (1940) in sheep and swine, respectively. Bone, which is an early maturing tissue, reaches its maximum development at a much earlier stage in the life of the animal than muscle (Palsson, 1955). In turn, muscle reaches its maximum development before fat.

Because the bone, lean and fat grow at different rates, the proportion of each tissue in the carcass varies as the age of the animal changes (Figure 3). When the weight of the bone was expressed as a percentage of the side, a slight decrease (2.4 percent) from 9 to 18 months was observed. This difference was not significant (Table XII). A slight increase in the percentage of bone was noted from 12 to 15 months of age. The reason for this is not apparent but may be attributed to chance.

The decline in the percentage of lean tissue was more pronounced than bone (Figure 3). Lean represented 55.7 percent of the side weight at 9 months of age compared to 45.9 percent at 18 months of age. The proportion of lean tissue decreased significantly ($P < .01$) with advancing age (Table XII).

From 9 to 18 months of age, the weight of the fat expressed as a percentage of the side increased more than 13 percent (Figure 3). As indicated in Table XII, the proportion of fat in the side was significantly influenced by animal age.

As the animal matures, the ratio of the three major tissues changes considerably. It is apparent that the proportions of bone and particularly muscle are determined by the deposition of fat. Although bone remains

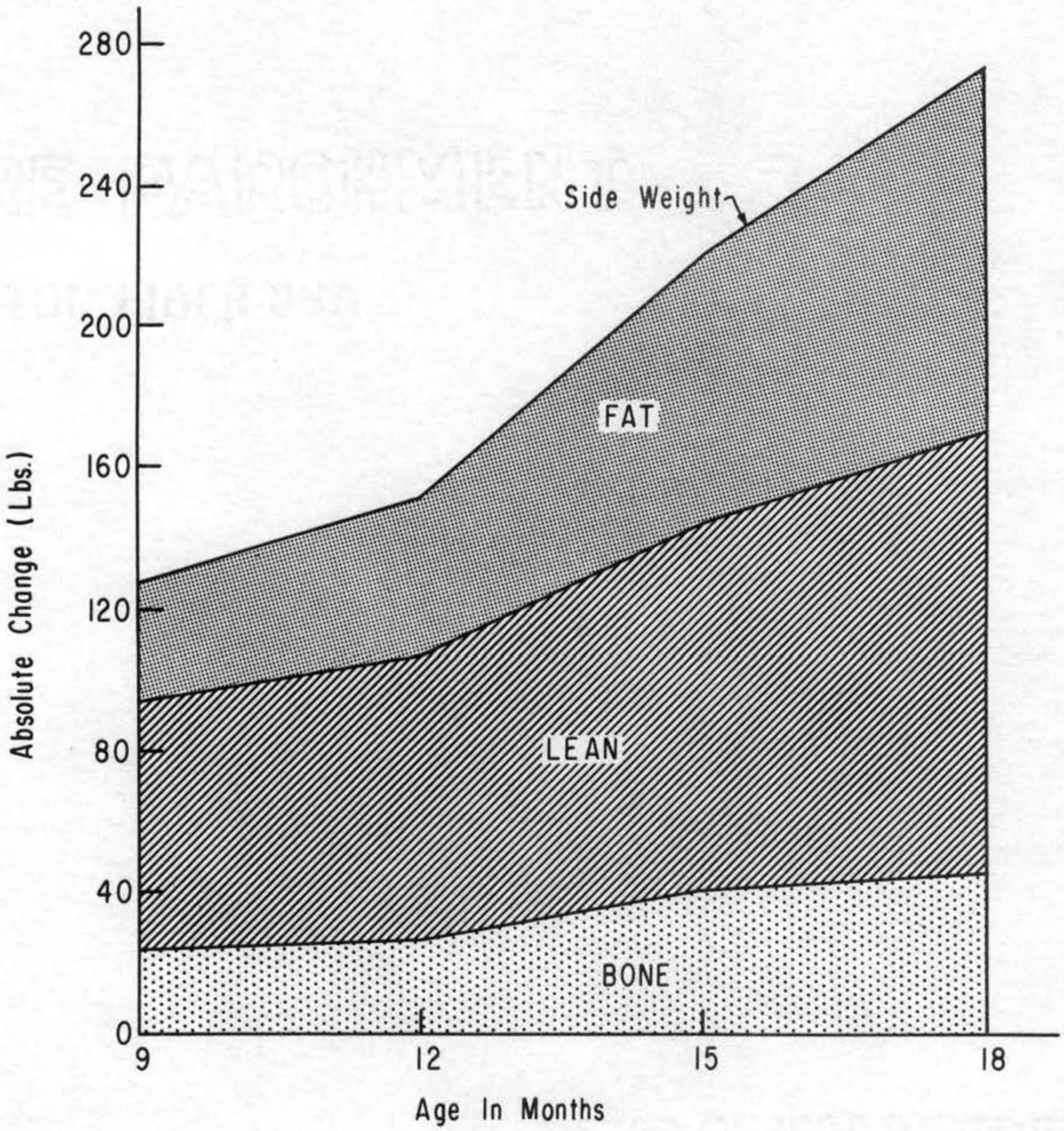

FIGURE 2 - Influence of Age on the Bone, Lean and Fat Weights of the Side.

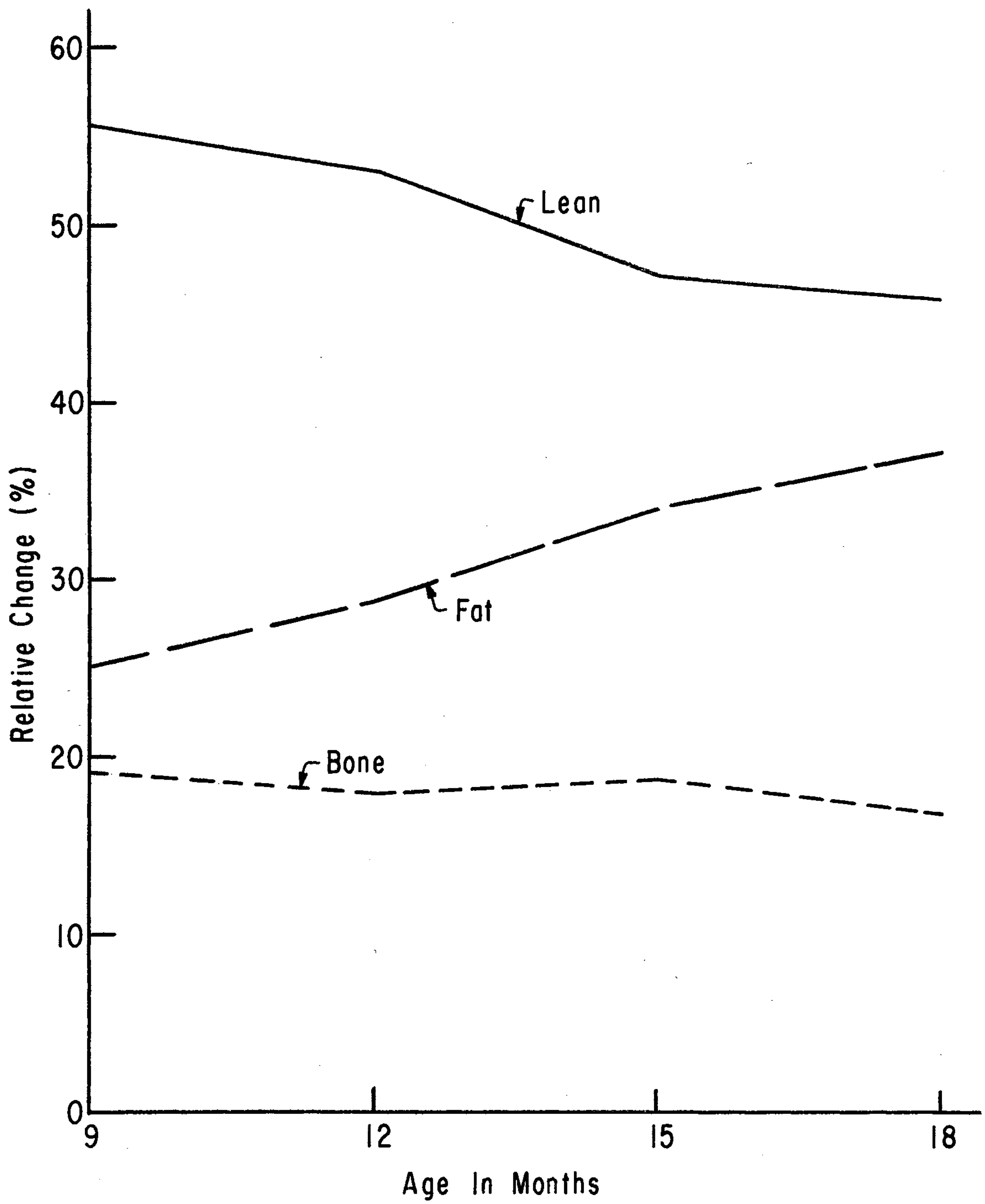

FIGURE 3 - Influence of Age on the Weights of Bone, Lean and Fat Expressed as a Percentage of the Side Weight.

relatively constant, the percentage of muscle decreases as the percentage of fat increases. McMeekan (1940) and Palsson and Verges (1952) found similar trends with swine and sheep, respectively, as the animal age increased.

Data concerning the effect of age on the physical composition of the individual wholesale cuts may be found in the Appendix, Tables XX and XXI. The changes which occurred in the physical composition of the wholesale cuts paralleled those previously discussed with respect to the physical composition of the side.

The data presented in Tables XIII, XIV and XV demonstrate the development of bone, lean and fat, respectively, in different regions of the body as age varies. The weight of each tissue in the wholesale cuts at the 12, 15 and 18 month age groups was expressed as a percentage of the weight of the corresponding tissue at 9 months of age. In general, there was a trend for a greater percentage increase in the weight of the bone, lean and fat in those wholesale cuts near the central regions of the body rather than those near the extremities.

Regarding the relative increase in the weight of the bone (Table XIII), the results indicate that the largest changes occurred in the plate and flank. From 9 to 18 months of age, the weight of the bone in these cuts increased 169 and 133 percent, respectively. The ribs account for the majority of the total bone weight of these two wholesale cuts and the results indicate that the bones in this region of the body are later maturing than other parts of the skeleton. This agrees with the findings of Palsson and Verges (1952) and Joubert (1959). They reported that the ribs are the latest maturing bones in the body.

TABLE XIII

AVERAGE PERCENTAGE INCREASE OF THE WEIGHT OF BONE IN WHOLESALE CUTS[a]

	Age (Months)			
	9	12	15	18
Fore Shank	100	115	142	162
Chuck	100	114	181	183
Brisket	100	92	166	175
Rib	100	111	184	189
Plate	100	118	181	269
Shortloin	100	100	178	171
Sirloin	100	118	182	218
Flank	100	83	167	233
Rump	100	106	169	169
Cushion Round	100	104	162	180
Hind Shank	100	110	145	166

TABLE XIV

AVERAGE PERCENTAGE INCREASE OF THE WEIGHT OF LEAN IN WHOLESALE CUTS[a]

	Age (Months)			
	9	12	15	18
Fore Shank	100	122	130	163
Chuck	100	110	145	174
Brisket	100	124	155	193
Rib	100	107	149	180
Plate	100	114	163	227
Shortloin	100	116	146	177
Sirloin	100	114	144	174
Flank	100	111	159	194
Rump	100	121	173	179
Cushion Round	100	111	136	153
Hind Shank	100	110	144	172

[a]The average weight of tissue in each wholesale cut at 12, 15 and 18 months of age was expressed as a percentage of the average weight of tissue in the corresponding cut at 9 months of age.

TABLE XV

AVERAGE PERCENTAGE INCREASE OF THE WEIGHT OF FAT IN WHOLESALE CUTS[a]

	Age (Months)			
	9	12	15	18
Fore Shank	100	150	167	200
Chuck	100	129	221	303
Brisket	100	142	204	258
Rib	100	133	237	348
Plate	100	127	267	358
Shortloin	100	133	147	344
Sirloin	100	145	250	370
Flank	100	136	240	326
Kidney Knob	100	125	209	319
Rump	100	160	280	353
Cushion Round	100	136	204	240
Hind Shank	100	125	188	212

[a]The average weight of tissue in each wholesale cut at 12, 15 and 18 months of age was expressed as a percentage of the average weight of tissue in the corresponding cut at 9 months of age.

As reflected by the data in Table XIV, the relative increase in the weight of lean was larger in the flank, plate and brisket than in the other wholesale cuts. From 9 to 18 months of age, the weight of lean in the plate increased 127 percent as compared to 94 and 93 percent for the flank and brisket, respectively. The percentage increase in the weight of lean in the remaining wholesale cuts ranged from 53 to 80 percent as age increased from 9 to 18 months.

The sirloin and plate had a larger percentage increase in the weight of fat than the other wholesale cuts as age advanced from 9 to 18 months (Table XV). This increase was 270 percent and 258 percent for the sirloin and plate, respectively. Large relative increases in the weight of fat were also found in the rib, rump and shortloin. Thus, it appeared as age increased the fat deposition is more concentrated near the central regions of the body.

When the relative increases of weight of bone, lean and fat are compared, it is apparent that fat was developing at a much higher rate than lean or bone in all the wholesale cuts. This trend would be expected since bone and lean mature earlier than fat (Palsson, 1955). There is also a trend suggesting that the region of the body which includes the plate is later maturing than other sections.

Chemical Composition

A summary of the results concerning the influence of age on the chemical composition of the boneless portion of the side is shown in Table XVI. Weights and percentages of moisture, ash, protein and ether extract for individual animals are shown in the Appendix, Table XXII. The absolute and relative changes in ash, protein, moisture and ether extract are presented graphically in Figures 4 and 5, respectively.

The weight of the ash in the side increased less than one pound from 9 to 18 months of age. On a relative basis, the proportion of ash in the side decreased significantly as age advanced (Table XVII).

The protein content of the side was approximately 13 pounds greater at 18 months of age than it was at 9 months. When the weight of protein was expressed as a percentage of the boneless side weight, the percentage protein decreased significantly with advancing age (Table XVII). Blackmon (1960) found that animal age did not significantly influence the percent protein. However, only the lean tissue of a portion of the longissimus dorsi muscle was analyzed. The fat and lean tissues of the boneless portion of the side were analyzed in this study and it is probable that the presence of the fat was responsible for the relative decrease in protein, ash and moisture (Figure 5).

TABLE XVI

INFLUENCE OF AGE ON THE CHEMICAL COMPOSITION OF THE SIDE

		9 Month		12 Month		15 Month		18 Month	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Protein	lbs.	17.34	1.59	20.72	3.37	26.16	2.58	30.03	1.56
	%	17.61	1.27	17.50	0.36	15.43	0.47	14.16	1.13
Ether Extract	lbs.	23.38	7.32	30.46	5.84	54.85	7.36	79.34	17.11
	%	23.13	5.30	25.64	1.80	32.26	1.81	36.80	4.18
Moisture	lbs.	56.93	5.14	66.56	10.75	88.57	10.27	103.27	5.83
	%	57.78	3.78	56.23	1.14	52.16	1.76	48.65	3.47
Ash	lbs.	0.84	0.10	0.98	0.14	1.14	0.14	1.35	0.08
	%	0.86	0.10	0.83	0.05	0.67	0.05	0.64	0.06

TABLE XVII

ANALYSIS OF VARIANCE SHOWING MEAN SQUARES FOR PERCENT PROTEIN, ETHER EXTRACT, MOISTURE AND ASH OF THE SIDE

Source	df	Protein	Ether Extract	Moisture	Ash
Total	23				
Age	3	16.86**	232.74**	102.05**	0.07**
Error	20	0.81	13.04	7.10	0.004

**$P < .01$

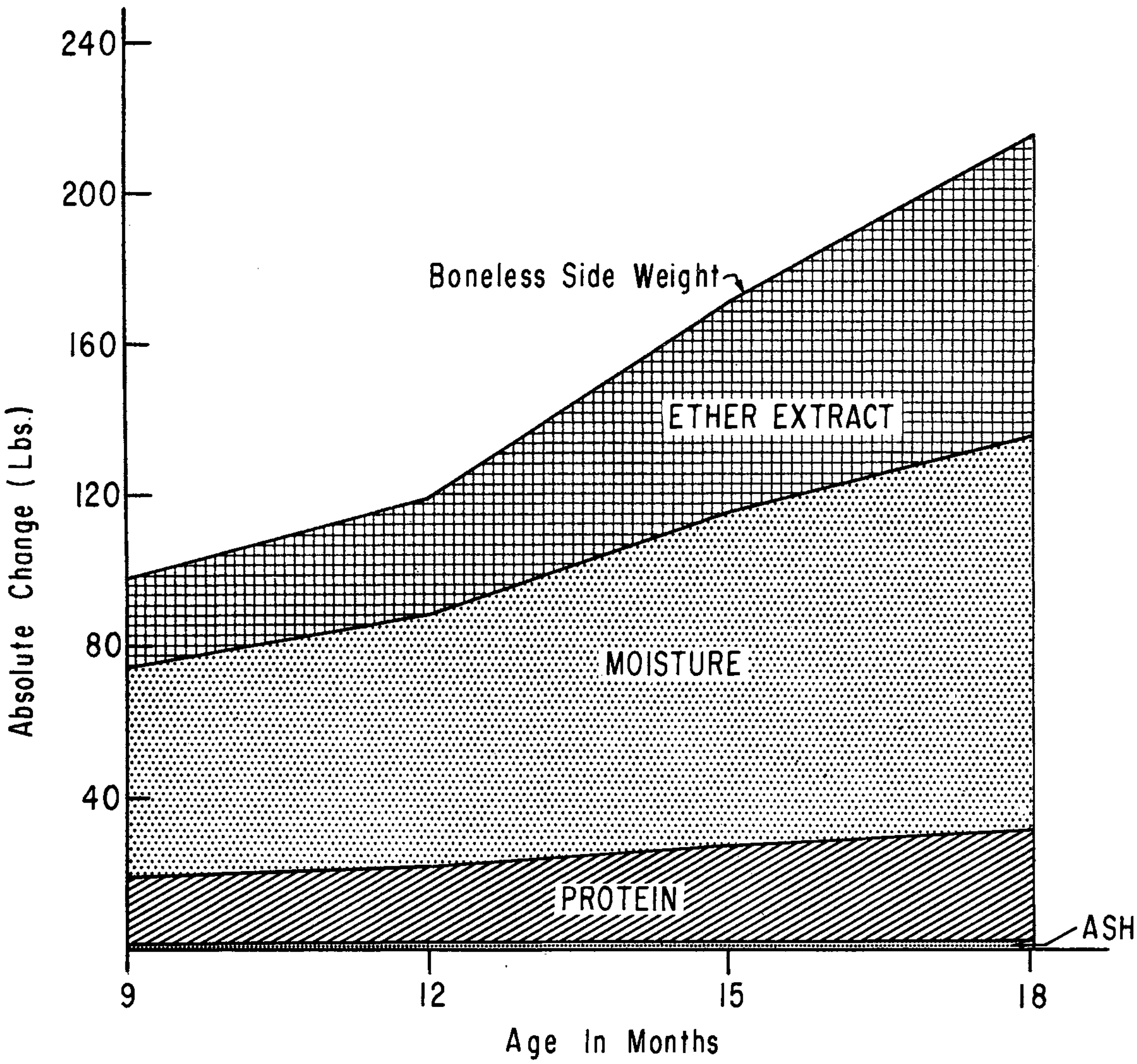

FIGURE 4 - Influence of Age on the Ash, Protein, Moisture and Ether Extracts Weights of the Boneless Side.

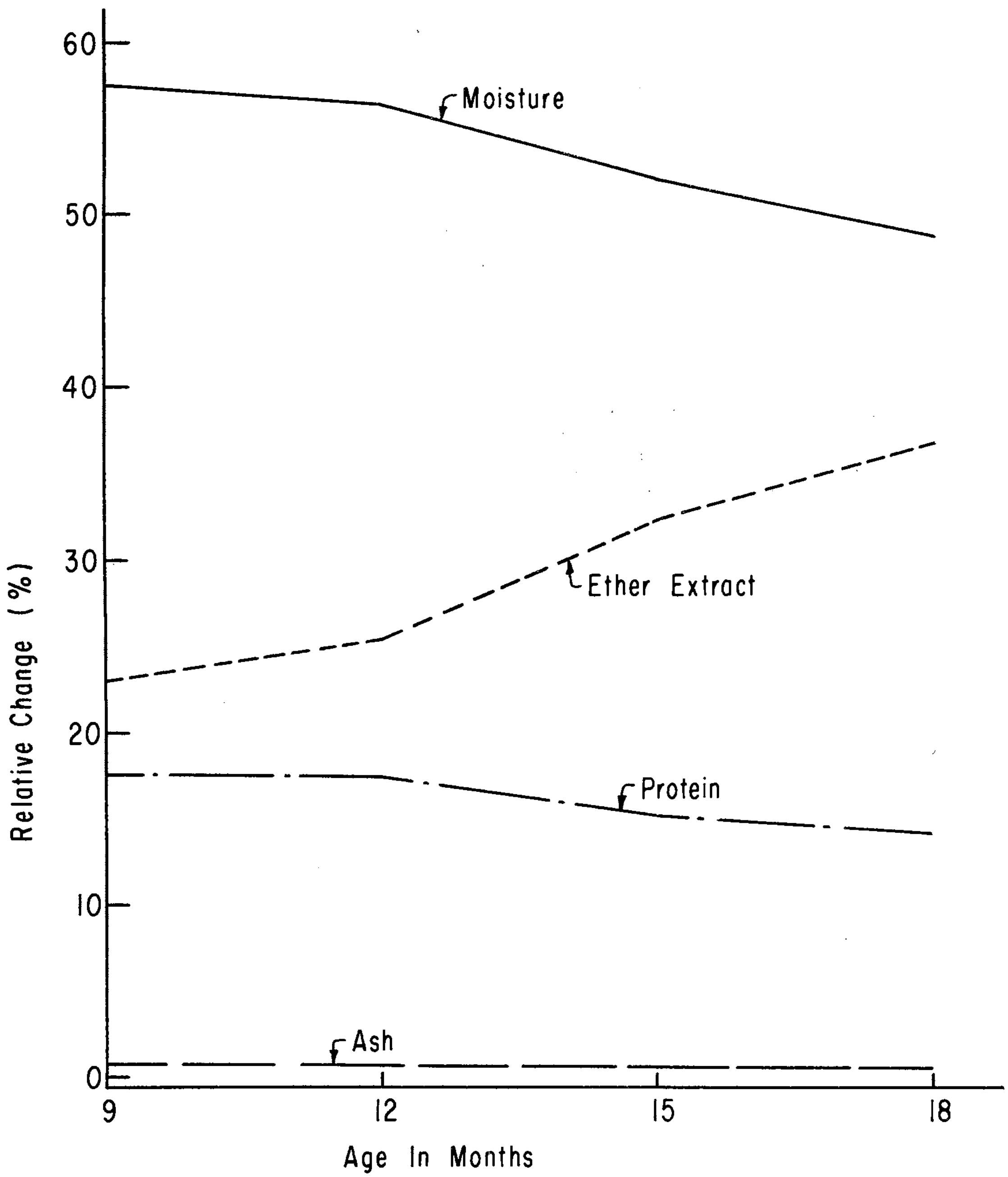

FIGURE 5 - Influence of Age on the Weights of Ash, Protein, Moisture, and Ether Extract Expressed as a Percentage of the Boneless Side Weight.

Although the moisture content increased more than 46 pounds from 9 to 18 months of age, the percentage of moisture decreased more than 9 percent. This difference was significantly influenced by animal age (Table XVII). Moulton (1923) reported that the percentage of moisture decreased with advancing age.

The fat content of the boneless portion of the side was determined by ether extraction. As age advanced from 9 to 18 months, the weight of the fat (ether extract) increased approximately 56 pounds (Table XVI). On a relative basis the ether extract increased more than 13 percent from 9 to 18 months of age. This increase was highly significant (Table XVII).

The average increase in the total weight of the side was 115.5 pounds from 9 to 18 months of age. The increase in the weight of ether extract represented 48.45 percent of the total increase in the weight of the boneless side as compared to 40.12, 10.99 and 0.44 percent for moisture, protein and ash, respectively.

In the previous discussion concerning the physical composition of the beef side, it was pointed out that the rapid development of fat, as age progressed, decreased the proportion of lean and bone in the side. The ether extract determinations reflect a similar effect on the proportion of ash, protein and particularly moisture (Figure 5).

SUMMARY

Twenty-four Hereford heifers were used to investigate the effects of increasing age on the changes in carcass composition. Six heifers were assigned to each of four age groups (9, 12, 15 and 18 months) at weaning. The 9 month old group was slaughtered at the outset of the experiment and used as a basis to study the subsequent changes in carcass composition as age increased. The remaining groups were fed a fattening ration until the assigned slaughter age was attained. Average slaughter weights were 451.8, 519.7, 712.2 and 844.3 pounds for the 9, 12, 15 and 18 month old groups, respectively. Carcass measurements, weights of offal products, yields of wholesale cuts, physical separation of the side and proximate analysis of the boneless tissues were obtained.

The results indicate that differential growth rates of various regions of the carcass and particularly the rate of fat deposition in the different wholesale cuts were the most important factors influencing the changes in carcass composition as age advanced. Vital organs and carcass extremities were well developed at 9 months of age, as evidenced by their slower rates of growth from 9 to 18 months. More intensive growth rates were found in the plate and flank than in the other wholesale cuts as the heifers matured.

Skeletal growth, as reflected by length of carcass, leg, loin and depth of carcass, increased slightly as age advanced. It was noted that there was only a 15 to 16 percent increase in the bone length, indicating

that most of the growth occurred prior to the beginning of this experiment. The rib bones were later maturing than other skeletal parts.

The increase in pounds of lean was approximately 2.5 times greater than the pounds of bone during the 9 to 18 month period. This suggests that bone growth was occurring at a slower rate than lean. The relative increase in the weight of lean was greater in the plate, flank and brisket than in the other wholesale cuts studied. Rate of muscle development, as reflected by the area of the longissimus dorsi muscle, was greater near the junction of the thoracic and lumbar vertebrae than at the more anterior locations.

Several factors provided evidence that the rate of fat deposition exceeded bone and muscle growth as age advanced. The average increase in the weight of separable fat between 9 and 18 months was 70.1 pounds as compared with 53.6 and 21.3 pounds for separable lean and bone, respectively. When the fat, lean and bone weights were expressed as a percentage of the side weight, the percent fat increased significantly, while the percent bone and lean decreased. Similar results were apparent from the proximate analysis of the boneless tissue. The percent of chemically determined fat (ether extract) increased while the percent protein, moisture and ash decreased. The weight of fat determined by ether extraction accounted for 48 percent of the increase in the boneless side weight during the 9 to 18 month period. In general, as age increased, fat was responsible for the major changes that occurred in the composition of the beef carcass.

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APPENDIX

TABLE XVIII

CARCASS DATA FOR INDIVIDUAL ANIMALS[a]

Animal No.	Slaughter Wt.	Cold Carcass Wt.	Yield %	Grade	Marbling	Head %	Hide %
			9 Month Age				
138	462.0	265.0	57.36	Standard+	Traces	3.72	8.81
406	398.0	275.0	52.14	Utility+	Prac. devoid	3.97	11.31
409	448.0	256.0	57.14	Standard	Traces	3.84	8.32
420	440.0	250.0	58.18	Standard	Traces	3.98	8.41
452	481.0	279.0	58.00	Standard	Traces	3.70	10.40
473	482.0	279.5	57.99	Standard+	Traces	3.30	9.25
			12 Month Age				
443	581.0	265.0	59.64	Good-	Traces	3.30	7.54
127	448.0	275.0	56.58	Good-	Traces	3.68	7.86
134	471.0	256.0	57.64	Good	Traces	3.63	8.20
463	511.0	250.0	59.20	Standard+	Traces	3.41	8.86
199	605.0	279.0	60.00	Standard+	Traces	3.31	8.26
103	502.0	279.5	58.86	Good	Sli. amt.	3.53	8.82
			15 Month Age				
105	714.0	346.5	60.85	Choice	Moderate	3.04	9.15
405	845.0	253.5	61.95	Choice-	Sm. amt.	2.96	7.92
407	683.0	271.5	61.35	Good-	Sli. amt.	3.31	7.96
305	674.0	302.5	61.94	Good	Traces	3.38	8.19
112	615.0	363.0	61.63	Good	Sli. amt.	3.15	8.70
159	742.0	295.5	63.61	Good+	Sli. amt.	2.90	7.59
			18 Month Age				
453	900.0	434.5	63.05	Good+	Sm. amt.	2.82	5.98
146	820.0	532.5	65.60	Good+	Sm. amt.	2.98	8.35
145	916.0	419.0	66.81	Good+	Sm. amt.	2.48	6.23
163	778.0	421.5	65.10	Good	Sli. amt.	2.85	7.76
197	920.0	384.5	65.05	Choice-	Moderate	2.67	6.75
140	730.0	479.0	64.69	Good	Sm. amt.	3.14	7.43

[a]Percentage values based on slaughter weight.

TABLE XVIII (Cont'd)

Animal No.	Heart %	Liver %	Pluck %	Feet %	Fill %	Visceral Fat %
			9 Month Age			
138	0.43	1.45	1.86	1.88	6.33	0.65
406	0.45	1.51	2.00	2.36	7.14	0.60
409	0.42	1.38	1.85	1.88	7.35	0.76
420	0.43	1.32	2.11	1.95	5.81	0.86
452	0.42	1.48	2.08	2.03	7.09	0.73
473	0.37	1.31	1.78	1.82	5.89	1.01
			12 Month Age			
443	0.44	1.51	1.96	2.03	6.17	1.02
127	0.40	1.94	2.17	2.06	7.54	0.95
134	0.42	1.73	2.17	2.04	7.13	1.00
463	0.37	1.41	1.92	1.97	5.28	1.96
199	0.40	1.49	1.87	1.82	6.11	0.99
103	0.40	1.77	2.03	2.03	4.58	1.33
			15 Month Age			
105	0.42	1.34	2.02	1.72	3.92	1.94
405	0.40	1.23	2.28	1.57	4.50	2.24
407	0.44	1.33	2.05	1.71	4.30	2.04
305	0.49	1.38	1.78	1.65	4.48	1.81
112	0.57	1.32	2.10	1.82	4.41	1.01
159	0.38	1.21	1.85	1.56	4.06	2.43
			18 Month Age			
453	0.36	1.14	1.82	1.44	4.63	3.89
146	0.33	1.22	1.62	1.59	3.91	2.45
145	0.33	1.10	1.79	1.42	3.38	2.64
163	0.32	1.05	1.59	1.14	2.86	2.81
197	0.35	1.07	1.77	1.45	2.39	3.66
140	0.36	1.23	1.79	1.72	3.70	2.46

TABLE XIX

WEIGHTS AND PERCENTAGES OF SEPARABLE LEAN, FAT AND BONE FOR INDIVIDUAL ANIMALS

Animal No.	Pounds in Side: Lean	Fat	Bone	Percent in Side: Lean	Fat	Bone
9 Month Age						
138	67.7	39.0	24.8	51.48	29.66	18.86
406	62.3	16.6	23.2	61.02	16.60	22.72
409	69.4	31.4	25.2	55.08	24.92	20.00
420	71.6	33.4	23.4	55.76	26.01	18.22
452	80.9	31.8	26.5	58.12	22.84	19.04
473	73.9	42.6	23.7	52.71	30.39	16.90
12 Month Age						
443	89.9	52.8	27.6	52.77	31.02	16.21
127	65.4	34.2	26.2	51.95	27.22	20.83
134	73.4	35.6	24.9	54.82	26.59	18.60
463	78.8	45.9	24.6	52.78	30.74	16.48
199	98.2	53.4	29.6	54.24	29.45	16.31
103	74.4	40.7	28.5	51.81	28.34	19.85
15 Month Age						
105	97.9	75.1	41.6	45.62	35.00	19.38
405	123.5	89.9	47.2	47.38	34.49	18.11
407	103.4	61.6	44.1	49.45	29.46	21.09
305	98.7	75.7	36.2	46.87	35.94	17.19
112	90.7	66.4	33.5	47.59	34.84	17.57
159	110.5	80.4	44.9	46.86	34.10	19.04
18 Month Age						
453	129.4	107.2	46.1	45.77	37.92	16.31
146	120.5	99.1	45.6	45.44	37.37	17.19
145	128.2	127.4	48.3	42.18	41.92	15.89
163	124.9	86.6	43.3	49.02	33.99	16.99
197	128.9	123.0	46.6	43.18	41.21	15.61
140	115.4	72.5	44.9	49.57	31.14	19.92

TABLE XX

AVERAGE WEIGHTS AND PERCENTAGES OF SEPARABLE LEAN, FAT AND BONE IN THE WHOLESALE CUTS OF THE FOREQUARTER

	Age (Months)							
	9		12		15		18	
	lbs.	%	lbs.	%	lbs.	%	lbs.	%
Fore Shank	5.7		7.2		8.2		9.8	
Lean	2.7	45.76	3.3	45.83	3.5	42.68	4.4	44.90
Fat	0.6	10.17	0.9	12.50	1.0	12.20	1.2	12.24
Bone	2.6	44.06	3.0	41.66	3.7	45.12	4.2	42.86
Chuck	31.8		36.3		52.8		63.5	
Lean	19.6	61.64	21.5	59.23	28.4	53.79	34.2	53.85
Fat	5.8	18.23	7.5	20.66	12.8	24.24	17.6	27.72
Bone	6.4	20.12	7.3	20.11	11.6	21.97	11.7	18.42
Brisket	6.5		8.1		11.4		13.9	
Lean	2.9	44.62	3.6	44.44	4.5	39.47	5.6	40.29
Fat	2.4	36.92	3.4	41.98	4.9	42.98	6.2	44.60
Bone	1.2	18.46	1.1	13.58	2.0	17.54	2.1	15.11
Plate	9.3		11.1		18.9		26.1	
Lean	4.4	47.31	5.0	45.04	7.2	38.10	10.0	38.31
Fat	3.3	35.48	4.2	37.84	8.8	46.56	11.8	45.21
Bone	1.6	17.20	1.9	17.12	2.9	15.34	4.3	16.48
Rib	10.1		11.6		18.1		22.9	
Lean	5.5	54.46	5.9	50.86	8.2	45.30	9.9	43.23
Fat	2.7	26.73	3.6	31.03	6.4	35.36	9.4	41.05
Bone	1.9	18.81	2.1	18.10	3.5	19.34	3.6	15.72
Forequarter	63.4		74.1		109.5		136.0	
Lean	35.0	55.20	39.2	52.90	51.9	47.40	64.0	47.06
Fat	14.7	23.19	19.5	26.31	33.8	30.87	46.1	33.90
Bone	13.7	21.61	15.4	20.78	23.8	21.74	25.9	19.04

TABLE XXI

AVERAGE WEIGHTS AND PERCENTAGES OF SEPARABLE LEAN, FAT AND BONE IN THE WHOLESALE CUTS OF THE HINDQUARTER

	Age (Months)							
	9		12		15		18	
	lbs.	%	lbs.	%	lbs.	%	lbs.	%
Flank	9.0		11.1		18.4		24.3	
Lean	3.4	37.78	3.8	34.23	5.4	29.35	6.6	27.16
Fat	5.0	55.56	6.8	61.26	12.0	65.22	16.3	67.08
Bone	0.6	6.67	0.5	4.50	1.0	5.43	1.4	5.76
Shortloin	7.5		8.8		13.0		16.2	
Lean	4.3	57.33	5.0	56.82	6.3	48.46	7.6	46.91
Fat	1.8	24.00	2.4	27.27	4.2	32.31	6.2	38.27
Bone	1.4	18.67	1.4	15.91	2.5	19.23	2.4	14.81
Sirloin	10.7		12.9		18.2		23.3	
Lean	7.0	65.42	8.0	62.02	10.1	55.49	12.2	52.36
Fat	2.0	18.69	2.9	22.48	5.0	27.47	7.4	31.76
Bone	1.7	15.89	2.0	15.50	3.1	17.03	3.7	15.88
Rump	6.9		8.7		13.5		14.8	
Lean	3.8	62.09	4.6	52.87	6.6	48.89	6.8	45.94
Fat	1.5	20.88	2.4	27.59	4.2	31.11	5.3	35.81
Bone	1.6	17.03	1.7	19.54	2.7	20.00	2.7	18.24
Cushion Round	20.1		22.7		29.7		33.8	
Lean	15.0	55.07	16.6	73.13	20.4	68.69	23.0	68.05
Fat	2.5	21.74	3.4	14.98	5.1	17.17	6.0	17.75
Bone	2.6	23.19	2.7	11.89	4.2	14.14	4.8	14.20
Hind Shank	6.2		7.1		9.1		10.8	
Lean	2.5	74.63	2.9	40.84	3.4	37.36	4.3	39.81
Fat	0.8	12.44	1.0	14.08	1.5	16.48	1.7	15.74
Bone	2.9	12.93	3.2	45.07	4.2	46.15	4.8	44.44
Hindquarter	64.5		76.5		110.6		136.9	
Lean	35.9	40.32	40.8	53.33	52.2	47.20	60.5	44.19
Fat	17.8	12.90	24.3	31.76	41.0	37.07	56.5	41.27
Bone	10.8	46.77	11.4	14.90	17.4	15.73	19.9	14.54

TABLE XXII

WEIGHTS AND PERCENTAGES OF MOISTURE, ASH, PROTEIN AND ETHER EXTRACT FOR INDIVIDUAL ANIMALS

Animal No.	Pounds in Side: Moisture	Ash	Protein	Ether Extract	Percent in Side: Moisture	Ash	Protein	Ether Extract
9 Month Age								
138	55.14	.80	16.72	27.37	54.81	.80	16.62	27.21
406	49.14	.74	14.88	10.78	64.57	.97	19.55	14.16
409	55.35	.81	17.15	22.24	57.48	.84	17.81	23.09
420	57.17	.87	17.78	24.08	56.60	.86	17.60	23.84
452	64.12	1.03	19.73	22.90	59.10	.95	18.18	21.11
473	60.66	.81	17.81	32.92	54.11	.72	15.89	29.37
12 Month Age								
443	76.42	1.07	23.23	36.22	55.70	.78	16.93	26.40
127	53.96	.84	16.78	22.50	57.28	.89	17.81	23.89
134	59.99	.91	18.45	25.08	57.46	.87	17.67	24.02
463	66.59	1.01	20.75	30.01	56.10	.85	17.48	25.28
199	82.04	1.21	25.96	37.01	56.50	.83	17.88	25.49
103	60.34	.87	19.15	31.92	54.36	.78	17.25	28.76
15 Month Age								
105	82.29	1.03	24.33	56.39	50.33	.63	14.88	34.49
405	106.16	1.32	30.41	65.97	52.09	.65	14.92	32.37
407	87.29	1.08	24.93	45.48	55.53	.69	15.86	28.93
305	84.93	1.15	26.32	53.94	51.63	.70	16.00	32.79
112	76.93	.99	23.32	48.51	51.46	.66	15.60	32.45
159	93.82	1.24	27.65	58.82	51.92	.69	15.30	32.55
18 Month Age								
453	106.40	1.32	31.02	81.74	48.19	.60	14.50	37.02
146	99.12	1.36	29.67	79.10	47.54	.65	14.23	37.94
145	108.84	1.29	31.02	97.62	45.50	.54	12.97	40.81
163	103.18	1.31	31.06	64.79	51.85	.68	15.61	32.56
197	108.18	1.51	30.38	97.55	45.80	.64	12.86	41.30
140	93.90	1.31	27.04	55.25	52.96	.74	15.25	31.16

VITA

Louis Alonzo Malkus

Candidate for the Degree of

Doctor of Philosophy

Thesis: CHANGES IN CARCASS COMPOSITION FROM 9 TO 18 MONTHS IN HEIFERS FED A FATTENING RATION

Major Field: Meat Science

Biographical:

Personal Data: Born in Washington, D.C., October 20, 1936, the son of Louis and Kathryn Dille Malkus. Married Mary V. Walton on August 20, 1960.

Education: Graduated from Charlotte Hall Military Academy in 1954, awarded the Bachelor of Science degree from University of Maryland, with a major in Animal Husbandry in May, 1958; received the Master of Science degree from University of Connecticut, with a major in Animal Husbandry in August, 1961.

Experience: Employed with several beef cattle farms and a meat packer during the summer recess from college; Graduate Assistant in Animal Husbandry, University of Connecticut, 1959-1960; Graduate Assistant in Animal Science, Oklahoma State University, 1960-1964.

Professional Organizations: Member of the American Society of Animal Production and Alpha Zeta.

Date of Degree: May, 1964.