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DEVELOPMENTAL CHANGES IN MAJOR TISSUES OF CONTINENTAL EUROPEAN CROSSBRED STEERS

By

Aubrey Lynn Schroeder

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ABSTRACT

DEVELOPMENTAL CHANGES IN MAJOR TISSUES OF CONTINENTAL EUROPEAN CROSSBRED STEERS

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Developmental changes in physical and chemical composition of the subcutaneous, intermuscular, perirenal and intramuscular adipose tissues (AT), major skeletal muscles, noncarcass tissues and bones of Continental European crossbred steers were examined. Intermuscular AT was the largest deposit of carcass AT, accounting for 49.2% of the total in 300 kg steers, declining to 39.6% in the 555 kg steers. Intramuscular AT was comparable in quantity to the perirenal AT, however, the chemical composition of each depot varied greatly. Perirenal AT contained the most lipid and the lowest percentage of protein at all weights. The longissimus dorsi and biceps femoris were the largest muscles in the carcass, each accounting for approximately 6.5% of the total skeletal muscle. Percentage skeletal muscle of the empty body, at each slaughter group was 42.3, 40.2, 38.1 and 38.7%, respectively. Carcass bone accounted for approximately 79.5% of total empty body bone for each group.

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INTRODUCTION

The effects of various treatments on the development and composition of beef cattle is well documented. The early studies of Trowbridge, (1919); Haecker, (1920); Moulton, (1922b); Hopper, (1944); Hankins and Howe, (1946); Callow, (1962); Luitingh, (1962) and Johnson et al. (1972) thoroughly examined the composition of British-bred beef cattle. From these and similar studies, numerous relationships and growth patterns of the major carcass components, muscle, fat, bone and other body tissues have been derived and continue to be used today. The forementioned studies were conducted during a period when the production of older (2 to 4 years of age), fat and high quality (average Choice to Prime) beef was deemed desirable in the marketplace. Consequently, British-bred cattle were the primary source of beef used in these studies involving the dissection and quantitation of the chemical and physical makeup of the carcass and body tissues. While the general patterns and principles behind the growth of the beef animal remain the same, recent studies by Koch et al. (1977); Jones et al. (1985b) and Shahin and Berg, (1985a,b,c) suggest that the relationships and distribution of tissues in the bovine body have been genetically altered

by the introduction of Continental European breeds.

This study was designed to examine the developmental changes in the composition of major body tissues in the increasingly common Continental European crossbred steers found in today's beef herds. Due to the prohibitive costs involved in complete dissection, a limited amount of data on Continental European crossbred cattle has been reported which extensively examines the changes in the distribution of the body tissues (i.e., fat depots, skeletal muscle, bone, major body tissues and visceral components). Through an extensive dissection procedure involving twenty genetically similar Continental European crossbred steers at four development stages, I have accumulated new data on the composition and distribution of the earlier mentioned carcass and body components. It is hoped that this study and resulting data will serve as a basis for further studies which will update and provide new relationships for development of equations to more accurately assess the effects of various treatments on the composition of today's leaner cattle.

LITERATURE REVIEW

The growth of animals has been extensively researched during the past 60 years. This will continue to be a widely investigated area as long as commercial livestock production and meat consumption are an integral part of agriculture. New marketing endpoints and greater understanding of the cellular mechanisms of growth have produced considerable research in the area of manipulating the growth processes by controlling endogenous body functions (Unruh, 1986) as well as by use of exogenous agents (Ricks et al., 1984a,b; Beermann et al., 1985,1986). Regardless of the method of control, the major emphasis continues to be the production of carcasses with maximum muscle content combined with acceptable fat and minimal amounts of bone.

Growth is a highly regulated, complex process, that has been described in many ways. Schlose (1911) described growth as an increase in body mass at definite time intervals. Hammond (1952) defines the increase in body weight until mature size is attained as growth. Fowler (1968) viewed growth in two aspects. The first is explained as a measured increase in mass or weight over time. The other aspect considers the effect of differential growth in components of the body and its effect on changes in form

and composition. Even though no single definition is entirely satisfactory, animal scientists generally accept the description presented by Maynard and Loosli (1969). True growth, is an increase in muscles, bones and organs which must be differentiated from the increase due to fat accumulation in adipose tissue. Any increase, therefore, of water, ash or protein in tissues constitutes true growth. Purchas (personal communication) agreed, stating that because of the very large number of biological processes involved in growth, to define growth simply as a change in size or mass is misleading. Therefore, he describes the overall process as growth and development.

Skeletal Muscle. Consideration of skeletal muscle development is necessary since skeletal muscle is by far the most significant lean tissue in the body. At birth the body of a calf consists of approximately two parts muscle to one part bone (Berg and Butterfield, 1976). Net skeletal muscle accretion, then, results from a complex interaction of myogenic cell proliferation and (or) differentiation and muscle protein accretion rates (Allen et al. 1979a,b). Since muscle fiber numbers become fixed soon after birth (Montgomery,1962; Holtzer, 1970a; Young and Allen, 1979), the ultimate growth of muscle tissue comes from the hypertrophy of muscle cells present at or shortly after birth. The embryonic origin of muscle is the mesoderm

(Kelly and Zachs, 1969). During early stages mesenchymal cells derived from the mesoderm are partitioned among cell lineages with a portion becoming part of the myogenic cell line (Allen et al. 1979.). At this stage, all presumptive cells contain similar cytoplasmic constituents and are capable of mitotic proliferation.

Differentiation produces presumptive myoblasts which are committed to formation of muscle tissue. However, also during this time, the presumptive myoblasts are unable to synthesize myofibrillar proteins. Eventually, the presumptive myoblasts further differentiate to become myoblasts which then fuse to form multinucleated myotubes. Synthesis of myofibrillar proteins is now possible but DNA synthesis and cell proliferation cease (Stockdale and Holtzer, 1961; Holtzer, 1970a,b; Stockdale, 1970). Further maturation continues with the migration of the nuclei to the periphery, resulting in the formation of myofibers. Bulk synthesis and alignment of myofibrillar proteins is now possible and maturation of muscle fibers continues. The development of the mitochondria, nerve and sarcotubular systems are among the final events in the maturation of the muscle fibers.

Numerous studies have examined the growth of muscle, finding both an increase in myofiber size and DNA content in the muscle. Increases in myofiber size has been shown to

be caused by an accumulation of myofibrillar proteins and the subsequent splitting of myofibrils (Goldspink, 1972; Stromer et al. 1974; Allen et al., 1979a; Young and Allen, 1979 and Mulvaney, 1981), with no measured increase in fiber number (McMeekan, 1940a; Goldspink, 1972). This would suggest that since nuclei can no longer divide or synthesize DNA, DNA content of the muscle should remain constant. However, extensive work (Stockdale and Holtzer, 1961; Mostafavi, 1978; Burleigh, 1980; Allen et al., 1979a), has indicated that the multinucleated muscle cells are definitely nonproliferative. Thus, any increase in DNA content, must represent an increase in the overall number of nuclei without an increase in myofiber number (Young et al., 1979a,b). Early work by Winnick and Noble (1965) showed a developmental increase in DNA within muscle. Convinced that increased muscle cell DNA was due to some source other than myonuclei hyperplasia, MacConnachie et al. (1964) found the incorporation of satellite cells, previously described by Mauro (1961) and later by Muir et al. (1965), were responsible for elevated DNA concentrations. Later studies confirmed that the mitotic and myogenic properties of these cells and the subsequent incorporation of their nuclei into muscle cells (Shafiq et al., 1968; Church, 1969; Moss et al., 1970; Stromer et al., 1974; Young et al., 1979a,b).

Adipose Tissue. Adipose tissue is the latest major body tissue to develop. Fat continues to accumulate long after muscle and bone growth has essentially ceased. This phenomenon has been observed in all meat animal species; cattle (Callow, 1948; Berg and Butterfield, 1976), swine (McMeekan, 1940a;Cole et al., 1976) and also in sheep (Hammond, 1932). Cattle go through a biphasic development of fat, with various depots of fat filling at different times, corresponding to the prefattening stage, followed by the fattening stage (Pomeroy et al., 1966). Regardless of the depot, the growth of adipose tissue until slaughter is accomplished by hyperplasia and hypertrophy.

As in muscle, the middle germ layer, the mesoderm is again responsible for origin of adipose tissue. Although the precise developmental histogenesis needs clarification, adipose tissue is thought to develop as a result of differentiation of the mesenchymal cells into preadipocytes (Allen et al.,1976). Ham (1969) found that adipose tissue is closely associated with connective tissues, in particular, loose connective tissue. During the early embryonic stage, distinguishing preadipocytes or presumptive adipoblasts from other presumptive cells is difficult since very little if any lipid is being stored in these cells. Wasserman (1965) states that eventually, however, distinct droplets of lipid material become visible

in the cytoplasm, confirming the presence of the preadipocytes. During the early development, the preadipocytes may develop characteristics of either brown or white adipose tissue, primarily in the perirenal and abdominal depots, depending on the species. Regardless of the type, the maturing preadipocytes form gland like, lobular structures containing a single flat peripherally oriented nucleus, a Golgi complex, several mitochondria, endoplasmic reticulum and a modest number of ribosomes (Simon, 1965; Wassermann, 1965; Allen et al., 1976). These cells are now referred to as adipocytes once unilocular lipid is present.

Adipose tissue exhibits a bimodal developmental pattern. Initially, at the cellular level, adipose tissue increases in mass by hyperplasia and(or) hypertrophy. Bell (1909) and Simon (1965) indicated that hyperplasia ceased when lipid accumulation began. However, later studies have shown that in fact, either hyperplasia and(or) recruitment of progenitor adipose tissue does occur later due to lipid filling or some external stimulus (Allen et al., 1976). Anderson (1972) and later Johnson (1978) reported that adipocytes do reach a maximum cell size, thus supporting the earlier reports of bimodal development as stated by Allen et al. (1976).

Adipose tissue is the last major tissue to develop,

having the lowest need for nutrients in early life (Palsson, 1955). While a certain level of adipose tissue is necessary for metabolic processes and functional support, excess lipid is stored as triacylglycerol in adipose tissue. The excess fat accretion has become an area of heightened concern, as it reduces profits by increasing production costs and reducing efficiency of growth in animals (Leat and Cox, 1980). While the major function of adipose tissue is to store and supply a stable source of energy, other roles include forming fat pads for protection between organs, providing heat insulation, shock and injury protection and generally holding organs in place.

Bone. Other than vital tissues such as the nervous, respiratory and vascular systems, bone is among the earliest developing of the major tissues. At birth, bone must have attained sufficient strength and integrity to support the body and provide protection of vital organs and tissues. During early postnatal growth, bone constitutes a large percentage of the body tissue weight. As development continues, muscle and adipose tissue surpass bone in growth rate to the point that the percentage of bone in the body remains relatively constant or actually declines (Berg and Butterfield, 1976). Although the actual growth rate of bone may virtually stop, bone is a very dynamic tissue, undergoing continuous remodeling (Ham, 1969).

Bone has been referred to as a highly specialized connective tissue (Vaughan, 1980). Young (1964) and Owen (1967) indicated that the precursor cells for bone, the skeletoblasts also arise from the mesenchymal cells, as do the cells of muscle and adipose tissue. Stutzman and Petrovic (1982) stated that the skeletoblasts differentiate to prechondroblasts (type I or type II). Type I prechondroblasts are found in the ephiphyseal plate cartilage of long bones where they mature. Osteoblasts in either compact cortical or spongy (cancellous) bone, also mature from preosteoblasts or originating from prechondroblasts (Petrovic, 1982). Further bone formation may occur by two methods, i.e., intramembranous or endochondral ossification. Location and function of the bone structures dictate the type of bone formation which occurs. Basically, the skull and calvarium develop by intramembranous ossification and most other bones plus the base of the skull are formed by endochondral ossification (Vaughan, 1980).

Regardless of the location and type of formation, all bone deposition occurs by a similar process. Once mesenchymal cells differentiate to form osteoblasts they in turn form centers of ossification (Ham, 1974). These clusters of cells surround themselves with an organic matrix, the osteoid, characteristic to the type of

ossification. Calcification of the osteoid tissue through vesicle formation and deposition of amorphous and crystalline calcium apatite is common to both types of ossification procedures (Bernard and Pease, 1969). Remodeling of newly formed bone is achieved through the osteoclasts, by digesting cartilage remnants (Dodds, 1932).

Developmental Changes in Animal Growth and the Distribution of Major Body Tissues or Organs. While considerable research has been performed on the cellular mechanisms responsible for growth, a general understanding of the interrelationships and patterns of developmental growth of body tissues is paramount in animal studies. Early workers (Meek, 1901; Brody and Ragsdale, 1924; Lush, 1926) studied body measurements and live weight. They concluded that live weight was the fastest increasing of any measured variable. Also, as age increased the amount of fat and muscle increased at a faster rate than the linear measures such as height at the shoulder or rump. Extensive studies of various species by Trowbridge (1918), Haecker (1920), McMeekan (1941), Callow (1948), Palsson and Verges (1952a,b), Berg and Butterfield (1966), Jesse et al. (1976) and Robelin et al. (1977) support these findings from complete dissections of animals.

Huxley (1932) approached studies of animal growth through the use of the allometric equation $Y = aX^b$ (Y =

size of the organ or part, X = size of the remainder of the body and b = the growth coefficient of the organ or part). He concluded that this equation gave reasonably accurate descriptions of organ to body relationships. Other workers applied this allometric equation to compare the growth of muscle, fat and bone (Elsley et al., 1964; for sheep and pigs; Berg and Butterfield, 1966; Mukhoty and Berg, 1971; for cattle). They determined that the growth coefficient for bone was low (<1.0), muscle intermediate (>1.0) and fat high (>1.5 to 2.0). Seebeck (1968a,b) indicated that the allometric equation was best to describe part - to - whole relationships. While these coefficients are generally true during postnatal life, there are exceptions at various times during development.

Hammond (1932) described increases in bone, muscle and fat as due to differential growth patterns. He showed bone to be the earliest developing, followed by muscle and then fat. Brody (1945) concluded that the order of tissue growth was the same in all species. This principle was supported by studies with cattle (Callow, 1948; Murray et al., 1974; Robelin et al., 1977). Graphic representation of the growth of body tissues over time is represented in figure 1. There are obviously numerous factors such as nutrition, hormones, genetics, environment, disease and others which can alter the normal growth of animals.

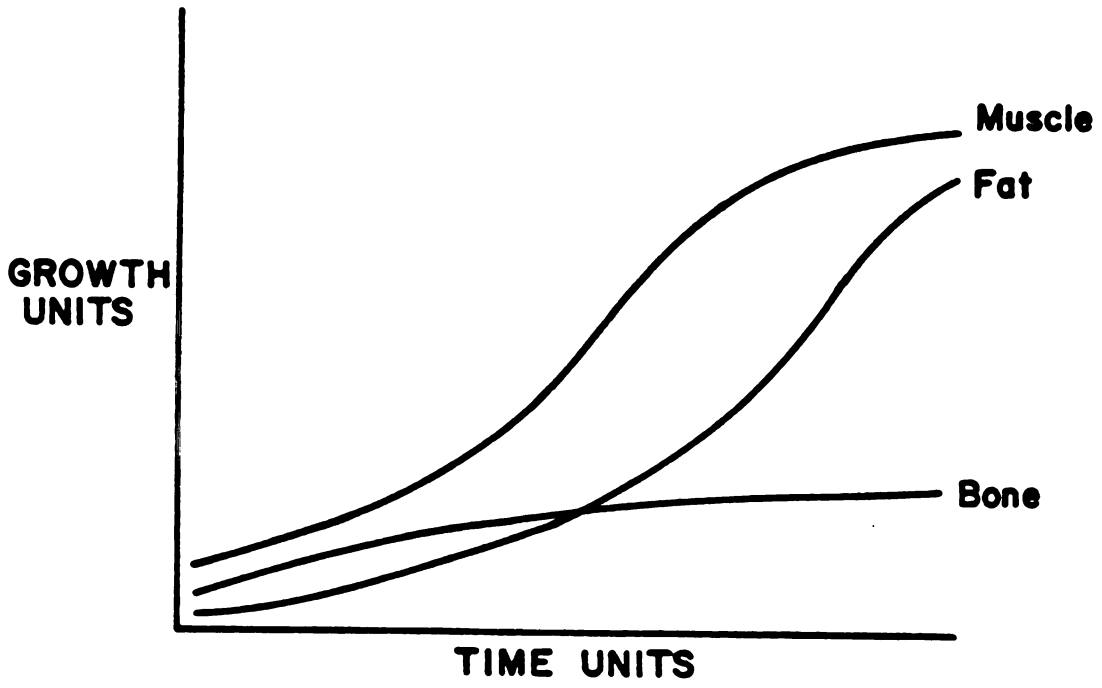

Figure 1. Postnatal growth curves of major body tissues.

If however, near optimal conditions can be maintained, animals will generally follow these patterns. There are numerous changes associated with the onset of puberty, but these changes are relatively small compared to the growth pattern from birth to puberty. While cattle will continue to grow up to six years of age, Crickton et al. (1959) and Nadarajah et al. (1984) stated that at least 80 to 90% of growth is complete by 20 to 24 months of age. Frisch (1976) generally agrees, stating that size at sexual maturity is about equal to adult size.

Relatively limited information exists on developmental changes in the weight and chemical composition of the major noncarcass tissues and (or) organs. Haecker (1920) performed chemical analyses separately on several organs and tissues, namely, blood, skin, edible and inedible offal. Studies by Moulton et al. (1922) were more extensive, examining developmental changes in Hereford/Shorthorn steers between three months and four years of age. They examined the changes in the weights and chemical composition of most vital organs and (or) body systems (i.e., circulatory, respiratory, alimentary, etc.)

More recent composition data on bovine organs and offal components is limited for British, Friesian and Continental European breeds of cattle. Moran and Wood (1985) examined the differences in development of

noncarcass components between five genotypes of Indonesian cattle. Their study however, was limited to examining genetic and dietary influences on the proportional development and weight of noncarcass components and the effect on dressing percentage. Information on the relative distribution and composition of noncarcass components in genetically leaner cattle would be especially useful today in studies which attempt to alter the partitioning of nutrients and protein among adipose tissue, muscle and body organs.

Bone has a relatively low impetus for growth as described by Berg and Butterfield (1976), which supports the findings of McMeekan (1959). Johnson (1974) indicated that postnatal bone growth occurs at a slow steady rate. At birth and in early life, the percentage of bone in the carcass is highest. Due to the later maturing nature of muscle, the early muscle to bone ratio may be as low as 2:1. The ratio increases to 4:1 or 5:1 as the animal approaches mature size (Callow, 1961; Hendrickson et al., 1965; Berg and Butterfield, 1976; Shahin and Berg, 1985). Growth varies from bone to bone with the skull and cranium increasing rapidly and long bones growth occurring at the epiphyseal plates. Considerable remodeling of bone occurs throughout life.

From a meat production basis, muscle is the most

important portion of the animal, and until recently, receiving almost all research attention. Muscle comprises a very high percentage of the animal at birth and early postnatal life. With the onset of fattening this percentage eventually drops to about 33% of the live weight in cattle, (Callow, 1947).

All muscles do not mature at the same rate. Palsson (1955) and Luitingh (1962) discussed the relative growth of muscles and Butterfield (1963) along with Berg and Butterfield (1968,1976) presented a thorough review of the various carcass muscles and the impetus for growth that each exhibits. They described the impetus classifications of growth as being : a) high, b)average, c)low or d) a combination of each depending on the stage of development. Lohse et al. (1971) refined this method, attempting to explain overlapping phases of muscle development. Luitingh (1962) reported that the "area" of the LD at the last rib as being average or constant in growth when compared with other muscles. Several studies have provided correlations between the size or weight of muscles with total muscle mass. However, relatively few studies have thoroughly examined the growth and composition of individual muscles in Continental European crossbred cattle, common in today's beef production systems.

Due to increasing concerns about health and animal fat

intake, interest in understanding and controlling the production of fat in the body is receiving primary attention today. Of the major body and carcass tissues, fat is undoubtedly the most variable. Fat to a large extent is the most complex tissue being partitioned among many depots during growth. In the newborn animal fat plays a minor role. In some species, brown adipose tissue supplies the substrates for energy needed immediately after birth, while other species essentially lack any such depots. Nevertheless, at birth or shortly thereafter, an animal acquires most of its fat cells. Filling of the fat cells with lipid occurs at an ever increasing rate as an animal develops.

In the bovine animal, fat is partitioned first to the organs and perirenal depots, followed by the intermuscular and subcutaneous depots and finally to the intramuscular deposits. Fat deposition and depot size is of interest to many researchers and was in this study. Many of the presently utilized composition prediction techniques have been developed using British breeds of cattle, mainly Angus and(or) Herefords. These animals exhibit a high propensity for large deposits of subcutaneous fat. Berg and Butterfield (1976), Jones et al. (1985b,c), Jesse et al. (1976), Kempster (1976a), Shahin and Berg (1985a,b) have indicated that the pattern of fat distribution in

Continental European breeds of cattle differs from British-bred cattle. Due to the tremendous introduction of Continental European blood lines into the bovine gene pool used for meat production, further research into the distribution of adipose tissues and major body tissues and the effects on the validity of the currently employed prediction techniques appears to be necessary.

MATERIALS AND METHODS

Experimental Animals. Twenty large-frame (frame score 5 to 6), Simmental x Charlois x Angus crossbred beef steers were selected from a group of 350 genetically similar calves. In the selection of the steers, I attempted to obtain steers that were as uniform as possible in type, frame score, muscling, condition, weight and projected final market fatness and size. There was a 2 mo variation in birth dates ranging from March 15 to May 15. Initial body weights averaged 260 +/- 10 kg at the start of this experiment.

Experimental Design and Diets. The experimental design consisted of a random allotment of five steers to each of four slaughter groups. Group 1 was slaughtered at 300 +/- 5 kg shrunk weight, (with a median age of 10 mo), Group 2 at 390 +/- 5 kg, (with a median age of 12 mo), Group 3 at 480 +/- 5 kg, (with a median age of 14 mo), and Group 4 at 560 +/- 5 kg, (with a median age of 16 mo). All animals were randomly penned and fed the same diet (Diet 1) for the first 120 d and a second diet (Diet 2) for the remainder of the experiment. Groups 1 and 2 were slaughtered during the growing phase and groups 3 and 4 during the finshing phase of the bovine growth curve; (figure 1). Experimental diet 1 consisted of 75.1% corn silage (CS), 20.1% high moisture

corn (HMC), 4.4% soybean meal base concentrate (44% crude protein) fortified with trace mineralized salt, Vitamin A, Vitamin D and dicalcium phosphate. The diet was formulated to supply 13.0% crude protein, NEm of 1.88 Mcal/kg and NEg of 1.22 Mcal/kg. Diet 2 consisted of 60% corn silage (CS), 35.6% high moisture corn (HMC), 4.4% soybean meal base concentrate (44% crude protein) and trace mineralized salt, Vitamin A, Vitamin D and dicalcium phosphate. The diet was formulated to supply 11.0% crude protein, NEm of 1.98 Mcal/kg and NEg of 1.30 Mcal/kg. Cattle were fed twice daily so all feed would be consumed. Water was provided ad libitum. Cattle were housed in half concrete, half dirt lots with a roof over one half of each lot. Cattle were also exposed to ambient temperatures and photoperiods. Animals were fed until they reached the designated slaughter weight. Animals were held off feed but not water for 16 h to obtain a shrunk live weight. Animals were transported to the MSU Meat Laboratory for slaughter the following morning. Live weights were recorded (to nearest .05 kg) and the steers were slaughtered according to common commercial procedures.

Tissue Dissection and Total Body Composition. Blood was subsampled as bleeding occurred and total blood was collected and weighed to the nearest gram. All individually sampled components of the body mentioned hereafter were

either immediately subsampled or placed in moisture impermeable bags to prevent water loss until dissected. After dissection, all samples were frozen and later powdered at -70 C (with Dry Ice) using a IKA Universalmuhle model M20 high speed impact analytical mill (Tekmar, Cincinnati, OH). Analyses for moisture, ether extractable lipid (EEL) and protein (N x 6.25) of all dissected tissues were performed according to AOAC (1965) methods. Hide was kept intact including that from the legs, tail and head (including ears). The hide was weighed (to nearest .05 kg), subsampled in ten locations composited and ground for later analysis. One front foot and one hind foot from the right side were removed, weighed and immediately separated into bone and soft tissues. The tail was removed, subcutaneous fat removed, weighed, ground and later analyzed. Immediately after removal of the hide the cod fat from the right side of the carcass was removed (to prevent excess water loss) and frozen. Subcutaneous fat (SQ) samples from the right side were removed from 12 different locations on the carcass and placed in bags. Each subsample was proportional to the size of the depot.

All components of the abdominal and thoracic cavities as well as other noncarcass parts were weighed individually (organs) or as groups, e.g., gastrointestinal tract. Components were placed in bags and later on the day of

slaughter dissected into individual body parts. The GI tract was emptied of contents, separated into individual components, weighed and stored for analysis. GI tract contents were pooled, subsampled and percentage dry matter later determined.

Prior to splitting the carcass, the right side kidney, pelvic and perirenal adipose tissue (KP) were removed, weighed and later analyzed for moisture, ether extract and protein. Extreme care was taken in splitting the carcass to ensure minimal deviation from the medial plane of the vertebra. Any deviations were immediately corrected while splitting; any bone unevenly split was removed from the corresponding side and added to the other side. Hot carcass weights from the right side were corrected to include the previously mentioned fat depots that had been removed before splitting. The left side was weighed, shrouded and then chilled for at least 24 h. Fat thickness measurements, longissimus dorsi (LD) cross- sectional area were determined and percentage KP fat estimated. Yield and quality grade data were obtained by trained university personnel.

After splitting, all subcutaneous fat (SQ) was removed from the right side as rapidly as possible, weighed, chilled, ground three times (3 mm plate) and subsampled. Intermuscular fat (IM) subsamples were removed from the

round, rib, chuck, plate and brisket, (between the major groups of muscles), pooled and analyzed. Twenty five muscles of the right side, were subsampled (proportional to total size), composited, later ground and analyzed to determine intramuscular lipid content. The sampled muscles included: longissimus dorsi (LD), semitendinosus (ST), semimembranosus and adductor (SM), trapezius (TP), triceps brachii (TR), brachialis (BR), biceps femoris (BF), rectus femoris (RF), gastrocnemius (GA), latissimus dorsi (LAT), pectoralis profundus (PP), intercostal muscles (INM), gluteus medius (GM), supraspinatus (SS), infraspinatus (IF), serratus ventralis (SV), rectus abdominus (RA), vastus lateralis (VL), vastus medialis (VM), spinalis dorsi (SD), biceps brachii (BB), gluteus profundus (GP), subscapularis (SB), rhomboideus (RH) and psoas major (PM).

Intramuscular adipose tissue was dissected from a second sample of the same muscles to determine moisture, fat and protein content of the intramuscular fat depot, for later calculations. The remainder of the right side was rapidly dissected into skeletal muscle, adipose tissue depots, tendons along with heavy connective tissue and bone plus cartilage. The skull was weighed (without hide and tongue), the brain was removed, the remainder reweighed and split longitudinally into right and left halves. Any deviations were corrected.

Bones were dissected completely free of muscle, tendons, fat and ligaments, but not cartilage, and separated either into individual bones or groups of bones for later analyses. Individual and group bone weights taken included: femur, tibia/fibula, radius/ulna, humerus, 3rd and 10th rib, skull, vertebral column, lower leg (front and hind foot), hind limb (carcass), front limb (carcass) and rib cage (including sternum and costal cartilages). All bones were ground by groups using an Autio 801 whole body grinder at The Ohio State University, Columbus, OH. After grinding, 10% of the weight of each group was taken for analyses. All groups of bones from the carcass were combined for a composite sample and 10% of the total weight subsampled. In order to correct for removed bone subsamples, an extra 10% of noncarcass bone groups was removed before pooling all ground bone to arrive at the composite total body bone to be subsampled for analyses.

Determination of Skeletal Muscle, Marbling and Intermuscular Adipose Tissue from Right Sides and Total Body. All soft tissues (less SQ fat, tendons and ligaments) dissected from the right side (including the head) were weighed, ground 3 times (3mm plate) and subsampled. Percentage moisture (M), ether extractable lipid in the intermuscular and intramuscular AT (EEIMMA) and protein (P; N X 6.25) were determined (AOAC, 1965) on the soft tissues

sample from the right side of the body. From this sample, the EEIMMA represented the lipid from the intermuscular (IMAT) and intramuscular (MAAT) adipose tissue. The remainder of the sample is referred to as the fat-free muscle (FFM). The FFM includes the moisture and protein associated with the muscle along with the IMAT and MAAT. The quantitative estimation of the weight of the empty body muscle, IMAT and MAAT can be determined using the following calculations and are diagrammed with an example in appendix A1.

The weight of FFM was divided by the difference of one minus the percentage EEL in the composite muscle sample taken from the previously mentioned 25 muscles of the right side (1- %EEL of composite muscle marbling determination sample). This resulted in the weight of the skeletal muscle, as well as marbling adipose tissue (includes M,EEL,P) and the M and P associated with the IMAT, labeled FFMEE. The difference between FFMEE and FFM represents the EEL from the MAAT of the skeletal muscle (EEMAAT). The EEMA is subtracted from the EEIMMA which resulted in the EEL associated with the IMAT (EEIM). The EEIM is divided by the percentage EE of the IMAT sample which gives the total weight of the IMAT. To determine the M and P associated with the IMAT, the EEIM is subtracted from the IMAT giving the moisture and protein (MPIM) associated with the IMAT.

In order to determine the estimated muscle tissue, M and P associated with the MAAT, the MPIM is subtracted from the FFM giving the total estimated fat-free muscle and marbling adipose tissue M and P, (FFMMA). Adding the EEMAAT to the FFMMA gives the estimated total skeletal muscle and marbling adipose tissue (TMM). The total weight of the marbling adipose tissue (TMAAT) is derived by multiplying the TMM by the percentage of total marbling adipose tissue (T%MAAT). Determination of T%MAAT is accomplished by dividing the percentage of EEL in the composite muscle sample (represents MAAT EEL) by the percentage EEL of the dissected composite marbling sample. Muscle tissue without MAAT, (TM) can then be derived by subtracting the TMAAT from the TMM.

Conversion of the right side tissue weights (muscle, subcutaneous AT, intramuscular AT, intermuscular AT and bone) to total body tissue weights was performed since earlier studies by Butterfield (1963), Briedenstein et al., (1964) and Hedrick et al., (1965) have shown cattle to exhibit bilateral symmetry. The tail, kidneys, perirenal fat and any internal cavity tissues which do not exhibit bilateral symmetry were removed prior to converting all right side tissue weights, to left side tissue weights and then to total body tissue weights. The weights of all tissues (muscle, adipose tissue and bone, etc.) as a

percentage of the right side were multiplied by the weight of the left side to give the weight of the tissues in the left side. The sum of both sides gives the total weight of muscle, adipose tissue (all depots), bones and other tissues in the body.

Statistical analyses; group means, standard errors and analysis of variance were performed using SPSS (Statistical Package for the Social Sciences, 1984).

RESULTS AND DISCUSSION

Carcass Data. Means and standard errors for the various carcass traits are presented in tables 1 and 2. All steers were started on feed at the same time and fed until each steer reached the designated fasted slaughter weight, in each randomly assigned group. The average live weight of the initial slaughter group (G1) was 298.5 kg and increased by approximately 90 kg between groups 1 and 2, and between 2 and 3 but only 75.54 kg between G3 and G4. This descrepancy was due partly to the difficulty in estimating amount of fill in the gastrointestinal tract (GI) and the increased weight loss associated with handling during transportation to the abattoir. The average final slaughter weight of 555.5 kg did not present any adverse effect on the final experimental outcome and carcass dissection, since all animals in G4 had attained the desired endpoint of USDA quality grade of low Choice, fat thickness of at least 10 mm and yield grade of 3.0.

Fat thickness at the 12th and 13th rib interface increased significantly ($P<.001$) between each group with the largest increase in fat thickness occurring between G2 and G3, as expected. Ribeye area increased between each group with the largest increase observed between G1 and G2. Calculated yield grades, using the equations of Murphy et

al., 1960, did not show differences (P>.10) between G1 and G2, but differences (P<.01) between G2 and G3 and G3 and G4 were significant. Marbling scores and USDA quality grade scores were not different (P>.10) between G1 or G2, and between G3 or G4, but differed significantly between G2 and G3.

Adipose Tissue. Data presented in table 3 show the weight of the major adipose tissue deposits of the carcasses in each group. The separable adipose tissue of the carcass (SATC) comprised 16.4% of the hot carcass weight in G1, 21.8% in G2, 27.1% in G3 and 29.5% in G4. The percentage of SATC of G3 and G4 closely resembled that of the cattle used by Johnson et al. (1972). However, the steers used in that study were 1200 d old compared to approximately 420d and 480d, respectively for group G3 and G4. The SATC data for G4 also closely resemble the carcass data of Callow (1961), work adapted from Lawrence and Pearce (1964) Hendrickson et al. (1965), Berg and Butterfield (1976) and Lunt et al. (1985b) which show that the cattle in their studies had 29.0, 29.5, 28.0 and 30.6%, SATC respectively. A major difference between this study and the previous studies, however is the final carcass weight of the cattle in each study. Previous studies used mainly British-bred cattle which finished with lighter live weights (450 to 480 kg), carcass weights and more

TABLE 1. MEANS AND STANDARD ERRORS FOR CARCASS TRAITS OF GROUP 1 AND 2[a]

	Group	
	1	2
No. of animals	5	5
Trait Age	10 mo	12 mo
Live weight, kg	298.5 (2.99)	390.1 (2.09)
Empty body weight, kg	273.9 (3.55)	358.4 (1.24)
Warm carcass weight, kg	188.1 (3.8)	247.2 (1.84)
Fat thickness (12th rib) mm	2.6 (.02)	4.8 (.03)
Longissimus dorsi area, cm2	60.33 (.98)	75.17 (1.93)
Kidney fat %	2.0 (.11)	2.5 (.16)
Yield grade	1.74 (.12)	1.82 (.16)
Marbling score[b]	Traces 58	Traces 74

a Standard error in parentheses.
b Minimum traces = 0, maximum traces = 100. Trace = USDA Standard.

TABLE 2. MEANS AND STANDARD ERRORS FOR CARCASS TRAITS OF GROUP 3 AND 4[a]

	Group	
	3	4
No. of animals	5	5
Trait Age	14 mo	16 mo
Live weight, kg	480.0 (.74)	555.5 (1.11)
Empty body weight, kg	440.0 (2.64)	514.9 (3.32)
Warm carcass weight, kg	303.7 (2.74)	365.7 (3.12)
Fat thickness (12th rib) mm	8.7 (.03)	11.4 (.05)
Longissimus dorsi area, cm2	80.8 (3.71)	86.6 (3.60)
Kidney fat %	2.5 (.16)	3.1 (.19)
Yield Grade	2.39 (.13)	3.01 (.18)
Marbling score[b]	Small 12	Small 58

a Standard error in parentheses.
b Minimum small =0, maximum small =100. Small =low Choice.

conventional frame scores. The cattle in this study were evaluated to be frame score 5+ to 6- with an optimal finished live weight of 550 to 570 kg. As is obvious from the previously mentioned studies, as the animals were fed to heavier weights and also in this study, the percentage of SATC rapidly and steadily increased to 30 % and more, before a final carcass weight similar to the present study was achieved.

Subcutaneous adipose tissue (SQAT) increased 110.2% from G1 to G2 and comprised 25.5% of the SATC in G1. The G2 SQAT made up 30.8% of SATC and increased in weight by 81.4% from G2 to G3 which made up 36.6% of SATC. While increasing in weight 26.2% from G3 to G4, the SQAT was not significantly different (P>.10) from G3, comprising 35% of SATC. The data from cattle in G3 and G4 are in close agreement with data of Charles and Johnson (1976) and Shahin and Berg (1985a,b,c), for animals of similar carcass weight and genetic makeup (Continental European crossbred) to the steers in G4 in my study.

Intermuscular adipose tissue (IMAT) made up 58.2% of SATC in G1 and increased in weight 53.1% from G1 to G2. The IMAT comprised 50.9% of the SATC in G2 and increased in weight by 34.5% to G3 where it made up 44.8% of SATC. From G3 to G4, IMAT weight increased 33.4%, but as a percentage of SATC remained essentially unchanged at 45.7% (P>.10).

TABLE 3. GROUP MEAN WEIGHTS AND STANDARD ERRORS CARCASS ADIPOSE TISSUE DEPOTS[a]

Fat depot	Group 1	2	3	4
Total carcass AT, kg	36.6 (1.01)	62.7 (2.7)	97.7 (3.25)	124.6 (2.47)
Subcutaneous AT, kg	7.9 (.23)	16.5 (.86)	30.0 (.70)	37.8 (1.06)
Intermuscular AT, kg	18.0 (.60)	27.5 (.77)	37.0 (2.42)	49.4 (1.61)
Perirenal[b] AT, kg	4.2 (.14)	8.2 (.37)	13.1 (.87)	17.5 (.86)
Intramuscular AT, kg	5.7 (.36)	8.8 (.77)	15.41 (.71)	16.6 (.76)
Separable carcass AT, kg	30.9 (.70)	53.9 (2.1)	82.3 (3.76)	108.0 (2.41)
Other carcass[c] AT, kg	.9 (.10)	1.7 (.13)	2.2 (.23)	3.3 (.26)

a Standard errors in parentheses.
b Includes both perirenal and pelvic cavity fat.
c Heart, thoracic cavity, rib overflow, spinal column AT.

These data for G3 and G4 are lower and differ from the results of the previously mentioned work, but they are consistent with the present data reported by Robelin (1986) on Friesian cattle in that the IMAT depot is the largest deposit of SATC.

The absolute weight of perirenal and pelvic cavity adipose tissue (KP) increased from G1 to G4 as did the other fat deposits, but did not change (P>.10) as a percentage of SATC over all the slaughter groups. The KP was 13.5% of SATC in G1 and increased in weight 95.7% to G2, in which it accounted for 15.2% of SATC. The increase in weight from G2 to G3 was 60.7% to 13.11 kg in G3. Percentage KP of SATC was virtually unchanged between G3 and G4 (15.9 vs 16.2%).

The absolute weight of the KP did, however increase 33.2% from G3 to G4. These data are again consistent with the study of Charles and Johnson (1976) and Shahin and Berg (1985a,b,c) in which comparable cattle had 12.3 to 15.7% and 12.8%, respectively, of the SATC as KP.

Intramuscular adipose tissue (MAAT) increased in weight 54.5% from G1 to G2 and 75.3% from G2 to G3. The large increase was expected with the change to a finishing diet and the position of the cattle on their projected growth curve. The increase in the absolute weight of MAAT was less dramatic than expected from G3 to G4. This may be due to

animal variation and environment, with the cattle in G4 less likely to consume substantial quantities of feed during the finishing phase which was in the late summer months. Another possibility may be that the MAAT in G3 was overestimated. Several cattle in G3 had the same marbling scores as several steers in G4 which may have caused an overestimation of the MAAT in G3. While the above arguments may be valid, one should remember that the MAAT discussed here includes not only EEL, but also the moisture and protein associated with the MAAT. Inclusion of these components greatly increases the weight of the MAAT while not increasing the EEL content of the muscle and accounts for the increased MAAT in G3. Johnson et al. (1973) determined the weight of the intramuscular fat (EE, % of total weight) in several muscles groups and in total side muscle. Numerous cattle with various amounts of total dissectable fat and %CF were used to derive the published relationships. The groups in my study corresponded to several groups reported by Johnson et al. (1973a). Group 1 (%CF, 16.4%) corresponded to the 15.5% CF group of Johnson, G2 (%CF, 21.8) corresponded to slaughter groups reported by Johnson et al. (1973) which had 21.0 to 22.7%CF, G3 (%CF, 27.1) corresponded to their 28.9%CF group and G4 (%CF, 29.5%) corresponded to their slaughter groups which range in %CF from 28.9 to 31.4%, respectively. The resulting

weights of MAAT EEL as a percentage of total muscle weight in my study were 1.6, 2.5, 4.3 and 4.4%, respectively. These results for G1 and G2 are about 52.2% below those reported by Johnson et al. (1973a), who found 3.35 and 5.16% of the total side muscle made up of MAAT EEL. The G3 MAAT EEL was 34.7% below the corresponding group determined by Johnson et al. (1973a; 4.3 in G3 vs 6.6). The G4 MAAT EEL was 37.1% below the mean of the corresponding groups (4.4 vs 7.1%). These data suggest that the Continental European crossbred steers used in my study had a lower propensity to deposit (or fill MAAT adipocytes with lipid) at the same percentage of dissectable fat than the British-bred cattle used in the previously mentioned study. The MAAT as a percentage of the total muscle weight was determined for each group to be 4.6, 5.7, 8.6 and 7.8%, respectively.

Composition of the SQAT at each slaughter group is presented in table 4. As expected the %M and %P decreased, while %EEL increased with development and fattening. Specifically, the %M decreased between G1 and G2 by 19.2%. The G1 %EEL increased by 10.7% and the %P decreased 28.1% from G1 to G2. The change in %M between G2 and G3 showed a decrease of 9.2%, an increase of 3.9% in %EEL and a decrease of 17.9% in the %P. The change in %M from G3 to G4 was a decrease of 7.9%, an increase in %EEL

TABLE 4. GROUP MEANS AND STANDARD ERRORS OF PROXIMATE ANALYSES FOR CARCASS SUBCUTANEOUS ADIPOSE TISSUE[a]

Group	Moisture	Ether Extract	Protein
1	25.9	66.5	7.5
	(1.91)	(1.16)	(.20)
2	21.0	73.6	5.4
	(.98)	(1.21)	(.23)
3	19.0	76.5	4.4
	(.62)	(.91)	(.28)
4	17.5	78.9	3.4
	(.67)	(.75)	(.14)

a Standard errors in parentheses.

of 3.2 and a decrease in %P of 22.3%. The composition of the SQAT in G4 was similar to the results of Brannang (1966), except for the %P which was considerably lower (3.4 vs 6.1). As is obvious in this study, growth and developmental changes greatly influence the composition of the SQAT.

The data in table 5 shows the developmental changes in the composition of IMAT in each of the weight groups. The %M in the IMAT decreased 19.4%, 15.2% and 15.5%, respectively, between each group. The %EEL increased 4.9% from 80.7% in G1 to 84.7% in G2, 2.6% in G3 to 86.9% and 2.6% in G4 to 89.2%. The results on the composition of IMAT in the present study, differ considerably from the IMAT composition findings reported by Brannang (1966). This difference from the Brannang data in my study as well as those of Charles and Johnson (1976), Jones (1985) and Shahin and Berg (1985a,b,c), may be due in part to the findings that Continental European crossbred cattle have more IMAT than British-bred cattle. Also, since Continental European breeds of cattle have more IMAT compared with a larger proportion of SQAT in British-bred cattle, this may be caused by an accelerated filling of the IMAT with lipid and thus account for the differences in the composition. The dramatic difference in the %P of the IMAT between the present study and published literature is

TABLE 5. GROUP MEANS AND STANDARD ERRORS OF PROXIMATE ANALYSES FOR CARCASS INTERMUSCULAR ADIPOSE TISSUE[a]

Group	Moisture	Ether Extract	Protein
1	16.1	80.7	2.8
	(1.14)	(1.18)	(.04)
2	13.0	84.7	2.1
	(.68)	(.60)	(.04)
3	11.0	86.9	1.7
	(.46)	(.57)	(.03)
4	9.3	89.2	1.2
	(1.19)	(1.07)	(.02)

a Standard errors in parentheses.

puzzling and may again be due to a dilution of the protein by the increased lipid in the type of AT studied.

Table 6 shows the changes in the composition of the KP from G1 to G4. As stated by Berg and Butterfield (1976), the KP had the lowest percentage of moisture and protein and the highest %EEL. Even though this is true, there continues to be developmental changes in the composition of the KP. The %M decreased by 21.0, 9.9 and 19.1%, respectively, between G1 and G2, G2 and G3 and G3 and G4. As expected the %EEL of the KP increased between each group by 4.9, 1.2 and 1.4%, respectively. Coinciding with the increased lipid filling of the KP cells, the %P decreased 10.9%, 23.8% and 24.1% between the respective groups. Composition of the KP in G4 closely resembled that reported by Brannang (1966), suggesting that although there may be other more pronounced changes in the distribution and composition of the other carcass adipose tissues, the early maturing KP remains relatively unchanged after 300 to 350 kg live weight regardless of breeding and genetics. It is interesting to note also, that the composition of KP in G3 very closely resembles the values presented by Brannang (1966) on work done with bulls.

Very little information, if any, exists concerning the composition of the intramuscular adipose tissue (MAAT) in cattle. Suess et al. (1969) and Johnson et al. (1972)

TABLE 6. GROUP MEANS AND STANDARD ERRORS OF PROXIMATE ANALYSES FOR CARCASS PERIRENAL ADIPOSE TISSUE[ab]

Group	Moisture	Ether Extract	Protein
1	9.3	88.1	2.1
	(.16)	(.25)	(.03)
2	7.4	90.8	1.9
	(.04)	(.10)	(.09)
3	6.6	91.8	1.4
	(.34)	(.36)	(.05)
4	5.4	93.1	1.1
	(.12)	(.25)	(.11)

a Standard errors in parentheses.
b Includes perirenal and pelvic cavity fat.

examined the relationship between MAAT and the growth of muscle. Johnson et al. (1972) slaughtered numerous cattle of varying degrees of fatness to determine the percentage of the total muscle which was intramuscular fat (MAAT EEL). However, none of the previously mentioned workers dissected MA to determine the actual composition, as was done in this study. Table 7 shows the composition of the MAAT for each group and the developmental changes between groups. The %M of the MAAT decreased 11.4, 12.6 and 10.1%, respectively between groups. Changes in the %EEL included an increase of 23.7% between G1 and G2, a 15.9% increase from G2 to G3 and a 13.3% increase between G3 and G4. Conversely, %P decreased 19.3, 11.6 and 24.1% between the respective groups. These data suggest that as an animal gets closer to the ideal finished weight and (or) higher marbling score, one may more accurately estimate the actual MAAT in individual muscles and the total muscle of the body. It should be pointed out, however, as will be discussed later along with the data in tables 9, 10, 11 and 12, not all muscles contain the same amount of MAAT EEL. This limits the development of only one standard relationship with which to predict the absolute weight of MAAT. It should also be pointed out, that many researchers have ignored the contribution of moisture and protein to the total weight of MAAT and other adipose tissue deposits and thus may

TABLE 7. GROUP MEANS AND STANDARD ERRORS OF PROXIMATE ANALYSES FOR CARCASS INTRAMUSCULAR ADIPOSE TISSUE[a]

Group	Moisture	Ether Extract	Protein
1	48.5	35.0	16.3
	(.14)	(.23)	(.19)
2	43.0	43.2	13.2
	(1.75)	(1.85)	(.18)
3	37.6	50.1	11.7
	(.60)	(.6)	(.14)
4	33.8	56.8	8.9
	(.86)	(1.17)	(.57)

a Standard errors in parentheses.

incorrectly estimate the weight and composition of soft tissues such as skeletal muscle and carcass fat.

Muscle. Total muscle and carcass muscle weights as well as various individual right side muscle weights are presented in table 8. Numerous workers have dissected either individual muscles or standard groups of muscles as described by Butterfield and Berg (1966) and Berg and Butterfield (1976). Many of the studies included either small-framed, large-framed, dairy type, double muscled cattle and (or) individual wholesale cuts from cattle (Butterfield, 1962; Luitingh, 1962; Berg and Butterfield, 1966; Allen et al., 1969; Johnson et al., 1972 ; Mukhoty and Berg, 1973; McAllister et al., 1976; Nour et al., 1981; Jones, 1985; Lunt et al., 1985a,b; and Shahin and Berg, 1985a,b). As is obvious from the data presented the LD and the BF are the largest muscles in the carcass in G1, accounting for 6.6 and 6.8% of the total carcass muscle. This relationship holds true and is relatively constant from G2 to G4, where the LD comprises 6.7 and the BF 6.3% of total carcass muscle. The LD and BF, in G1, are essentially the same in weight, with the BF being slightly heavier. However, the LD surpassed the growth of the BF in G2 and continued to be larger than the BF in G3 and G4. The SM (which includes the adductor) is the third largest muscle of the carcass. As discussed by Berg and

TABLE 8. MEAN GROUP WEIGHTS AND STANDARD ERRORS OF TOTAL EMPTY BODY SKELETAL MUSCLE, CARCASS SKELETAL MUSCLE AND SELECTED INDIVIDUAL MUSCLES FROM THE RIGHT SIDE OF THE CARCASS[a]

	Group			
Item	1	2	3	4
Empty body skeletal muscle, kg	126.3 (3.72)	157.0 (.58)	182.7 (2.81)	215.0 (2.69)
Carcass muscle, kg	124.2 (3.68)	154.5 (.46)	179.7 (2.76)	211.7 (2.72)
Muscle				
LD, g	4076.0 (8.0)	5248.0 (6.0)	5873.0 (14.0)	7106.0 (15.0)
SM, g	4403.0 (11.0)	5151.0 (8.0)	5823.0 (14.0)	6133.0 (15.0)
ST, g	1479.0 (5.0)	1793.0 (6.0)	2034.0 (1.0)	2339.0 (8.0)
RF, g	1365.0 (2.0)	1584.0 (4.0)	1717.0 (6.0)	2133.0 (6.0)
GS, g	1331.0 (4.0)	1508.0 (4.0)	1675.0 (8.0)	1772.0 (6.0)
BF, g	4197.0 (10.0)	5163.0 (2.0)	5716.0 (14.0)	6635.0 (18.0)
QD, g	3928.0 (9.0)	4380.0 (3.0)	4981.0 (7.0)	6069.0 (21.0)
TR, g	2554.0 (18.0)	3050.0 (5.0)	3632.0 (2.0)	4362.0 (11.0)
BR, g	284.0 (1.0)	329.0 (1.0)	356.0 (1.0)	394.0 (1.0)
TP, g	708.0 (3.0)	924.0 (1.0)	1066.0 (3.0)	1324.0 (5.0)

a Standard errors in parentheses.

Butterfield (1976) different muscles have different growth impetuses and thus different rates of accumulating EEL and final weights.

The percentage of the total skeletal muscle as a percentage of live weight was 42.3% in G1, declined to 40.2% for G2 and remained constant at 38.1 and 38.7% (P>.10) from G3 to G4. Carcass skeletal muscle as a percentage of carcass weight was 66.0, 62.5, 59.2 and 57.9%, respectively, from G1 to G4.

Changes in the chemical analyses of the skeletal muscles in each group is presented in tables 9, 10, 11 and 12. As expected, the %M of each muscle decreased from G1 to G4, while the %EEL of each muscle increased. The small changes in %P in the individual muscles were expected, since once the protein is deposited most changes are due mainly to the dilution of the protein in the muscle by lipid accumulation. The results in G4 followed the same developmental trends as those found by Brannang (1966) and reported by Berg and Butterfield (1976), for the average composition of muscle from steers and bulls. However, the muscles of the G4 animals in this study contained less intramuscular EEL and higher %M than reported by Brannang (1966) and Johnson et al.(1972). These data suggest that the steers used in my study were less predisposed to the deposition of MA EEL than British-bred cattle. The %EEL of

TABLE 9. GROUP MEANS AND STANDARD ERRORS OF PROXIMATE ANALYSES FOR SELECTED RIGHT SIDE MUSCLES FROM GROUP 1[a]

Muscle	Moisture	Ether Extract	Protein
	%		
LD	75.5 (.09)	1.9 (.10)	21.7 (.09)
SM	75.6 (.36)	1.5 (.12)	21.8 (.27)
ST	75.7 (.07)	1.4 (.07)	21.5 (.17)
RF	76.1 (.17)	1.5 (.10)	21.1 (.21)
GS	76.2 (.10)	.9 (.02)	21.8 (.09)
TR	76.8 (.10)	1.5 (.08)	20.6 (.03)
BR	77.8 (.04)	1.4 (.08)	19.9 (.03)
TP	76.6 (.05)	1.5 (.12)	20.7 (.03)

a Standard errors in parentheses.

TABLE 10. GROUP MEANS AND STANDARD ERRORS OF PROXIMATE ANALYSES FOR SELECTED RIGHT SIDE MUSCLES FROM GROUP 2[a]

Muscle	Moisture	Ether Extract	Protein
	%		
LD	75.1 (.16)	2.1 (.08)	22.0 (.10)
SM	75.0 (.13)	2.2 (.25)	21.8 (.09)
ST	75.0 (.23)	3.1 (.30)	21.4 (.11)
RF	76.1 (.25)	1.6 (.19)	21.2 (.23)
GS	76.1 (.13)	1.4 (.10)	21.5 (.11)
TR	75.7 (.51)	2.6 (.49)	20.6 (.24)
BR	76.5 (.24)	2.3 (.18)	20.0 (.10)
TP	75.6 (.33)	2.7 (.29)	20.4 (.21)

a Standard errors in parentheses.

TABLE 11. GROUP MEANS AND STANDARD ERRORS OF PROXIMATE ANALYSES FOR SELECTED RIGHT SIDE MUSCLES FROM GROUP 3[a]

Muscle	Moisture	Ether Extract	Protein
	%		
LD	73.8 (.09)	3.7 (.18)	21.5 (.13)
SM	74.7 (.15)	2.6 (.24)	21.7 (.09)
ST	74.5 (.31)	3.5 (.25)	21.4 (.18)
RF	74.9 (.22)	2.9 (.34)	21.2 (.17)
GS	75.6 (.23)	1.8 (.20)	21.7 (.12)
TR	74.4 (.11)	3.6 (.25)	20.7 (.22)
BR	76.7 (.18)	2.1 (.09)	20.5 (.10)
TP	74.2 (.20)	4.5 (.33)	20.6 (.35)

a Standard errors in parentheses.

TABLE 12. GROUP MEANS AND STANDARD ERRORS OF PROXIMATE ANALYSES FOR SELECTED RIGHT SIDE MUSCLES FROM GROUP 4[a]

Muscle	Moisture	Ether Extract	Protein
	%		
LD	72.8 (.26)	5.0 (.35)	21.2 (.09)
SM	73.6 (.35)	4.1 (.44)	21.4 (.16)
ST	74.0 (.44)	3.5 (.26)	21.8 (.18)
RF	74.6 (.13)	3.3 (.09)	21.1 (.15)
GS	75.5 (.21)	1.8 (.03)	21.7 (.31)
TR	74.2 (.45)	4.0 (.48)	20.8 (.15)
BR	76.1 (.27)	2.4 (.15)	20.6 (.15)
TP	73.1 (.31)	6.2 (.33)	20.1 (.27)

a Standard errors in parentheses.

the dissected muscles in this study, which correspond to the muscle groups studied by Garrett et al., (1971), were found to support their findings, although mine were nearer the lower ranges of EEL reported.

Bone. Table 13 contains the mean bone weights for the total body, total carcass, individual major carcass bones and several groups of bones for each slaughter group. Total bone weight increased 13.8% from G1 to G2, 11.9% between G2 and G3 and 10.4% from G3 to G4. Carcass bone weight followed a similar pattern of development, increasing 15.9, 11.3 and 11.4% between respective groups.

Carcass bone as a percentage of total bone remained relatively constant across each group, accounting for 78.5% of total bone in G1, 79.9% in G2, 79.5% in G3 and 80.2% in G4. Carcass bone as a percentage of carcass weight decreased from 15.1% of carcass weight in G1 to 13.3, 12.05 and 11.1% for G2, G3 and G4, respectively. Total bone as a percentage of empty body weight (EBWT) followed a similar decline from 13.2% of EBWT to 11.5, 10.5 and 9.9% in G2, G3 and G4, respectively.

These data follow similar patterns of development for British-bred cattle as discussed by Callow (1961), Lawrence and Pearce (1964), Hendrickson et al.,(1965) and Berg and Butterfield (1976). However, the results of my study differ from the previously reported literature on cattle of

similar carcass fatness by Lawrence and Pearce (1964), Hendrickson et al. (1965) and Lunt et al. (1985b), which had 13.8 to 15.3% carcass bone. These workers overestimated the percentage of bone by including the ligaments, tendons and cartilages with the bone portion of the carcass. These data however, are in agreement with the data of Callow (1961) who reported percentage of carcass bone of 11.8 to 12.8% in cattle of similar fatness and carcass weight as those in G3 and G4. These data also suggest that the decreased percentage of carcass bone is due to an increase in carcass soft tissues, especially muscle, in Continental European crossbred cattle.

Carcass muscle to bone ratios in this study were 4.4, 4.7, 4.9 and 5.2% for G1 to G4, respectively. These data are slightly higher than most reports in the literature by Luitingh (1962), Hendrickson et al. (1965), Berg and Butterfield (1966;1976), Jones (1985) and Lunt et al. (1985a,b), but are consistently lower than those reported by Shanin and Berg (1985a,b,c,) for double muscled, "synthetic" beef (Galloway x Angus x Charolais crossbreds) and small framed British breeds. These data indicate the heavy muscling of the steers in my study and lend support to the reported increased skeletal muscle deposition in Continental European cattle.

Table 14 contains the means and standard errors of the

composition of total body and carcass bone in each of the slaughter groups. Very limited information of this type is available in the literature, since most researchers report bone either by the carcass side or wholesale cut bone weight. Most however, do not analyze bone for moisture, ether extract, protein and ash. As expected, %M decreased across groups and showed an overall decrease of 12.6 and 13.7% for total and carcass bone, respectively, from G1 to G4. The %EEL in the total bone increased 9.7% compared to a larger increase of 14.8% in total carcass bone. This is due in part, to the characteristics of the round bones such as the femur, tibia, humerus and radius, which contain more bone marrow and consequently more lipid. Total bone, on the other hand, contains the bones of the skull and lower legs which are either flat or denser and contain less marrow and lipid. The %P in both total bone and carcass bone increased slightly, 4.4% and 1.7%, respectively, but nonsignificantly (P>.10) from G1 to G4. The increase in protein may be due to an increase in the cartilage associated with the vertebra, distal ends of the long bones and the costal cartilage of the rib cage.

As one would expect, the percentage of ash associated with both the total and carcass bone increased 6.7% from G1 to G4. This is due partly to the decrease in moisture content of the maturing bones and to the increased

TABLE 13. GROUP MEANS AND STANDARD ERRORS OF SELECTED BONES FROM THE TOTAL BODY, CARCASS AND INDIVIDUAL RIGHT SIDE BONES[a]

	Group			
Bone	1	2	3	4
Total bone, kg	36.15 (.51)	41.13 (1.10)	46.04 (.75)	50.83 (1.43)
Carcass bone, kg	28.36 (.37)	32.88 (.95)	36.60 (.61)	40.76 (1.32)
Femur, kg	1.68 (.02)	1.92 (.06)	2.11 (.05)	2.35 (.07)
Tibia, kg	1.09 (.01)	1.24 (.04)	1.35 (.03)	1.51 (.03)
Humerus, kg	1.26 (.01)	1.45 (.06)	1.60 (.05)	1.74 (.04)
Radius /Ulna, kg	.95 (.02)	1.07 (.04)	1.20 (.03)	1.32 (.02)
3rd rib, kg	.104 (.002)	.117 (.01)	.133 (.002)	.152 (.002)
10th rib, kg	.164 (.01)	.196 (.01)	.226 (.01)	.247 (.01)
Rib cage, kg	2.95 (.06)	3.29 (.11)	3.83 (.12)	4.40 (.08)
Vertebral column, kg	3.44 (.11)	4.26 (.08)	4.53 (.08)	5.37 (.19)

a Standard errors in parentheses.

TABLE 14. GROUP MEANS AND STANDARD ERRORS OF PROXIMATE ANALYSES FOR TOTAL BODY AND CARCASS BONE[a]

Group		Moisture	Ether Extractable lipid	Protein	Ash
		%			
Total bone	1	34.65 (.49)	15.11 (.83)	19.88 (.05)	30.36 (1.24)
	2	32.56 (.58)	15.73 (.38)	20.98 (.27)	30.73 (.51)
	3	31.64 (.16)	15.51 (.62)	20.60 (.15)	32.25 (.51)
	4	30.29 (.22)	16.57 (.43)	20.75 (.16)	32.39 (.28)
Carcass bone	1	34.93 (.62)	16.80 (.57)	20.15 (.26)	28.12 (.84)
	2	31.92 (.35)	17.76 (.53)	20.25 (.28)	30.08 (.19)
	3	31.35 (.56)	17.32 (.70)	20.17 (.30)	31.17 (.70)
	4	30.16 (.36)	19.29 (.22)	20.54 (.13)	30.01 (.40)

a Standard errors in parentheses.

calcification or mineralization of the bones which occurs with maturation.

Noncarcass Tissues. Table 15 contains the means and standard errors for the weight and composition of the total blood. As expected the total weight of blood increased with increasing age and weight, except between G3 and G4. The composition of blood remained relatively constant in %M and %P, exhibiting only a slight trend toward decreasing %M (due to individual animal variation) in the latter weight groups. The composition of blood in this study, very closely resembles the composition of blood found by Haecker (1920). Results of this study are slightly lower in %M and higher in %P than steers of comparable ages in the study by Moulton et al. (1922 b,c). The absolute weight of the blood in this study was greater than in all reported studies for steers of comparable weights and ages.

Table 16 contains the composition and absolute weight of the hide from each group in this study. The weight of the hide increased between groups with the largest increase occurring between G1 and G2, and comparable increases between G2, G3 and G4. The %M of the hide in my study was similar to that of steers with comparable weights and ages reported by Haecker (1920) and Moulton et al. (1922b,c). The %EEL and %P in my study also agrees with the values of Moulton et al. (1922). However, the %P reported by Haecker

TABLE 15. GROUP MEANS AND STANDARD ERRORS FOR THE WEIGHT AND PERCENTAGE OF MOISTURE, ETHER EXTRACT AND PROTEIN FOR BLOOD[a]

Item	Group 1	2	3	4
Weight, kg	15.73 (.37)	19.72 (.68)	23.20 (1.30)	23.47 (.25)
Moisture, %	80.4 (.51)	80.9 (.59)	79.4 (.22)	78.6 (.25)
Ether Extract, %	.1 (.01)	.2 (.03)	.3 (.04)	.2 (.05)
Protein, %	19.0 (.53)	18.1 (.62)	19.3 (.12)	20.1 (.34)

a Standard errors are in parentheses.

TABLE 16. GROUP MEANS AND STANDARD ERRORS FOR THE WEIGHT AND PERCENTAGE OF MOISTURE, ETHER EXTRACT AND PROTEIN FOR HIDE[a]

Item	Group 1	2	3	4
Weight, kg	21.84 (.87)	31.0 (.70)	35.6 (.60)	41.98 (.46)
Moisture, %	63.8 (.22)	63.2 (.11)	62.9 (.39)	62.9 (.21)
Ether Extract, %	.8 (.08)	.8 (.13)	1.1 (.03)	1.4 (.08)
Protein, %	34.7 (.27)	34.8 (.12)	34.8 (.30)	34.7 (.17)

a Standard errors are in parentheses.

(1920) was considerably lower than in my study as was the %EEL. The absolute weight of the hide of each group in my study was found to be greater than from steers in the study by Haecker (1920), Moulton et al. (1922b,c) and Moran and Wood (1985). This increase is due to the increased body size of Contiental European crossbred cattle.

Table 17 contains the weight and composition of the heart for each group in this study. The largest increase in weight occurred between G1 and G2, when actual growth is greatest, with a smaller increase between G3 and G4, when fattening is the prevalent growth-related activity. Composition of the heart in my study was similar to the reported values of Moulton et al. (1922b,c), the only exception being that the %EEL of the heart was slightly greater in my study. The weight of the heart in the present study was also greater than previously reported studies, with the exception of the heavier heart weights in Grati cattle and buffalo as reported by Moran and Wood (1985).

Table 18 contains the liver weight and composition for the steers in my study. Liver weight increased most from G1 to G2, with smaller increases between G2, G3 and G4. Liver weights reported from the studies of Moulton et al. (1922b,c) were considerably lighter than in my study, while the liver weights of ruminants reported by Moran and Wood

TABLE 17. GROUP MEANS AND STANDARD ERRORS FOR THE WEIGHT AND PERCENTAGE OF MOISTURE, ETHER EXTRACT AND PROTEIN FOR HEART[a]

Item	Group 1	2	3	4
Weight, kg	1.49 (.06)	1.85 (.08)	2.09 (.10)	2.19 (.07)
Moisture, %	69.6 (.45)	67.5 (.65)	68.0 (.25)	67.2 (.41)
Ether Extract, %	14.3 (.61)	17.4 (.70)	17.7 (.53)	18.4 (.66)
Protein, %	15.4 (.31)	15.0 (.09)	14.4 (.44)	13.9 (.32)

a Standard errors are in parentheses.

TABLE 18. GROUP MEANS AND STANDARD ERRORS FOR THE WEIGHT AND PERCENTAGE OF MOISTURE, ETHER EXTRACT AND PROTEIN FOR LIVER[a]

Item	Group 1	2	3	4
Weight, kg	3.71 (.08)	4.98 (.20)	5.34 (.20)	6.02 (.18)
Moisture, %	70.7 (.26)	70.9 (.35)	70.7 (.39)	70.7 (.29)
Ether Extract, %	2.2 (.23)	1.9 (.21)	1.8 (.05)	2.4 (.03)
Protein, %	20.2 (.19)	19.8 (.22)	19.7 (.23)	19.2 (.21)

a Standard errors are in parentheses.

(1985) were similar. Composition of the liver in my study were very similar to those reported by Moulton et al. (1922b,c).

Table 19 contains the weight and chemical composition of the kidneys in this study. Kidney weights increased between the lighter weight groups when increased growth rates occurred, with much lower increases as the steers reached the designated market endpoint. Composition of the kidney in this study remained relatively constant, with only slight decreases in %M and increases in %EEL between G1 and G4. This is in general agreement with the findings of Moulton et al. (1922b,c). However, the %M and %P in the present study were higher and the %EEL lower than those reported in the literature. This might be expected with changes in the degree of fatness in cattle from earlier studies compared to today's cattle. The weight of the kidneys in the study by Moulton et al. (1922a,b,c) were less than in the present study. Recent data by Moran and Wood (1985), however, showed similar weights of the kidneys in Madura, Ongole and Bali cattle and slightly heavier kidney weights in Grati cattle and buffalo.

Table 20 contains the weight and composition of the lungs in steers from the present study. Lung weight increased slightly between each group as expected, but composition remained relatively constant across all groups.

TABLE 19. GROUP MEANS AND STANDARD ERRORS FOR THE WEIGHT AND PERCENTAGE OF MOISTURE, ETHER EXTRACT AND PROTEIN FOR KIDNEY[a]

Item	Group 1	2	3	4
Weight, kg	.69 (.08)	.77 (.02)	.84 (.01)	.86 (.02)
Moisture, %	76.3 (.38)	75.7 (.40)	76.2 (.52)	74.5 (.30)
Ether Extract, %	6.6 (.35)	7.3 (.59)	7.7 (.33)	8.5 (.45)
Protein, %	15.1 (.36)	16.1 (.07)	15.0 (.19)	16.1 (.16)

a Standard errors are in parentheses.

TABLE 20. GROUP MEANS AND STANDARD ERRORS FOR THE WEIGHT AND PERCENTAGE OF MOISTURE, ETHER EXTRACT AND PROTEIN FOR LUNGS[a]

Item	Group 1	2	3	4
Weight, kg	1.94 (.06)	2.44 (.06)	2.55 (.10)	2.81 (.10)
Moisture, %	78.9 (.20)	78.5 (.19)	78.5 (.12)	78.5 (.06)
Ether Extract, %	3.1 (.09)	2.9 (.03)	3.1 (.04)	3.1 (.11)
Protein, %	16.7 (.24)	17.7 (.20)	17.6 (.16)	17.6 (.17)

a Standard errors are in parentheses.

The composition of the lungs in this study differed slightly from reported values by Moulton et al. (1922b,c), having lower %M, higher %EEL and higher %P. The previously reported values, however, included both the lungs and trachea, but only the lungs were analyzed in my study. The lungs in steers from this study were heavier than the respiratory system weights reported by Moulton et al. (1922b,c) but were similar in weight to Madura, Ongole and Bali cattle of comparable weight comparable by Moran and Wood (1985) and slightly less than Grati cattle and buffalo.

Table 21 contains the weights and composition of the brain for the steers in this study. Weight of the brain increased most between G1 to G2 and between G2 to G3 with no change between G3 and G4. Chemical composition remained essentially unchanged across all groups. Moulton et al. (1922b,c) reported the weight and composition of the nervous system (includes spinal cord). Their values were lower in %M, higher in %EEL, the same in %P and greater in absolute weight. Very little, if any other information is available from other studies.

Table 22 contains the weight and chemical composition of the tongue from steers in this study. Again, tongue weight increased with increasing weight with the largest increase occurring between G2 to G3 and between G3 to G4.

TABLE 21. GROUP MEANS AND STANDARD ERRORS FOR THE WEIGHT AND PERCENTAGE OF MOISTURE, ETHER EXTRACT AND PROTEIN FOR BRAIN[a]

Item	Group 1	2	3	4
Weight, g	404.8 (13.16)	421.8 (2.76)	468.7 (7.78)	461.9 (12.26)
Moisture, %	79.2 (.43)	79.4 (.27)	79.6 (.19)	78.8 (.17)
Ether Extract, %	9.8 (.31)	9.4 (.22)	9.7 (.28)	9.7 (.09)
Protein, %	10.4 (.20)	10.3 (.13)	10.6 (.15)	10.0 (.18)

a Standard errors are in parentheses.

TABLE 22. GROUP MEANS AND STANDARD ERRORS FOR THE WEIGHT AND PERCENTAGE OF MOISTURE, ETHER EXTRACT AND PROTEIN FOR TONGUE[a]

Item	Group 1	2	3	4
Weight, g	952.0 (42.59)	1032.1 (22.85)	1322.1 (44.70)	1459.9 (38.40)
Moisture, %	71.6 (.11)	69.1 (.42)	67.9 (.58)	66.9 (.78)
Ether Extract, %	10.9 (.43)	13.5 (.64)	15.8 (.72)	16.3 (1.0)
Protein, %	16.7 (.19)	16.2 (.20)	15.7 (.13)	15.3 (.42)

a Standard errors are in parentheses.

As expected, %M decreased with increasing weight, %EEL increased and %P was slightly decreased due to increased lipid deposition.

Table 23 contains the weight and chemical composition of the thymus gland from cattle in my study. The weight of the thymus gland increased greatly from G1 to G2 and remained essentially unchanged in G3 and G4. The %M decreased, %EEL increased and %P decreased as the steers increased in weight.

Tables 24 and 25 contain the weight and chemical composition of the omentum (stomach, OAT) and mesentery adipose tissue (MSAT) from the steers in my study. Moulton et al. (1922) dissected the adipose tissue associated with the gastrointestinal tract into three divisions; caul fat, stomach and intestinal fat. The OAT in my study included both the caul and stomach fat. The MSAT is comparable to the intestinal fat in the study by Moulton et al. (1922).

Weight of the OAT from G1 steers in my study, which are comparable in age to the 10 to 11 month old steers in the study by Moulton et al. (1922), was less than in the previously reported study. This most likely indicates that the G1 steers are either physiologically less mature or genetically less predisposed to depositing OAT at 10 mo of age. The OAT increased 330% between G1 and G4. The G4 steers are comparable in age to the 17 to 18 mo old steers

TABLE 23. GROUP MEANS AND STANDARD ERRORS FOR THE WEIGHT AND PERCENTAGE OF MOISTURE, ETHER EXTRACT AND PROTEIN FOR THYMUS GLAND[a]

Item	Group 1	2	3	4
Weight, g	314.5 (17.60)	683.4 (58.08)	654.4 (52.12)	648.3 (101.13)
Moisture, %	75.6 (.44)	74.2 (.82)	67.9 (.54)	61.9 (.63)
Ether Extract, %	8.0 (.46)	10.3 (.62)	17.0 (1.0)	23.7 (.82)
Protein, %	15.5 (.44)	14.3 (.38)	14.6 (.36)	13.6 (.14)

a Standard errors are in parentheses.

in the study of Moulton et al. (1922). The weight of the OAT from the G4 steers was greater (14,398 vs 9229 g), than the previously mentioned steers. This may be due in part to the fact that the Continental European crossbred steers in my study were heavier in live weight and also may be predisposed to depositing more internal body AT than carcass AT.

The MSAT from the G1 steers followed the same developmental pattern as the OAT. The G1 MSAT was less than comparable steers of the study by Moulton et al. (1922). The MSAT increased about 260% from G1 to G4. Weight of MSAT from G4 steers was essentially the same as that from comparable steers in the study by Moulton et al. (1922).

Composition of each AT depot (OAT, MSAT) differed from that reported by Moulton et al. (1922). Moulton et al. (1922) combined all fat depots before analyzing for %M, %EEL and %P. In my study, the OAT was analyzed separately from MSAT. The %M and %P of the OAT and MSAT from G1 was greater than that reported for offal AT by Moulton et al. (1922). Consequently, the %EEL of G1 OAT and MSAT was lower than that reported by Moulton et al. (1922). The %M and %P of G4 OAT was lower and the %EEL greater than the composition of the offal fat reported by Moulton et al. (1922). Conversely, the %M and %P of the MSAT was greater

and the %EEL was lower than the values reported by Moulton et al. (1922).

TABLE 24. GROUP MEANS AND STANDARD ERRORS FOR THE WEIGHT AND PERCENTAGE OF MOISTURE, ETHER EXTRACT AND PROTEIN FOR OMENTUM ADIPOSE TISSUE[a]

Item	Group 1	2	3	4
Weight, g	4363.7 (241.9)	7514.2 (480.7)	11778.2 (449.9)	14398.2 (825.4)
Moisture, %	18.4 (.28)	18.0 (.56)	9.5 (.37)	7.7 (.22)
Ether Extract, %	79.6 (.36)	80.2 (.64)	89.4 (.28)	92.0 (.44)
Protein, %	2.7 (.06)	2.2 (.15)	1.4 (.08)	1.2 (.03)

a Standard errors are in parentheses.

TABLE 25. GROUP MEANS AND STANDARD ERRORS FOR THE WEIGHT AND PERCENTAGE OF MOISTURE, ETHER EXTRACT AND PROTEIN FOR MESENTERY ADIPOSE TISSUE[a]

Item	Group 1	2	3	4
Weight, g	3930.8 (89.0)	5802.0 (389.0)	8554.6 (379.5)	10182.1 (610.0)
Moisture, %	25.4 (.90)	18.3 (.50)	13.7 (.20)	13.0 (.19)
Ether Extract, %	73.2 (1.2)	79.3 (.61)	84.4 (.13)	85.6 (.19)
Protein, %	2.7 (.03)	2.7 (.09)	2.4 (.06)	1.7 (.11)

a Standard errors are in parentheses.

SUMMARY

Twenty Continental European crossbred steers were randomly allotted to one of four slaughter groups. Slaughter weights for each group 1 to 4, were 300, 390, 480 and 560 kg, respectively. Each steer was slaughtered at the designated weight and totally dissected into individual adipose tissue depots, separable carcass adipose tissue and total adipose tissue. Major individual carcass muscles were also dissected along with total carcass and total empty body skeletal muscle. Moisture, ether extractable lipid and protein (%N x 6.25) were determined on all adipose tissue and muscle samples. Major individual bones from the right side, total carcass and total empty body bone weights and composition were also determined. Numerous major noncarcass tissues were also individually dissected and chemical composition was determined.

Intermuscular adipose tissue (IMAT) was the major adipose tissue component of the total carcass at each weight. IMAT accounted for 49.2% of the total adipose tissue (AT) and 50.9% of SATC in steers weighing 300 kg. While the weight of IMAT increased, the %IMAT of total AT decreased to 39.6% and 45.7% of SATC, respectively, in 555 kg steers. The SQAT increased from 21.6% as a percentage of total AT and 25.6% of SATC in 300 kg steers to 30.3% of

total AT and 35% of SATC, respectively, in 555 kg steers. Weight of perirenal AT increased both in absolute weight and as a percentage of total AT from 11.4 to 14.0% from the start of the study to the end. Intramuscular adipose tissue weight was at least as large or larger than the perirenal depot and was comparable to KP in percentage of total AT in each weight group.

Moisture and protein content of all adipose tissues decreased, while EEL increased as weight increased. The order of highest % M content of the adipose tissues studied in group 1 was MAAT (48.5%), SQAT (25.9%), IMAT (16.1%) and KP (9.3%). Group 1 EEL was least in MAAT (35%), followed by SQAT (66.5%), IMAT (80.7%0 and KP (88.1%), respectively. Group 1 percentage protein was greatest in MAAT (16.3%) followed by SQAT (7.5%), IMAT (2.8%) and KP (2.1%), respectively.

Percentage muscle of the live and carcass weight decreased from 42.3, 66.0; 40.2, 62.5; 38.1, 59.2, and 38.7, 57.9%, respectively, from G1 to G4. Overall carcass muscle weight increased by 70.5% from G1 to G4. The LD and BF were the largest individual muscles in the carcass at all weight groups, each accounting for approximately 6.5 % of total carcass muscle. Carcass muscle consistently accounted for 98.4% of total empty body skeletal muscle. As expected the percentage moisture in each muscle

decreased with each weight group, EEL increased (the most in the TP, followed by the LD and the least in the GS and BR of the muscles studied), while protein remained constant. Moisture content of muscles from G1 ranged from 75.5 to 77.0% and decreased to 72.0 to 75.0% in G4. However, not all muscles decreased in moisture content to the same extent.

Carcass bone as a percentage of total bone was relatively constant at about 79.5%. Carcass bone as a percentage of carcass weight was 15.1% in group 1 declining to 13.3, 12.1 and 11.1% in successive weight groups. Total body bone as a percentage of empty body weight was 13.2% in group 1 declining to 11.5, 10.5 and 9.9% in succeeding groups. The femur was consistently the largest bone in the body in each weight group, followed by the humerus, tibia and radius/ulna, respectively. As expected the percentage moisture in both the total and carcass bone decreased with increasing weight from 34.6% to 30.2%. EEL increased from 15.1 to 16.6% in total bone, however, EEL of carcass bone increased from 16.8 to 19.3%. Protein content of the bone remained relatively constant across groups while ash content increased.

Composition of the major noncarcass tissues and vital organs have for the most part, remained constant when compared with the limited data from studies conducted in

the 1920's. Relatively small changes have occurred in the distribution of moisture, lipid and protein in the noncarcass tissues studied. The major change in noncarcass tissues and vital organs occurred due to the selection of animals which grow to a larger body size before fattening, thus increasing the need for larger organs and tissues to support the necessary body functions.

GLOSSARY OF ABBREVIATIONS

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Adipose Tissues:

AT	--	Adipose tissue
EEL	--	Ether extractable lipid
IMAT	--	Intermuscular
KP	--	Perirenal and pelvic cavity adipose tissue
MAAT	--	Intramuscular
MSAT	--	Mesentery
OAT	--	Omentum (stomach)
SATC	--	Separable adipose tissue of carcass
SQ	--	Subcutaneous fat
SQAT	--	Subcutaneous adipose tissue

Muscles:

BB	--	Biceps brachii
BF	--	Biceps femoris
GA	--	Gastrocnemius
GM	--	Gluteus medius
GP	--	Gluteus profundus
IF	--	Infraspinatus
INM	--	Intercostal muscles
LAT	--	Latissimus dorsi
LD	--	Longissimus dorsi

PM	--	Psoas major
PP	--	Pectoralis profundus
RA	--	Rectus abdominus
RF	--	Rectus femoris
RH	--	Rhomboideus
SB	--	Subscapularis
SD	--	Spinalis dorsi
SM	--	Semimembranosus and adductor
SS	--	Supraspinatus
ST	--	Semitendinosus
SV	--	Serratus ventralis
TP	--	Trapezius
TR	--	Triceps brachii
VL	--	Vastus lateralis
VM	--	Vastus medialis

Abbreviations of terms used in calculations:

EEIM	--	EEL of IMAT
EEIMMA	--	Ether extractable lipid in the intermuscular and intramuscular AT
EMMA	--	EEL of MAAT from the skeletal muscle
FFM	--	Fat-free muscle
FFMEE	--	Skeletal muscle including MAAT and the M, P from IMAT
FFMMA	--	Fat-free muscle and marbling adipose tissue (includes M and P of MAAT)
M	--	Moisture

P	--	Protein
MPIM	--	Moisture and protein associated with IMAT
TM	--	Muscle Tissue Without MAAT
TMAAT	--	Total weight of marbling adipose tissue
T%MAAT	--	Percentage of total MAAT
TMM	--	Total of skeletal muscle and MAAT

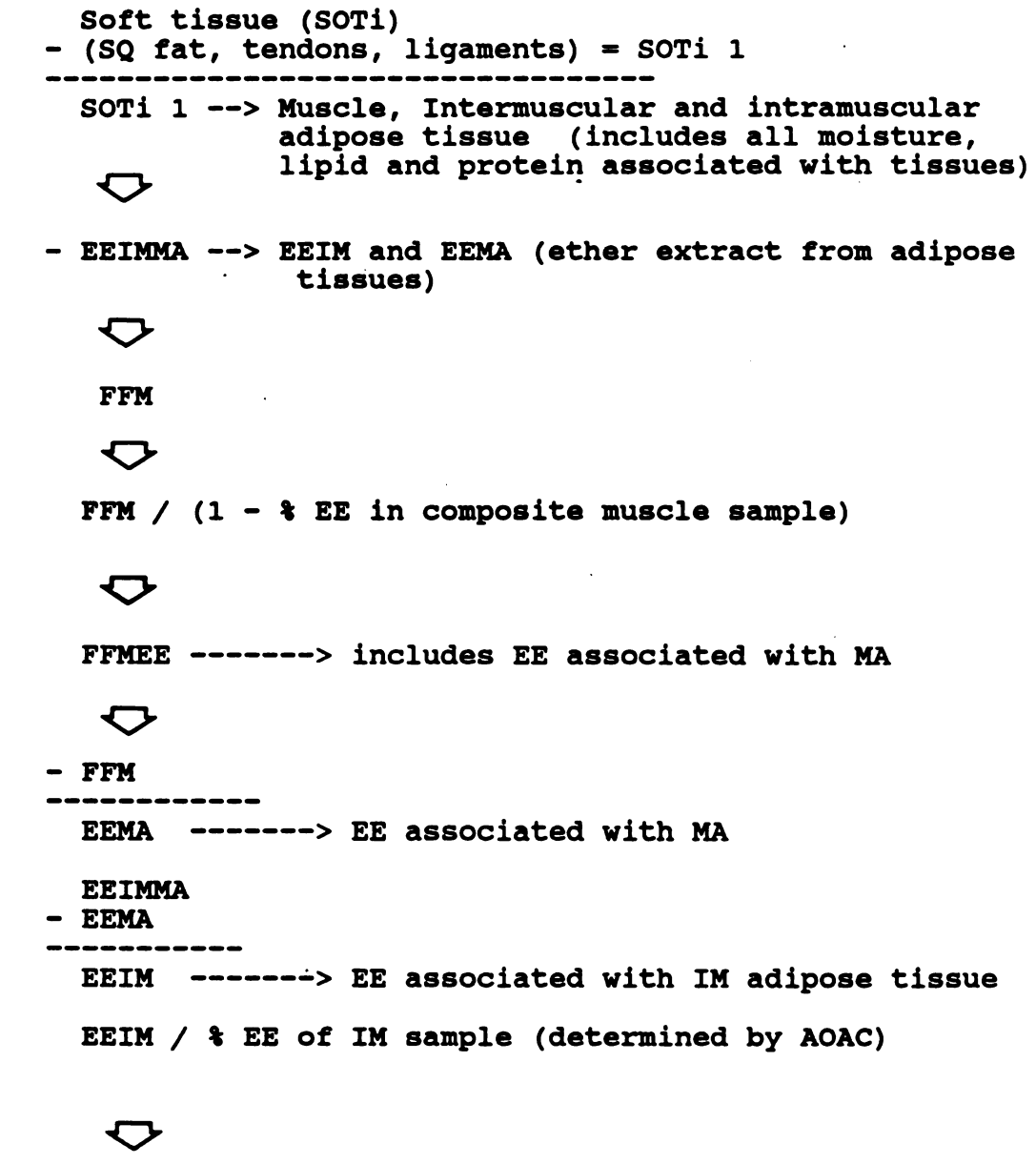
Other Abbreviations:

CS	--	Corn Silage
HMC	--	High Moisture Corn

APPENDIX

APPENDIX A.1

Flow diagram for calculation of skeletal muscle, intermuscular and intramuscular adipose tissue



```
  IMAT
- EEIM
------------
  MPIM  ------------> M and P associated with IMAT


  FFM
- MPIM
------------
  FFMMA  ---------> Muscle and intramuscular adipose
                    tissue moisture and protein
+ EEMA
------------
Total muscle and marbling tissue (TMM)


  TMM
x T%MAAT  ------> % EE of composite muscle / % EE of MA
------------
  TMAAT  -------> Total intramuscular adipose tissue

  TMM
- TMAAT
------------
  Total Muscle tissue (TM)
```

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