CARCASS COMPOSITION IN SINGLE AND MULTIPLE BIRTH CATTLE

By

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CHAPTER I

INTRODUCTION

Ranchers and stockmen have long been aware of the tremendous problems facing their operations relative to the less than optimum reproductive efficiency of their livestock. This problem is compounded in the cattle industry by the fact that under normal range conditions, an operator can expect, at best, an 85 percent to 90 percent annual calf crop. For this reason several research stations have conducted extensive studies in the area of reproductive efficiency in beef cattle. Many of the early projects dealt primarily with the improvement of calf crop percentage through the use of improved feeding, breeding, and management techniques. However, some of the more recent work has shown promise in the area of the induction of multiple births in beef cattle through the use of exogenous gonadotropins such as pregnant mare serum and human chorionic gonadotropin. There is a need for much more research in this field; and if, in the future, a practical treatment scheme can be formulated, the artificial induction of multiple births would surely prove a great boon to the beef cattle industry.

These previous studies have identified many of the problems associated with multiple births; however, very little work has been done to evaluate the carcass characteristics of multiple birth animals after a period in the feedlot. For these reasons, a project was initiated in an attempt to cast some light on the question of how well multiple birth animals compare to single birth animals in feedlot performance, growth patterns, and carcass composition.

CHAPTER II

LITERATURE REVIEW

I. Growth and Development

From the time of conception to maturation, an animal undergoes a continuous process of growth and development. Many investigators have conducted extensive studies in an attempt to secure knowledge of the nature of these growth processes. However, there seems to be little agreement in this area as exemplified by the differences in opinions on how the term growth should be defined. For example, Brody [1945] defined growth as the production of new biochemical units brought about by cell division, cell enlargement, or incorporation of materials from the environment; while Hammond [1952] and McMeekan [1959] defined it as increase in weight until a mature size is reached.

Development, on the other hand, seems somewhat easier to define in that it denotes the progressive change in the shape of an animal until the mature form of the species is reached. Hammond [1952] and McMeekan [1959] referred to development as the changes in body shape and/or conformation until the body structure and its various parts reach maturity.

Thus, growth and development may be defined separately, but a more meaningful method for the purpose of this study would be to combine the two as done by Joubert [1956] who defined growth and development as the changes in size and shape of the individual from the time of fertilization until mature proportions are obtained.

II. Prenatal Growth and Development

Prenatal growth results from a series of orderly differential processes that transform a fertilized egg into an animal [Hafez, et al., 1969]. Winters, et al. [1948] reported that the prenatal life of the bovine may be divided into three phases: the ovum, the embryonic, and the fetal. The period of the ovum usually lasts from the day of ovulation to about the eleventh day of pregnancy and encompasses the time in which very little change in the shape of the embryo takes place. In contrast, there is a great deal of developmental activity occurring during the ovum phase including cleavage, formation of the blastocyst, formation of the trophoblast, and formation of the inner cell mass. The embryonic phase, which lasts from the eleventh to the forty-fifth day, is characterized by the formation of the major tissues and organs and the differentiation of the major body systems. The period of the fetus lasts from the forty-sixth day of pregnancy to parturition. During this phase the organs of the body begin to grow and great changes in the form and shape of the animal can be seen. Also in the fetal stage a great increase in fetal weight takes place.

The various tissues of the body develop at different rates during prenatal growth as shown by Joubert [1956] who found that increases in muscle weight during the first two-thirds of the prenatal period were due to increase in cell numbers or hyperplasia. However, during the latter third of the prenatal period, hypertrophy of the existing fibers contributes more to weight increase than during the intitial two-thirds of the prenatal stage. In a like manner many other workers have attempted to assign time intervals to the various developmental stages of the body parts. These workers have generally found that the developmental changes in the animal body are caused by a "primary wave" of growth from the cranium down to the facial parts of the head and backwards to the lumbar region. They also note a secondary wave of growth from the lower parts of the limbs down to the digits and upwards along the limbs and the trunk to the lumbar region of the animal body [McMeekan, 1940, Pålsson and Vergés, 1952; Hammond, 1932; Pálsson, 1955; and Wallace, 1948]. The same workers have shown that the various tissues also attain maximum growth in a definite order with nervous tissue being the earliest maturing followed by bone, muscle, and fat tissue. In a like manner, fat is deposited in the various depots at different rates with mesenteric fat appearing first followed by kidney fat, intermuscular fat, subcutaneous fat, and intramuscular fat.

Prenatal growth and development is affected by several factors such as heredity, size and nutrition of the mother, litter size, placenta size, and temperature [Hafez and Dyer, 1969]. The maximum size attained by an animal is determined by his genotype, but this size is modified to a large extent by the size and nutrition of the dam. This fact was shown dramatically by Walton and Hammond [1938] who made reciprocal crosses between a very large breed of horses, the Shire, and a small breed of horses, the Shetland, and compared the foals. A similar study was conducted by Hunter [1956] who crossed the large Border Leicester and small Welsh breeds of sheep. In both of these cases, the offspring from the larger dams were bigger than the offspring from the smaller dams even though in each case the offspring should have received similar genes for size from each parent breed. These studies clearly indicated that maternal effects on the size of the offspring do exist.

Nutrition of the dam also has an effect on prenatal growth. Wallace [1948] showed that if a ewe was well-fed early in pregnancy but undernourished during the last third of gestation, she would produce a stunted lamb. However, if the ewe was well-fed late in pregnancy, a normal lamb was born. Litter size also plays a role in prenatal growth, especially in animals that normally produce only a single young. Johnson [1972] demonstrated that single birth calves were significantly heavier at birth than multiple birth calves. His work further revealed that twins were heavier than triplets and both twins and triplets were heavier than quadruplets. Certainly there are many other factors that play an important role in prenatal growth some of which will be discussed in subsequent sections.

III. Post-Natal Growth and Development

A. Bone

Hammond [1933] reported that the major tissues of the animal body continue to grow and develop at different rates post-natally with maximum bone growth preceding that of muscle and muscle preceding that of fat deposition. As regards bone, Zobrisky [1969] has defined bone growth as being "the period when addition of ions predominates over withdrawal of ions, resulting in a net increase in size and possibly in number of bone crystals." The increase in size of bone is by the addition of minerals and matrix on the surfaces of pre-existing bone.

For this reason, an increase in length of bone can occur only at the cartilaginous epiphyseal plates. Bones, on the other hand, increase in thickness by progressive development of new bone on the outer surface. From these points, it becomes obvious that linear bone growth can occur as long as the epiphyses are separated from the bone shaft; and growth ceases after the epiphyses unite with the shaft [Guyton, 1971].

Much experimental work has been conducted in an attempt to determine exactly when the periods of maximum bone and skeletal growth occur in farm animals. Pálsson and Vergés [1952] showed that the cranium is the earliest developing part of the ovine skeleton. They also noted that from the cranial region waves of increasing growth intensity pass backwards to the lumbar regions and downwards to the nose and lower jaw. There also seem to be growth waves for each limb that pass with age from the early developing metacarpals and metatarsals down to the distal bones and up into the lumbar region resulting in the pelvis and scapula being later developing than the femur and the humerus. Pálsson and Vergés [1952] further showed that the ribs are the latest maturing bones of the ovine body. The bones of the hind limb are earlier maturing than the bones of the fore limb while growth rate in length reaches a maximum at an earlier age than growth rate in thickness. Similar findings were reported for cattle skeletons by Brovar and Leontjeva [1939]; but in the pig, the hind limbs are later maturing than the fore limbs [McMeekan, 1941; Hammond, 1922].

In trying to explain the interrelationships between bone growth and overall body size, Cuthbertson and Pomeroy [1962] working with swine, showed that bones from the lighter carcasses grew relatively more in length than in thickness; and thickening and ossification were characteristic signs of older carcasses. In a like manner, Tulloh [1964] stated that bone increases with body weight but at a decreasing rate. To further substantiate the increase in bone growth as live weight increases, Zinn [1967] reported that during the first third of the feedlot period, muscle and bone of steers and heifers developed at a near proportional rate. However, during the latter third of the trial, bone increased less than muscle, possibly indicating that bone growth rate had declined.

B. Muscle

Butterfield and Berg [1966] have stated that muscles vary widely in their growth patterns even though muscle tissue usually develops earlier than adipose tissue but slower than bone. Following birth, muscle growth appears to be the result of hypertrophy of existing fibers since no new muscle fibers are formed after birth [Bendall and Voyle, 1967] except in some animals such as mice [Goldspink, 1962]. Hammond [1960] reported that the maximum adult size of an animal is fixed at birth since an increase in post-natal weight of muscle is by muscle cell hypertrophy. Hammond [1960] further noted that differences between breeds within a species are due to differences in muscle cell number and not to cell size.

Pálsson [1955] stated that the development of muscle in the different body regions "is governed by growth gradients similar to those met within the skeleton." There is a wave of growth intensity which increases with age and passes from the head and neck backwards and upwards from the lower parts of the limbs to the loin region. Hammond [1932], using Suffolk ewes, showed that muscle was 162 percent of the bone weight at birth, while in the adult ewe muscle was 645 percent of the bone weight indicating a definite increase in muscle mass with age. Similarly, McMeekan [1941] suggested that age dictates the upper limit to muscle fiber growth above which the fiber cannot exceed despite a prolonged high plane of nutrition. Further discussion of muscle growth will be included in subsequent sections involving the various factors affecting tissue growth and development.

C. Fat

Emery [1969] stated that fat in adipose tissue "should be considered a pool of calories for maintenance of homeostasis." Growth of adipose tissue is primarily due to hypertrophy of fat cells; but, unlike muscle cells, new fat cells do form, always along blood vessels. During the fattening period, the number of fat cells in adipose depots may double while the weight of the depot usually increases many fold due to hypertrophy [Emery, 1969]. Reciprocally, when a fat deposit regresses during restricted caloric intake, the central vacuole is normally depleted in a few weeks; but months are required for the additional adipose cells to regress [Hausberger, 1965].

In the growing animal weight gain consists of the formation of protein and structural lipid until the caloric intake exceeds the limits of growth rate at which time the excess calories are deposited as fat. This deposition of fat is normal in the process of developing meat animals. Deposition of fat, like bone and muscle, follows definite growth trends. In the experiment mentioned previously, Hammond [1932] demonstrated that total fat comprised eight percent of the ovine bone weight at birth; but at adulthood fat made up 165 percent of the bone weight. Therefore, not only does fat percentage normally increase with age, the level of fatness encompasses a major portion of the change in composition of the animal body [Callow, 1950]. As was the case with bone and muscle, fat is also deposited at varying rates in different parts of the body [Hankins and Titus, 1939]. In younger animals fat first appears around the mesentery and in the area of the kidney. With an increased age and the proper food intake, fat deposits then appear between the muscles, followed by subcutaneous fat, and finally intramuscular fat appears [Andrews, 1958; Callow, 1948; Zinn, 1967].

IV. Factors Affecting Body Composition

A. Sex

The effect of sex on body composition and carcass value is well known throughout the livestock industry and volumes of literature exist on the subject. Pomeroy [1955] stated that sex plays a role in growth in two ways. First, there is a direct effect of sex resulting from genetic differences between males and females; and secondly, there is an indirect effect of sex due to the influence of the sex hormones. Whatever the cause, Pálsson and Vergés [1952] state that in cattle and sheep, males are heavier than females at birth; and this difference persists throughout life. More recent studies indicate that bulls have considerably less finish than steers and steers less than heifers [Brannang, 1960; Dahl, 1962; Arthaud and Adams, 1964]. Similarly, Kennedy [1958] noted that steers had less finish than heifers when both sexes were slaughtered after the same length of time on feed.

As regards edible portion, studies indicate that bulls have a higher yield of retailable meat than steers and steers higher than heifers [Arthaud and Adams, 1964; Klosterman, 1963]. One report stated that fat, lean, and bone of heifers grew at a slower rate than steers during a feedlot period, but the overall growth pattern of the tissues was not altered by sex [Zinn, 1967].

B. Age

Age, like sex, has a definite effect on body composition. For example, McMeekan [1941] suggested that age defines the upper boundaries of muscle fiber size; and in the same respect, the percent of intramuscular fat appears to be more dependent upon age than plane of nutrition or state of fatness (Pálsson and Vergés, 1952; Andrews, 1958]. However, there also seems to be certain age-weight relationships that function to govern tissue growth in the animal body [Joubert, 1954]. Possibly, these age-weight factors could be due to the varying rates at which different muscles grow and develop [Joubert, 1956; Luitingh, 1962]. Henrickson, Blackman and Urban [1962] reported that the percentage of lean meat in the carcass tended to decrease as the age of the animal advanced. However, most data indicate that weight and stage of fattening have a greater effect on the physical composition of the carcass than does age [Callow, 1948; Zinn, 1967].

C. Breed

Definite differences exist between breeds of livestock as regards carcass composition. The early work of Hammond [1932] gives some possible explanations to these differences. Hammond stated that in an early maturing animal, the developmental changes take place in a much shorter time and are extended further than in a late maturing one.

Larger breeds are, as a rule, later maturing than the smaller breeds. Hammond [1932] dramatized these breed differences with respect to maturity by comparing the carcasses of small Southdown sheep to the much larger and later maturing Lincoln breed. At a common age, muscle comprised 503 percent and fat 201 percent of the bone weight in the Southdown; while in the Lincoln, muscle made up 366 percent and fat 99 percent of the bone weight showing the breed and maturity effects on carcass composition quite clearly.

Many studies have been conducted in an attempt to examine breed differences in beef cattle. Recently projects have been initiated to also evaluate beef x dairy crossbred animals with respect to carcass composition. Branaman, et al. [1962] could show no appreciable difference in the percent high priced cuts or separable lean between Holstein and beef-type steers. The beef-type steers did, however, have higher dressing percentages and graded higher than did the dairy type. A major difference between dairy and beef breeds is the area of the carcass in which fat depots are located. It would appear that the dairy breeds have a higher proportion of kidney and pelvic fat and a smaller proportion of subcutaneous fat than do the beef breeds [Callow, 1961].

CHAPTER III

MATERIALS AND METHODS

I. General Procedure

A. Types of Animals Used

This study was conducted from October, 1971 to July, 1972, at the Fort Reno Livestock Research Station, El Reno, Oklahoma. The experimental animals consisted of 20 weaning steers and 20 weaning heifers produced in the experimental cow herd of project 1375 as part of a previous study in the multiple birth project [Johnson, 1972]. Two multiple birth steers died from lead poisoning at the beginning of the trial resulting in only 18 steers being available for analyses. All multiple birth heifers were born twin to bulls and were, therefore, potential freemartins.

All animals were sired by Angus bulls, but their dams were of varied breeding including Holstein X Angus cows, Hereford X Angus cows, and straightbred Hereford cows. For the purpose of this analysis, animals were classified into two breeding groups, Dairy Cross if their dams had any Holstein breeding, or Beef Cross for those whose dams were either of straightbred or crossbred beef breeding. The classification of experimental animals according to sex, breeding group, and type of birth is presented in Table 1.

TABLE I

CLASSIFICATION OF ANIMALS ACCORDING TO SEX, BREEDING GROUP, AND TYPE OF BIRTH

Type of Birth	Breeding Group				Totals
	Steers		Heifers		
	Dairy Cross	Beef Cross	Dairy Cross	Beef Cross	
Multiple Births	5	3	5	5	18
Single Births	5	5	4	6	20
Totals	10	8	9	11	38

B. Feeding

At the time of weaning, the calves were placed in feedlot facilities at the Fort Reno Livestock Station. The steers were weaned at an average weight of 442 pounds and an average age of 215 days; while the heifers were weaned at 404 pounds and 208 days. The steers and the heifers were maintained in separate pens that were approximately 135 feet long and 75 feet wide and were allowed free access to water and minerals. The animals were full fed once a day for a variable length of time depending on the rate at which individual animals reached the desired weight. The ingredients used in the ration for this study are given in Table II.

TABLE II

RATION INGREDIENTS

Ingredient	Percent of Ration	Percent of Supplement
Milo	70	
Alfalfa Hay	8	
Cottonseed Hulls	12	
Molasses	5	
Supplement B-035	5	100
Contents of Supplement		
Soybean Oil Meal (44 percent)		67.6
Urea, 45 percent N		12.0
Calcium Carbonate		10.0
Salt		8.0
Antibiotic [Aurofac 10]		1.25
Vitamin A, 4000 IU per gram		0.63
Trace Minerals		0.50

C. Stress Imposed

The animals in this project were also used simultaneously in another study designed to evaluate the Whole Body Counter as a predictor of fat free lean in weaning age and slaughter weight cattle as well as to monitor the changes in lean muscle mass throughout the feedlot period. As a result of this two-way study, all these animals were transported once every six weeks from the feedlot at the Fort Reno Station to the Live Animal Evaluation Center near Stillwater, Oklahoma, where the Whole Body Counter was located.

On the day that the animals were to be transported to Stillwater, they were taken off feed and water in the morning and then trucked 90 miles to the Evaluation Center. The following day, after a fast of at least 24 hours, they were individually placed in the Whole Body Counter. Following the evaluation procedure, the cattle were transported back to the Fort Reno Station. The net result was a period of approximately 35 hours with no feed or water and a 180 mile trip by truck.

II. Specific Procedure

A. Slaughter Criterion

The original goal of this study was to slaughter at weights of 1,000 pounds and 900 pounds for steers and heifers respectively. However, this goal was not obtained in most cases due to the large variation in weaning weights, the stress imposed, the possible effects of type of birth, and certain limitations on scheduling of facilities for slaughter dictated by the available force and schedule of other events at the Meats Laboratory. In actuality, the steers were killed at an average weight of 909 pounds; while the heifers were killed at an average weight of 803 pounds.

Slaughter Procedure. The labor situation at the Meats Laboratory made it desirable to slaughter the animals in groups of ten on each kill date. With this in mind, the animals were weighed in May, 1972, average daily gains calculated; and projections were made as to when the groups of cattle would be ready for slaughter. Table III shows the number of animals sacrificed on each of the four kill dates.

TABLE III

SCHEDULE OF SLAUGHTER DATES AND NUMBER OF ANIMALS KILLED

	Kill I May 18, 1972 Number	Kill II June 1, 1972 Number	Kill III June 23, 1972 Number	Kill IV July 28, 1972 Number
Single Steers	3	3	4	
Multiple Steers	2	1	1	4
Single Heifers	4	3	2	1
Multiple Heifers	1	1	3	5
Total	10	8	10	10

Two days prior to slaughter, the cattle were transported to Stillwater. After a 24 hour fast, the final evaluation through the Whole Body Counter was performed on the day preceding the kill date. Slaughtering was then done at the Oklahoma State University Meats Laboratory at which time hide, head, and shank weights were taken; and reproductive tracts were recovered from the heifers to determine the freemartin status of multiple born heifers. The hot carcasses were then weighed, shrouded, and placed in a holding cooler for 48 hours.

B. Cut Out Procedure

After chilling, the right half of each carcass was ribbed and tracings made for later determination of rib eye area and average fat thickness; and a quality and conformation grade was placed on each carcass. The right halves were then divided into the forequarters and hindquarters, and specific gravity measurements were taken according to the method of Kraybill [1952].

After the preliminary data were collected, the right half of each carcass was divided into the wholesale cuts, the chuck, rib, loin, round, and thin cuts. Each wholesale cut was then physically separated into fat, lean and bone. At each step of the cut out procedure, appropriate weights were recorded.

C. Sampling Procedure

Following the physical separation, samples of the separable lean were taken for later determination of intramuscular fat by ether extraction. The procedure used for sampling the separable lean was as follows:

1. All equipment, including grinders, mixers, pans, etc., were placed in the cooler at least 12 hours prior to sampling.
2. The separable lean was hand mixed to obtain a uniform mixture of the fatter and leaner pieces as they passed through the grinder.
3. The lean was ground using a coarse plate followed by both manual and mechanical mixing for a period of approximately two minutes each.
4. The coarsely ground mixture was then ground a second time through the same coarse plate. This second grinding was followed by a thorough mixing using the mechanical mixer.

5. The coarse plate was then replaced by a fine plate, and the beef was ground a third time.
6. As the beef was being ground through a fine plate, 15 grab samples were taken from each side. The time of sampling was evenly distributed in an effort to obtain representative samples of the entire carcass.
7. The 15 grab samples were randomly allotted into three groups each containing five of the original grab samples. Each of the three groups were separately hand mixed and denoted as Sample A, Sample B, and Sample C.
8. Approximately 50 grams of meat was then taken from Sample A and placed in a small plastic bag. As much air as possible was forced from the bag before it was sealed. The same procedure was followed for Sample B and C resulting in a total of three samples for each animal.
9. After labeling, the three small plastic bags for each animal were placed together in a larger plastic bag and transferred to the blast freezer for 24 hours [-23.3° C.]. After this period the samples were transferred to the freezer [-17.8° C.] where they remained until the proper analysis could be performed.

D. Ether Extraction Procedure

After a period of storage, the samples were thawed at 1.7° C. and homogenized at 20° C. using a Sorvall Omni-Mixer without an ice pack. Following homogenization, the samples were thoroughly mixed at a very low speed using a food mixer. Duplicate five gram aliquots were taken from each sample, and percent ether extract was determined using the Soxlet Method [A.O.A.C., 1965]. The average of six determinations of fat content of the lean for each animal was used to determine the total quantity of fat free lean for each carcass as well as to determine the total quantity of fat in each carcass.

E. Statistical Analysis

The basic statistical design of this study entailed two 2 x 2 factorial experiments. The data were analyzed on a within sex basis due to the large variation in slaughter weights between sexes. The data that were analyzed included total fat, fat free lean, and total bone expressed as a percentage of cut weight to aid in controlling the variation in slaughter weights. Cut weight, in this instance, is defined as the weight of the cold right side of each carcass taken on the day that physical separation of the fat, lean and bone was performed.

Slaughter weights varied greatly by breeding group and type of birth within sex. Thus, fat, lean and bone were regressed on slaughter weight to develop prediction equations for adjusting the percentage fat, lean and bone of each animal to a common slaughter weight. Regression coefficients were pooled for each breed type and birth type within each sex. Separate analyses were then performed on the corrected data to determine if significant differences existed between multiple birth and single birth animals in fat, lean and bone on a within sex basis according to the Method of Disproportionate Numbers using a 2 x 2 Table as described by Snedecor and Cochran [1967]. If, however, a significant interaction existed between type of birth and breed group, only the simple effects of type of birth within breed group were examined. This analysis was accomplished by the method for comparing group means as described by Snedecor and Cochran [1967].

CHAPTER IV

RESULTS AND DISCUSSION

I. General Comments

Forty animals were originally allotted to this study including ten single birth steers, ten multiple birth steers, ten single birth heifers, and ten multiple birth heifers. However, two multiple birth steers were lost to lead poisoning within the first six weeks of the trial; consequently, only 38 animals were available for analysis. At the time of slaughter, reproductive tracts from the heifers were examined; and all multiple birth heifers, with the exception of one, were determined to be freemartins.

II. Carcass Composition

Table IV shows the amount of fat, fat free lean (FFL), and bone as well as the percentage of each expressed on a live weight basis for the steers and the heifers used in this trial. However, Table IV does not give an adequate picture of the data due to the large variation in slaughter weight between sexes. The average weights at the time of slaughter were: single steers, 930 pounds; multiple steers, 883 pounds; single heifers, 828 pounds and multiple heifers, 778 pounds. There was also the possibility of breed effects since both beef and dairy-beef cross dams were used. Therefore, the analysis was based on a within sex within breed basis. In an effort to correct for the variation in

TABLE IV

UNADJUSTED VALUES FOR TOTAL FAT, FAT FREE LEAN, SEPARABLE LEAN, AND BONE IN SINGLE AND MULTIPLE BIRTH STEERS AND HEIFERS

Item	Steers		Heifers	
	Singles	Multiples	Singles	Multiples
Number	10	8	10	10
Slaughter Weight	930 ± 7.62	883 ± 16.23	828 ± 9.15	778 ± 10.92
Total Carcass Fat (lbs)	220.6 ± 5.77	218.3 ± 7.57	207.4 ± 6.54	195.7 ± 7.67
Percent Fat	23.70 ± 0.51	24.73 ± 0.74	25.06 ± 0.76	25.13 ± 0.92
Separable Lean From 1/2 Carcass (lbs)	159.7 ± 2.26	154.4 ± 3.89	144.0 ± 2.79	131.6 ± 3.10
Percent Separable Lean	34.35 ± 0.48	34.97 ± 0.42	34.79 ± 0.53	33.78 ± 0.41
Total Carcass Fat Free Lean (lbs)	279.2 ± 3.01	267.3 ± 5.87	249.6 ± 4.76	231.6 ± 5.09
Percent Fat Free Lean	30.02 ± 0.34	30.28 ± 0.37	30.15 ± 0.47	29.74 ± 0.33
Bone from 1/2 Carcass (lbs)	27.8 ± 0.69	36.3 ± 1.21	32.0 ± 0.65	30.0 ± 0.90
Percent Bone	8.12 ± 0.16	8.21 ± 0.18	7.74 ± 0.15	7.69 ± 0.14
Percent Wholesale Cuts	60.17 ± 0.38	61.14 ± 0.32	60.73 ± 0.65	60.04 ± 1.01

Data Presented as Mean ± Standard Error

All Percentages are Expressed on a Live Weight Basis slaughter weights, the data on each animal were individually adjusted for slaughter weight through the use of regression coefficients pooled over type of birth and breeding group for each sex group. The regression coefficients used for these computations are shown in Table V. The steer records were adjusted to a common weight of 909 pounds while the heifer data were adjusted to 803 pounds.

Table VI shows the steer data in which the animals have been divided into type of birth and breeding groups. The values shown in this table are expressed as a percentage of the cold right side of the carcass on the day that physical separation was performed. This "cut-weight" was used instead of chilled or hot carcass weight in an effort to remove any bias associated with day of physical separation. The figures for total fat represent the cumulative total for kidney fat, separable fat, and chemical fat as determined via ether extraction. No appreciable differences were seen in total fat in the steer group, but the multiple birth steers did tend to be slightly fatter than the single birth steers in each of the breed groups.

Fat free lean (FFL) is defined as the separable lean portion of the carcass after the ether extractable fat has been removed. Once again, no significant differences were seen in FFL between types of birth within breeding group; but the single birth animals showed slightly more FFL than did the multiple birth animals.

As regards bone in the steer group, no differences could be seen in the unadjusted data when examining the records on a within breeding group basis. However, after the adjustment procedure was completed, a significant difference ($P < .05$) was detected in bone content of single birth beef cross steers and multiple birth beef cross steers as shown in

TABLE V

INDIVIDUAL AND POOLED REGRESSION COEFFICIENTS COMPUTED ACROSS BREEDING GROUPS AND TYPES OF BIRTH WITHIN SEX GROUPS

		% Fat on Weight	% Lean on Weight	% Bone on Weight
Steers	Single Birth Beef Cross (5)[1]	0.0137	-0.0117	-0.0021
	Multiple Birth Beef Cross (3)	0.0499	-0.0382	-0.0111
	Single Birth Dairy Cross (5)	0.0564	-0.0388	-0.0771
	Multiple Birth Dairy Cross (5)	-0.0189	0.0191	0.0009
	Pooled	0.0202	-0.0128	-0.0203
Heifers	Single Birth Beef Cross (6)	-0.0203	0.0247	-0.0082
	Multiple Birth Beef Cross (5)	-0.0549	0.0427	0.0123
	Single Birth Dairy Cross (4)	-0.0626	0.0627	-0.0052
	Multiple Birth Dairy Cross (5)	0.0206	-0.0253	-0.0039
	Pooled	-0.0118	0.0083	-0.0025

[1]Numbers in parentheses indicate number of animals in each cell.

TABLE VI

ADJUSTED STEER VALUES FOR FAT, FAT FREE LEAN (FFL) AND BONE EXPRESSED ON A TYPE OF BIRTH AND BREEDING GROUP BASIS

Item	Single Birth Beef Cross Steers	Multiple Birth Beef Cross Steers	Single Birth Dairy Cross Steers	Multiple Birth Dairy Cross Steers
Number	5	3	5	5
Shrunk Slaughter Weight	993 ± 14.75	852 ± 19.05	927 ± 14.75	902 ± 14.75
% Total Fat[1]	38.98 ± 1.18[2]	39.83 ± 1.53	37.54 ± 1.18	38.69 ± 1.18
% Total Fat (Adjusted)[3]	38.50 ± 1.15	40.99 ± 1.48	37.17 ± 1.15	38.84 ± 1.15
% FFL	48.05 ± 0.86	48.04 ± 1.11	48.91 ± 0.86	47.88 ± 0.86
% FFL (Adjusted)	48.36 ± 0.84	47.31 ± 1.08	49.14 ± 0.84	47.78 ± 0.84
% Bone	12.83 ± 0.35	12.19 ± 0.45	13.41 ± 0.35	13.49 ± 0.35
% Bone (Adjusted)	13.32 ± 0.39[4]	11.03 ± 0.50[4]	13.78 ± 0.39	13.34 ± 0.39

[1]Expressed as a Percent of the Cold Right Side of the Carcass on the Day of Physical Separation

[2]Mean ± Standard Error

[3]Adjusted Data Corrected to Mean Slaughter Weight of 909 Pounds

[4]Means Significantly Different ($P < .05$)

Table VI. No detectable difference in bone percentage was found between the single birth dairy cross steers and the multiple birth dairy cross steers. These steer data correspond closely to the data on sheep presented by Whiteman, Walters and Munson [1969] who found essentially no differences in fat, lean, and bone content between single and twin lambs.

The results of the analysis of the heifer carcasses is shown in Table VII. As previously stated, the figures given are expressed as a percentage of the weight of the cold right side of the carcass on the day that physical separation was performed. Also the adjusted data represent calculations made to correct all animals to an equivalent weight basis of 803 pounds. Although no significant differences were seen in the beef cross heifers, results indicate that single birth beef cross heifers tend to possess less fat, more fat free lean, and more bone than do multiple birth beef cross heifers. These data correspond closely to those presented previously for the steers.

On the other hand, the dairy cross heifers present quite a different picture. Once again no significant differences were observed; but in this case, the single birth dairy cross heifers tended to possess more fat, less fat free lean, and less bone than did the multiple birth dairy cross heifers. These results are just the opposite of those seen for the beef cross heifers, and the reason for this discrepancy would be extremely difficult to postulate.

The trends presented in these results seem to support the theory presented by Hammond [1932] relative to the order of development of body parts and tissues. According to this theory, growth of the body tissues occurs in waves of varying intensity with the period of maximum rate of growth occurring in the following order: nervous tissue,

TABLE VII

ADJUSTED HEIFER VALUES FOR FAT, FAT FREE LEAN (FFL) AND BONE EXPRESSED ON A TYPE OF BIRTH AND BREEDING GROUP BASIS

Item	Single Birth Beef Cross Heifers	Multiple Birth Beef Cross Heifers	Single Birth Dairy Cross Heifers	Multiple Birth Dairy Cross Heifers
Number	6	5	4	5
Shrunk Slaughter Weight	815 ± 12.51	769 ± 13.71	847 ± 15.33	787 ± 13.71
% Total Fat[1]	38.68 ± 1.15[2]	41.41 ± 1.26	41.35 ± 1.41	38.79 ± 1.26
% Total Fat (Adjusted)[3]	38.83 ± 1.14	41.01 ± 1.25	41.87 ± 1.40	38.60 ± 1.25
% FFL	48.95 ± 0.92	47.10 ± 1.01	46.32 ± 1.13	48.21 ± 1.01
% FFL (Adjusted)	48.85 ± 0.91	47.38 ± 1.00	45.96 ± 1.12	48.34 ± 1.00
% Bone	12.31 ± 0.32	11.53 ± 0.35	12.32 ± 0.40	13.15 ± 0.35
% Bone (Adjusted)	12.34 ± 0.32	11.44 ± 0.35	12.42 ± 0.39	13.11 ± 0.35

[1]Expressed as a Percent of the Cold Right Side of the Carcass on the Day of Physical Separation

[2]Mean ± Standard Error

[3]Adjusted Data Corrected to Mean Slaughter Weight of 802 Pounds

skeletal tissue, muscular tissue, adipose tissue. To achieve maximum development of any tissue the animal must have been able to achieve ultimate growth during the period of maximum growth intensity of that tissue.

These data suggest that multiple birth animals possess more fat, less lean, and less bone than do single birth animals. One might, therefore, conclude that the multiple birth animals may have been stressed prenatally during the period of maximum bone and muscle cell deposition, which can be somewhat substantiated by the fact that single birth animals were reported to be significantly heavier at birth than were multiple birth calves [Johnson, 1972]. Postnatal undernutrition was also a possibility since the multiple birth calves were raised as twins. The fact that the multiple birth animals possessed more fat at slaughter would indicate that they were not stressed during the period of maximum fat development which probably occurred while they were in the feedlot.

However, none of the differences seen in fat or lean were significant. Perhaps this lack of significance was due to the number of animals used, but another possibility may be accounted for by what Bohman [1955] has termed "compensatory growth." Brody [1926] has suggested that an animal whose growth has been retarded exhibits, when the restriction is removed, a rate of growth greater than that which is normal in animals of the same chronological age. In the same light, Wilson and Osbourn [1960] have said that the enhanced postnatal growth rates of many animals which are small at birth or hatching may be cited as a basic example of compensatory growth.

The lack of significant differences between multiples and singles in fat and lean at slaughter could partially be explained by the suggestion of Pálsson [1955]. He proposed that any region or part of a growing animal which has been retarded in development by restricted nutrition may recover completely if the animal is changed on to a high level of nutrition and if the period of undernutrition was not too severe. The results presented in this thesis agree closely with other workers who have shown that animals fed high and low planes of nutrition produced carcasses of equal composition and economic value if they were slaughtered at a constant weight [Winchester and Howe, 1955; Joubert, 1954]. Finally, McCay, et al. [1939] have stated that in only the most extreme cases of undernutrition is the normal orderly sequency of proportional development prevented from reaching its normal conclusion.

III. Carcass Measurements

Several additional carcass measurements that were calculated on these animals are presented in Table VIII. The primary objective of this study was to test for differences in fat, lean, and bone between single and multiple birth animals within sex and breeding group. Table VIII, however, compares multiples and singles within sex but does not consider breed effects. Nevertheless, these data are available and should, therefore, be examined.

The values presented in Table VIII indicate similar performance by multiple and single birth steers although several interesting trends might be noted. For instance, the single steers tended to acquire more pounds of separable lean as well as fat free lean per day of age than did the multiple steers. On the other hand, multiple steers had more kidney, heart, and pelvic (KHP) fat but less fat cover at the 12th rib than did the single birth steers. In the same light, the multiple birth steers graded average choice, while the single steers graded high good.

TABLE VIII

UNADJUSTED CARCASS VALUES FOR SINGLE AND MULTIPLE BIRTH STEERS AND HEIFERS

Item	Steers		Heifers	
	Singles	Multiples	Singles	Multiples
Number	10	8	10	10
Dressing %	62.75 ± 0.32[1]	64.21 ± 0.34	63.28 ± 0.64	63.30 ± 0.86
Hot Carcass Weight (lbs)	597 ± 6.11	581 ± 11.06	534 ± 7.04	503 ± 11.16
KHP % (Actual)	2.84 ± 0.13	3.23 ± 0.13	3.54 ± 0.26	3.95 ± 0.23
Rib Eye Area (Sq. In.)	10.53 ± 0.16	10.95 ± 0.33	10.76 ± 0.64	9.84 ± 0.37
Sq. In. Rib Eye Per 100 Lbs. Cold Carcass Weight	1.81 ± 0.04	1.93 ± 0.05	2.05 ± 0.12	1.99 ± 0.05
Avg. Fat at 12th Rib (inches)	0.72 ± 0.06	0.66 ± 0.08	0.69 ± 0.04	0.64 ± 0.03
Final Grade[2]	9.3 ± 0.34	11.12 ± 0.30	10.0 ± 0.42	10.4 ± 0.27
Marbling Score[3]	13.40 ± 0.72	18.75 ± 0.62	16.0 ± 1.25	16.80 ± 0.87
Pounds of Fat Per Day of Age	0.5198 ± 0.0158	0.4716 ± 0.0203	0.5024 ± 0.0210	0.4212 ± 0.0167

TABLE VIII (Continued)

Item	Steers		Heifers	
	Singles	Multiples	Singles	Multiples
Pounds of Separable Lean Per Day of Age	0.7526 ± 0.0164	0.6677 ± 0.0276	0.6971 ± 0.0228	0.5674 ± 0.0187
Pounds of FFL Per Day of Age	0.6576 ± 0.0118	0.5774 ± 0.0212	0.6042 ± 0.0205	0.4994 ± 0.0158

[1]Mean ± Standard Error

[2]Expressed on a Scale where: 9 = Good^{+}; 10 = Choice^{-}; 11 = Avg. Choice

[3]Expressed on a Scale where: 14 = Small; 16 = Modest^{-}; 17 = Modest; 19 = Moderate^{-}

The multiple steers also had a higher marbling score. The differences in the amount of fat and marbling were probably due to the increased age of multiples at slaughter.

The heifers showed similar carcass trends to those seen in the steer group with very little, if any, differences being observed in the heifer group. However, the single heifers did tend to possess more separable lean and fat free lean per day of age than did the multiple heifers.

IV. Feedlot Data

As indicated previously, the feedlot data collected in this trial were marred somewhat by the stress imposed on the animals during the course of this study. For this reason, the data presented in Table IX should be examined with caution. The birth weights reported in Table IX were obtained as part of the study in which these animals were produced [Johnson, 1972]. As shown in Table IX, values for average daily gain were very similar on a within sex basis. In both the steer and the heifer groups, the multiple birth animals were somewhat older and lighter at weaning than were the single birth animals. A more important figure, however, is the age of these animals at slaughter. In either sex group, the multiple birth animals tended to be somehwat older than the singles before even a tolerable slaughter weight could be reached.

TABLE IX

UNADJUSTED FEEDLOT VALUES FOR SINGLE AND MULTIPLE BIRTH STEERS AND HEIFERS

Item	Steers		Heifers	
	Singles	Multiples	Singles	Multiples
Number	10	8	10	10
Birth Weight (lbs)	79.8 ± 1.59[1]	56.1 ± 4.67	73.7 ± 2.12	49.1 ± 3.30
Age At Weaning (Days)	207.8 ± 3.11	224.1 ± 4.42	198.2 ± 7.52	218.5 ± 3.16
Adjusted Weaning Weight (210 day)	479.2 ± 13.15	385.1 ± 16.64	486.8 ± 15.96	374.5 ± 15.38
Pre-Weaning Avg. Daily Gain (lbs)	1.73 ± 0.05	1.52 ± 0.08	1.72 ± 0.08	1.53 ± 0.04
Days on Feed	217.3 ± 5.03	240.8 ± 11.69	217.3 ± 7.25	246.6 ± 8.56
Weight Gained During Trial	460.7 ± 19.78	476.0 ± 21.22	389.3 ± 8.63	409.6 ± 14.08
Age At Slaughter (Days)	425.1 ± 3.99	464.9 ± 8.69	415.5 ± 9.69	465.1 ± 5.89
Post Weaning Avg. Daily Gain (lbs)	2.12 ± 0.07	2.00 ± 0.10	1.81 ± 0.07	1.70 ± 0.05
Shrunk Slaughter Weight (lbs)	930.0 ± 7.62	882.9 ± 16.23	827.9 ± 9.15	778.1 ± 10.92

[1]Mean ± Standard Error

CHAPTER V

Summary

Twenty heifers and 18 steers were placed in the feedlot at Fort Reno, Oklahoma, at the time of weaning. The experimental animals were either single born or born as a member of a multiple set. All calves were sired by Angus bulls and were classified into two breeding groups depending on the breeding of the dams. Calves with Angus X Holstein crossbreed dams were classified as dairy cross, and those with Hereford or Hereford X Angus crossbred dams were classified as beef cross. The heifer group consisted of six single birth beef cross heifers, four single birth dairy cross heifers, five multiple birth beef cross heifers and five multiple diary cross heifers. The steer group consisted of five single birth beef cross steers, five single birth dairy cross steers, three multiple birth beef cross steers and five multiple birth dairy cross steers.

These animals were full fed an 80 percent concentrate ration until slaughtered at an average weight of 909 pounds for the steers and 803 pounds for the heifers. Total carcass cut-out information was obtained by dissecting the various components of the carcass. The weights of the total fat, fat free lean, and bone were recorded and ultimately expressed as a percentage of the weight of the cold right side of the carcass at the time of physical separation.

The data were analyzed on a within sex basis due to the large variation in slaughter weight between sexes. Also due to the large variation

in slaughter weights, regression coefficients were computed for fat, lean, and bone in an attempt to correct the values for each animal to one slaughter weight of 909 pounds and 802 pounds for steers and heifers respectively. The results of analyses of these data indicate that single birth steers tend to possess a lower percentage of total fat and a higher percentage of fat free lean than do multiple birth steers. The single birth beef cross steers possessed significantly more bone than did the multiple birth beef cross steers ($P < .05$), while the percentage bone in the dairy cross steers was relatively constant. No significant differences were detected in the heifer group. However, single birth beef cross heifers tended to possess a higher percentage of fat free lean and bone but a lower percentage of total fat than did the multiple birth beef cross heifers. On the other hand, the single birth dairy cross heifers tended to possess a lower percentage of fat free lean and bone but a higher percentage total fat than did the multiple birth dairy cross heifers.

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