AN EVALUATION OF THE ^{40}K WHOLE-BODY COUNTER AS A PREDICTOR OF LEAN TISSUE IN WEANING AND SLAUGHTER-WEIGHT BEEF CATTLE FOR MONITORING MUSCLE GROWTH

By

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Bachelor of Science

University of Nebraska

Lincoln, Nebraska

1971

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
July, 1973

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ACKNOWLEDGEMENTS

The author wishes to express his sincere appreciation to Dr. R. R. Frahm, Associate Professor of Animal Science, for his guidance and counsel throughout the course of this study.

The author also wishes to thank Dr. J. V. Whiteman for his contribution toward the preparation and proofing of the manuscript. A special vote of thanks goes to Dr. L. E. Walters for his help and guidance in the collection of the data as well as his contribution to the preparation of this thesis.

Appreciation is extended to Mr. D. F. Stephens and Mr. John MaGee of The Fort Reno Livestock Research Station for their assistance in the care of the experimental animals through the course of the study.

The author is grateful to Dennis M. Hallford, Thomas Carr, Richard Queener, LeRoy Kimbrell and Albert Rutledge who assisted in the collection of the data.

The author wishes to express special appreciation to the many graduate and undergraduate students at Oklahoma State University whose friendship and encouragement over the duration of this study will not soon be forgotten.

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CHAPTER I

INTRODUCTION

The whole-body ^{40}K counter has been evaluated as a predictor of lean muscle mass in beef cattle by several researchers. All previous work has involved slaughter weight cattle. No information is available to evaluate the ^{40}K counter as a predictor of lean in younger, light-weight, growing beef cattle before they reach a desirable slaughter weight. The ability to monitor differential muscle growth would be an important asset to animal scientists in their efforts to improve the efficiency of animal protein production.

This study consisted of two major phases. The first phase was the evaluation of the ^{40}K counter as a predictor of lean tissue in weaning age beef cattle. The second phase was the evaluation of the ^{40}K counter as a monitor of differential muscle growth in growing and finishing beef cattle.

CHAPTER II

LITERATURE REVIEW

Considerable research has been and is being conducted to develop an effective, non-destructive instrument to evaluate the carcass composition of the live animal. One such instrument currently in use at the Oklahoma State University Live Animal Evaluation Center is the ^{40}K whole body counter.

Principles of ^{40}K Technique

The two major principles upon which the instrument is based are: (1) potassium contains a fixed, measurable portion of naturally occurring radioactive atoms (^{40}K) which give off small amounts of gamma radiation and (2) that a high percentage of body potassium is located in the muscle of the live animal. Anderson (1959) reported that about 0.01% of all naturally occurring potassium was in the form of the ^{40}K isotope. Kulwich et al. (1960) reported an isotope abundance of 0.0119%; Forbes (1963) and Ward et al. (1967) reinforced the earlier findings by reporting that ^{40}K comprised 0.012% of all naturally occurring potassium.

Not all research results support the theory that a high percentage of potassium is located in the muscle. Lawrie and Pomeroy (1963) concurred with Anderson (1959) that most potassium was mainly associated with the intracellular, nonfat phase in the body and that the quantity of potassium in the muscle tissue was constant.

In a detailed study involving 90 steers, Lohman and Norton (1968) reported that potassium was found in all steer tissue. Trimmed lean contained 53.4% of the total body potassium. Carcass bone contained 12.4% and the gastrointestinal tract 16.4%. Kirton and Pearson (1963) reported a potassium concentration in separable fat of 0.82 grams of potassium per kilogram of fat as determined by flame photometry. This same study, using lamb carcasses, revealed that 11% of the potassium content of the carcass was in bone. Earlier, Kirton et al. (1961) found 50% of the total body potassium of sheep to be in lean tissue, however, Pfau (1965) indicated 69% of the total body potassium was in the muscle of swine. Kirton et al. (1963) reported that pig carcasses comprised 77% of the empty body mass and contained 81% of the potassium in the empty body. Pfau and Kallistratos (1963) found 84% of the carcass composition was in the muscle of swine. Stant et al. (1969) had similar results with 81% of the carcass potassium in the muscle of the pigs. These reports reveal that the amount of body potassium in other than lean tissue is too great to be ignored.

Use of naturally occurring ^{40}K to predict lean muscle mass in both live animals and carcasses has been reported by several researchers. Results of these studies indicated that estimates of ^{40}K content may be used to predict lean muscle in livestock or carcasses. Whole body ^{40}K counters as predictors of leanness have two principle assets: (1) they are non-destructive to either live animals or carcass components; and (2) measurements can be taken with relative rapidity.

^{40}K Evaluation of Sheep

Many workers have attempted to pinpoint the relationship between ^{40}K count and several carcass characteristics: fat-free lean, separable lean, ether extract, and separable fat. Studies using slaughter-weight sheep as the experimental animal have shown inconsistent relationships between ^{40}K count and carcass characteristics.

Kirton et al. (1961), using 10 lambs, obtained a correlation coefficient of 0.58 between separable lean and grams of potassium per kilogram of live weight. Judge et al. (1963), in a study with 27 live lambs and 38 carcasses, found that carcass weight was as good as ^{40}K count as a predictor of pounds of edible portion. Judge et al. (1963), Lohman et al. (1965) and Breidenstein et al. (1965a) have reported ^{40}K count to account for 53 to 90.3% of the variation in carcass lean muscle mass. Kirton et al. (1961) used ^{40}K count to approximate carcass composition of 10 shorn lambs. Correlations between percent protein in the carcass and live ^{40}K counts did not differ greatly from unwashed lambs ($r = 0.80$) to washed ($r = 0.83$).

Lohman et al. (1965) contradicted earlier reports by stating that whole body ^{40}K count accounted for 90.3% of the variation in carcass lean muscle mass, and they concluded that ^{40}K measurements on the live animal or the carcass were more precise in predicting carcass lean than either carcass weight or loin eye area. Breidenstein et al. (1965a) reported results in agreement with Lohman. A linear model involving sex, age, live weight, and carcass weight accounted for 59.5% of lean muscle mass variation while ^{40}K count alone accounted for 87.0% of the variation in their study.

^{40}K Evaluation of Swine

Researchers using swine also found a wide range in relationships between carcass components and ^{40}K counts. With 53 pigs of five weight groups (100, 150, 200, 250, 300 lbs.), Moser (1970) reported correlations ranging from -0.37 to 0.96 between live animal ^{40}K count and standard trimmed lean, and 0.16 to 0.83 for fat-free lean. Groups of heavier pigs generally had higher correlations.

A near linear relationship between lean content of hams and ^{40}K count was reported by Pringle and Kulwich (1961), Kulwich et al. (1958), and Kulwich (1961a). The latter worker did note a lower relationship between ^{40}K count and percent separable or fat-free lean.

Breidenstein et al. (1965b) slaughtered 30 pigs after ^{40}K counting. ^{40}K count in a linear model with breed, sex, live weight and carcass weight, accounted for 91.3% of the variation in carcass lean muscle mass. This same model without ^{40}K count accounted for 44.7% of the variance.

Mullins et al. (1968) reported a correlation coefficient of 0.70 between percent four lean cuts (ham, loin, picnic and Boston Butt) and percent potassium in the carcass as measured by ^{40}K based on a study involving 32 pigs. In 1969, these same workers found higher relationships between percent potassium in the carcass and yield of lean cuts than similar comparisons of percent potassium in the live animal and yield of lean cuts. Larger standard errors were associated with ^{40}K in the live animal than in the carcass.

Addison (1973) evaluated 115 market weight pigs with ^{40}K counter over a two-year period. Using a pooled prediction equation for fat-free lean, 77% of the variation was accounted for by live ^{40}K count alone and 79% was accounted for when weight was added to the model. The standard error for both equations was 2.94 pounds.

^{40}K Evaluation of Beef

Research involving the evaluation of leanness in beef cattle using the ^{40}K counter has thus far produced results somewhat more consistent than those in swine. Breidenstein (1965a) demonstrated the importance of non-lean sources of potassium in the gastro-intestinal tract as a source of variation in ^{40}K counting. He reported that 10% to 30% of the potassium was accounted for by the GI tract depending upon the diet of the animal. Johnson (1971) more closely studied this source of variation. Using 36 steers, he found that the primary influence to ^{40}K counting was the potassium in the intracellular fluids. Frahm et al. (1971) evaluated 40 bulls after 24, 48 and 72 hours of shrink, and concluded that shrinking animals beyond 24 hours did not increase the precision of fat-free lean estimates.

Significant correlations between ^{40}K counts per pound of intact beef rounds and percent separable fat (-0.865) and percent separable lean (0.798) were reported by Kulwich et al. (1961b). In a study involving 46 steers, Smith et al. (1965) reported that ^{40}K counts alone accounted for 42.5% of the variation and weight alone accounted for 86.7% of the variation in fat-free lean. Together, these variables removed 90.6% of the total variation in fat-free lean.

Frahm et al. (1971) evaluated 40 bulls over four slaughter-weight groups. They reported a pooled-within group correlation of 0.87 between the average of two ^{40}K counts after 24 hours shrink and pounds of fat-free lean. By design, these bulls were similar in breeding, as well as body type and weight. The standard deviation in live weight of all 40 bulls (weights taken after 24 hours shrink) was 15.6 pounds. Between 4% and 10% of variance in fat-free lean was accounted for by weight alone, while ^{40}K count accounted for 69% to 74% of that variance. These workers concluded prediction equations utilizing count and weight were no more accurate in predicting fat-free lean than those based on ^{40}K counts alone.

McLellan (1970) studied 31 steers and heifers in four slaughter-weight groups. Again, no difference was reported between correlations in fat-free lean and ^{40}K count after 24 hours shrink and ^{40}K count after 72 hours shrink. The pooled-within group correlation coefficient was 0.80. Live weight accounted for 21% of the variation in pounds of fat-free lean; the average of two counts after 24 hours shrink was associated with 64% of the fat-free lean variance.

Muscle Growth

The major tissues of the animal body (bone, muscle, fat) grow and develop at relatively different rates post-natally. Hammond (1933) reported that this occurred in three overlapping phases, with maximum bone growth preceding that of muscle and muscle in turn preceding fat deposition.

Recent work by Zinn (1967) indicated that considerable variation occurred in growth rate of the boneless lean tissue of the various primal wholesale cuts (round, loin, rib, and chuck) during a 270-day feeding period of 100 steers and 100 heifers. Animals were slaughtered at 30-day intervals. Percent edible portion decreased significantly from

90 to 120 ($P < .01$), 120 to 150 ($P < .01$) and 240 to 270 days. Sex did not alter the growth pattern of bone, fat or edible portion, but these tissues grew at a slower rate in heifers than in steers during Zinn's 270-day feeding period.

Hiner and Bond (1971) slaughtered 51 Angus steers at 6, 12, 18, 24, 30 and 36 months of age to study the growth of muscles, separable lean and separable fat in beef steers. The cattle were separated into three different nutritional regimes. In all three groups the most rapid increase in muscle weight occurred between 6 and 12 months of age.

CHAPTER III

MATERIALS AND METHODS

The Experimental Animals

This experiment was originally designed to involve 60 weaning-age calves from a beef cattle multiple birth study. The cattle were born and reared at the Fort Reno Livestock Research Station at El Reno, Oklahoma. These calves were divided into two major groups. Twenty steers (all single births) were designated for the "weaning slaughter group" (Group I). The other 40 calves (twenty steers and twenty heifers) were to grow and finish to market weight (Group II). The calves used in both groups were from either Hereford, Angus X Hereford crossbred, or Holstein X Angus crossbred dams. All the calves were sired by Angus bulls. The steers in Group I were all single births and were chosen without regard to breed of dam. Group II was designed to consist (as nearly as possible) of one-half of the steers to be multiple births and one-half single births. Within each of these divisions by type of birth one-half were to be dairy crossbred and one-half were to be beef crossbred calves. A similar grouping of the heifers was obtained. The animals in Group II were also involved in another study which had as its principle objective the comparison of multiple birth cattle to single birth cattle with regard to feedlot performance and carcass composition.

Very soon after the study was initiated, three multiple birth steers died, and one alternate steer was added. Thus, there was a total of 18 steers and 20 heifers in Group II that completed the study. Table I describes Group II as it appeared through the duration of the study.

TABLE I

BREED COMPOSITION, SEX, AND TYPE OF BIRTH OF ANIMALS IN GROUP II

Type of Birth	Steers (18)[a]		Heifers (20)		Totals
	Breed of Animal				
	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

[a]After three steers died, and one alternate added.

The OSU ^{40}K Whole-Body Counter

The same self-contained whole body counter located at the Live Animal Evaluation Center described by Frahm et al. (1971) and previously discussed by Moser (1970) and McLellan (1971) was used in this study. There was some modification of the counter prior to the initiation of the present study. Only seven of the original fourteen ^{40}K parallel scintillation detectors were employed and the circular detector at the rear of the chamber was not used. With the new configuration, the detectors were brought closer to the animal's body and more nearly surrounded the animal. Shorter calves were elevated in the counter by placing one or more one-inch boards on the floor of the chamber for the purpose of maintaining a common distance from the animal to the detectors. Midway through the study, it was necessary to enlarge the configuration of the detectors to account for the increasing height and width of the growing calves. This change was made only once to minimize configuration differences and because of the laborious, time-consuming process involved.

Animal Management

All of the cattle were reared and maintained at the Fort Reno Livestock Research Station throughout the study. Calves were reared without access to creep or any supplemental feed. After weaning on October 28, 1971, they were placed on test and maintained under typical feedlot conditions. The 18 steers (average weight, 442 lbs.) and 20 heifers (average weight, 404 lbs.) were placed in two separate feedlots on a self-fed, ground and mixed finishing ration. The approximate content of this finishing ration is shown in Table II.

Counting Procedure

At weaning, all of the steers and heifers to be placed in the feedlot were brought to the OSU Live Animal Evaluation Center for ^{40}K evaluation. The single exception was the multiple birth steer added at a later date because of the death loss of three multiple birth steers.

TABLE II

RATION INGREDIENTS

Ingredient	% of Ration	% of Supplement
Milo	70	
Alfalfa Hay	8	
Cottonseed Hulls	12	
Molasses	5	
Supplement B-035	5	100
Contents of Supplement:		
Soybean Oil Meal (44%)		67.6
Urea, 45% 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

At approximate six-week intervals, the cattle in Group II were returned to Stillwater for evaluation by the ^{40}K counter. All animals had at least five six-week interval counts before slaughter (slower gaining cattle were in the feedlot longer and were counted a sixth time before slaughter). As the Group II animals reached a projected slaughter date (based on a goal of 1000 and 900 lbs. for steers and heifers, respectively), they were counted a final time just prior to slaughter.

The 20 steers in Group I were counted only once shortly after weaning and just prior to slaughtering. They were brought to Stillwater on two different days, 20 days apart. This was in an effort to make them more typical of the age and weight of the cattle in Group II. They were slaughtered at an average of 206 days of age at a mean shrunk weight of 389 lbs. Table III lists all of the days that cattle in this study were evaluated by the ^{40}K whole-body counter.

TABLE III

SCHEDULE OF COUNTING DATES BY ANIMAL GROUPS
FROM FALL 1971 TO SUMMER 1972

Steers	Group I (Weaning Calves)	Heifers
	Pre-Slaughter Counts	
November 18 (11)[a]		none
December 8 (9)		none
Steers	Group II (After Finishing Phase)	Heifers
	Six-Week Interval Counts	
November 16 (17)		November 17 (20)
December 29 (18)		December 30 (20)
February 8 (18)		February 7 (20)
March 21 (18)		March 20 (20)
May 2 (18)		May 3 (20)
June 13 (18)		June 13 (20)
	Pre-Slaughter Counts	
May 16 (5)		May 16 (5)
May 30 (4)		May 30 (4)
June 21 (5)		June 21 (5)
July 26 (4)		July 26 (6)

[a]Number of animals in parenthesis.

On the day preceding each counting date, the cattle were taken off feed and water at noon and trucked the ninety miles to Stillwater. The cattle were thoroughly rinsed with soap and water to remove dirt and mud from the hair. They remained off feed and water until the counting process was completed the next day. A minimum of 19 hours shrink occurred before the cattle were counted. At the start of each day when the cattle were to be ^{40}K counted, a small plastic container of 619.03 gm. of potassium chloride was placed in the center of the chamber and counted in the same way that each animal was counted. The net ^{40}K count per minute was obtained by (1) taking five two-minute background counts with the chamber empty, (2) taking five two-minute sample counts with either the standard potassium source (KCl) or with one of the experimental animals in the chamber, and (3) taking another set of five two-minute background counts. The standard source was again counted after all the cattle had been in the chamber. The cattle were then returned to Fort Reno and placed back in the feedlots except in the case of the final count. Following the final count, the animals were taken to the OSU Meat Laboratory for slaughter the next day.

Because the calves differed in height, one or two wooden planks were placed at the bottom of the counting chamber to keep the cattle at a relatively constant distance from the radiation detectors. During the February counting days, the configuration was enlarged to better accommodate the taller one-half of the heifers (February 7) and then was used thereafter for all subsequent counts taken in this study.

Slaughter, Separation, and Sampling Procedures

All of the cattle were slaughtered at the Oklahoma State University

Meat Laboratory. The hot carcasses were weighed, shrouded, and placed in a holding cooler for 48 hours. The right side of each carcass was further divided into wholesale cuts (chuck, rib, loin, round, and thin cuts) followed by physical separation of fat, lean, and bone. The weight of the lean separated from the half carcass was multiplied by 2.0 to obtain the "separable lean" for that animal. Brungardt and Bray (1963) have shown that there were essentially no differences in carcass fat, muscle, and bone between the right and left sides of the beef carcasses.

The procedure for determining fat-free lean in each carcass was comprised of two major steps: (1) the grinding, mixing, and sampling of the separable lean; and (2) the removal of the ether-extract portion to give an estimate of the intra-muscular fat remaining in the separable lean. The grinding, mixing, and sampling are described by these nine steps:

(1) All equipment, including grinders, mixers, and pans, were placed in a cooler at least 12 hours prior to sampling.

(2) The separable lean was hand mixed to insure an even mixture of the fatter and leaner pieces as they passed through the grinder.

(3) The lean was ground using a coarse plate (3/8 inch) followed by both manual and mechanical mixing for a period of approximately two minutes each.

(4) The beef was then transferred to the grinder and was ground a second time through the same coarse plate. This second grinding was followed by a thorough mechanical mixing.

(5) The beef was ground a third time with a fine plate (1/8 inch) in the grinder.

(6) As the beef was ground the last time, 15 grab samples were taken for each animal. These samples were taken so as to be evenly distributed, random samples of the entire carcass.

(7) The 15 grab samples were randomly allotted into three piles each containing five of the original grab samples. The three piles were individually mixed and labeled as Sample A, Sample B, or Sample C.

(8) From each of these piles, 50 gm. of the ground beef was placed in a properly labeled plastic Whirl-Pac bag. As much of the air as possible was removed from the bags before sealing.

(9) The samples were taken immediately to a quick freezer cooler (-23.30° C.) for 24 hours and then removed to a -17.80° C. freezer until the samples were ready for ether extract determination.

Ether Extraction Procedure

In preparation of ether extract determination, the samples were thawed at 1.7° C. and then homogenized at 20° C. using a Sorvall Omni-Mixer without an ice pack. Following homogenization, the samples were thoroughly mixed at a low speed in a food mixer. Two 5.0 gm. aliquots were taken from each sample and percent ether extract was determined using the Soxhlet Method (A.O.A.C., 1965). The average of the six determinations of the fat content became the estimate of percent ether extract in the separable lean of that carcass. The average percent ether extract of the carcass multiplied by total pounds of separable lean gave the pounds of intra-muscular (non-separated) fat. Fat-free lean was the difference between pounds of total separable lean and the pounds of intra-muscular (non-separated) fat.

Preparation of the Data

Six of the two-minute counts were eliminated from the data because they were more than three standard deviations (Johnson, 1971) from the mean of that group of counts. The net, "unadjusted" ^{40}K count for each animal or standard source is the average background count per minute subtracted from the average sample count per minute.

A study of the unadjusted net counts of the standard source over the duration showed a definite increase from November to June. This is graphically illustrated in Figure 1. An explanation for this nearly linear increase is not apparent. Because this represents a change in the efficiency with which the whole-body counter detected a constant source of potassium, it was deemed necessary to adjust the counts per minute of the experimental animals to account for this change in efficiency over time. This adjustment was made by first calculating the "efficiency" of the counter on that counting day. The unadjusted net count per minute was then divided by the counting efficiency to give the adjusted net ^{40}K count for that animal on that day. The counting efficiency was calculated by dividing the average unadjusted net count per minute of the KCl by 66,045 (the expected number of gamma emissions per minute from 619.03 gm. of KCl).

A portion of the statistical analysis was concerned with average daily fat-free lean change of the Group II experimental animals. Average daily change in fat-free lean was determined by subtracting the predicted pounds of fat-free lean at the start of the feeding period from the actual pounds of fat-free lean at slaughter and dividing by the number of days in the feedlot. The pounds of fat-free lean in each animal at the start of the feeding period was estimated by using the prediction equation for pounds of fat-free lean developed for weaning age animals in Group I.

Statistical Procedures

The statistical analysis of this data was performed in three major categories:

(1) Means and standard deviations were computed for pounds of fat-free lean, pounds of separable lean, pounds of live weight, pounds of carcass weight, and adjusted and unadjusted net animal ^{40}K count per minute. These variables were calculated for both Group I and Group II. Means and standard deviations for pounds of average daily gain, pounds of average daily fat-free lean increase, and average daily net count increase are presented only for Group II animals that were involved in the experiment at the outset.

(2) Simple correlations were calculated for all combinations of the variables: fat-free lean, separable lean, net ^{40}K count, and live weight. Pooled, within-slaughter day correlations were calculated for both Group I and Group II. Pooled, within-sex correlations were also calculated for Group II. In addition, pooled, within-weight correlations were computed for the 37 Group II cattle that were present from start to finish. With the mean slaughter weight as the dividing point,

the 16 heaviest cattle and the 21 lightest cattle each made up a respective weight division. Also, correlations were calculated between all combinations of average daily gain, average daily fat-free lean change, and average daily ^{40}K count change. These calculations were made by weight division, across both weight divisions, and pooled, within-weight division.

(3) Linear prediction equations were developed for both Group I and Group II. Fat-free lean and separable lean are the dependent variables with ^{40}K count and live weight being used in the model as the individual or the multiple sources of variation. Average daily fat-free lean change is the dependent variable of the equations calculated by weight divisions and across 37 cattle where average daily gain and/or average daily ^{40}K count change are in the model. The regression analyses were based on the linear models:

(1) $Y = B_o + B_1 (wt) + e$

(2) $Y = B_o + B_1 (ct) + e$

(3) $Y = B_o + B_1 (wt) + B_2 (ct) + e$

(4) $Y_{FFLC} = B_o + B_1 (adg) + e$

(5) $Y_{FFLC} = B_o + B_1 (ctc) + e$

(6) $Y_{FFLC} = B_o + B_1 (adg) + B_2 (ctc) + e$

where Y = predicted pounds of fat-free or separable lean,

Y_{FFLC} = predicted pounds of average fat-free lean change per day,

B_i (i = 1, 2) = regression or partial regression coefficient for each predictor variable, respectively,

wt = live weight,

ct = net ^{40}K count per minute,

adg = average daily gain,

ctc = average net ^{40}K count change per day, and

e = unique random error associated with each set of observations.

Equations (1), (2), and (3) were computed for Group I and Group II, and for each sex and weight division in Group II. Equations (4), (5), and (6) were developed only for Group II as a total population of 37 and by weight divisions.

All statistical analysis with the exception of the pooled correlations were completed at the Oklahoma State University Computer Center using The Statistical Analysis System, developed by Barr and Goodnight and described by A User's Guide to the Statistical Analysis System by Service (1972).

CHAPTER IV

RESULTS AND DISCUSSION

Means and Standard Deviations

The means and standard deviations for all the live and carcass traits studied are presented in Table IV. The large standard deviations for live weight indicate that both Group I and Group II were heterogeneous populations. This particular group of cattle was chosen for this study for the purpose of providing diverse muscle growth patterns. Considerable differences in body type and body weight could be expected because of the mixing of beef and dairy crossbreds for both groups, coupled with the variation caused by different sexes and types of births (multiple versus single) found in Group II. Dividing Group II into weight divisions produced consistently smaller standard deviations, but not greatly different than those for each sex. The 16 heaviest Group II cattle consisted of 15 steers and one heifer, while the 21 lighter cattle (below the mean slaughter weight) consisted of two steers and 19 heifers.

Correlations

One of the problems inherent with using equipment such as the ^{40}K whole-body counter is the maintenance of stable and uniform operating conditions so that comparative estimates can be obtained during different operating periods. It was quite apparent for the duration of this

TABLE IV

MEANS AND STANDARD DEVIATIONS

Trait	Group I		Group II									
	20 Steers		38 Cattle		18 Steers		20 Heifers		16 Heaviest		21 Lightest	
	Mean	± S.D.	Mean	± S.D.	Mean	± S. D.	Mean	± S.D.	Mean	± S.D.	Mean	± S.D.
Live Weight (lbs)	388.7	52.2	853.3	67.3	909.2	42.0	803.0	40.2	919.8	29.1	800.9	35.4
Carcass Weight (lbs)	230.5	33.9	552.5	46.4	589.9	25.8	518.8	32.8	595.5	18.5	518.0	30.4
Separable Lean (lbs)	152.3	22.1	294.1	28.2	314.6	18.4	275.6	22.2	319.8	14.6	273.8	18.7
Fat-free Lean (lbs)	140.0	19.7	256.4	23.1	273.9	14.3	240.6	17.6	277.8	11.01	239.3	14.7
Unadjusted ^{40}K (counts per min)	2321	271	5143	535	5416	456	4896	486	5421	516	4941	475
Adjusted ^{40}K (counts per min)	37178	4744	50214	7038	52591	4616	47597	4520	52932	4660	47746	4421
Average Daily Gain (lbs)[a]	--	--	2.13	0.29	2.31	0.26	1.97	0.22	2.36	0.22	1.96	0.21
Average Daily Fat-free Lean Change (lbs)[a]	--	--	0.51	0.09	0.55	0.06	0.47	0.09	0.56	0.05	0.46	0.09
Average Daily ^{40}K Count Change[a] (counts per min)	--	--	78.1	25.4	81.1	22.8	75.6	27.7	81.2	24.6	75.8	26.2

[a]Includes 37 animals.

study that operating conditions and/or the equipment were not stable as evidenced by the very pronounced increase over time in the net ^{40}K count for the standard source of potassium (Figure 1). Thus, with regard to the net unadjusted ^{40}K counts, comparisons could properly be made only among animals counted on the same day. In order to make ^{40}K counts on different days more comparable and also to allow the development of prediction equations for fat-free lean and separable lean appropriate for the type of cattle utilized in this study, the raw net ^{40}K counts were adjusted for differences in counting efficiency as described in the Materials and Methods.

Table V presents a comparison of unadjusted ^{40}K count and the adjusted-for-efficiency ^{40}K count as they are correlated with live weight and fat-free lean. Adjusted ^{40}K is more highly correlated with both traits than is unadjusted ^{40}K count in both Group I and Group II. However, none of the differences are statistically significant.

The consistently higher correlations resulting from the adjusted count suggest that future ^{40}K measurements taken on separate days can be improved by the adjustment discussed previously in Chapter III, and this adjustment would be recommended if a comparison of counts obtained on different days are to be made. The remaining correlations and prediction equations presented in this report will use only the adjusted net ^{40}K counts per minute and the term "^{40}K count" will refer to ^{40}K counts that have been adjusted for differences in counting efficiency.

Table VI presents all combinations of correlations between ^{40}K count, live weight, fat-free lean, and separable lean for both Groups I and II by slaughter day. The extremely high correlations between fat-free lean and separable lean indicate that the mass of separable lean

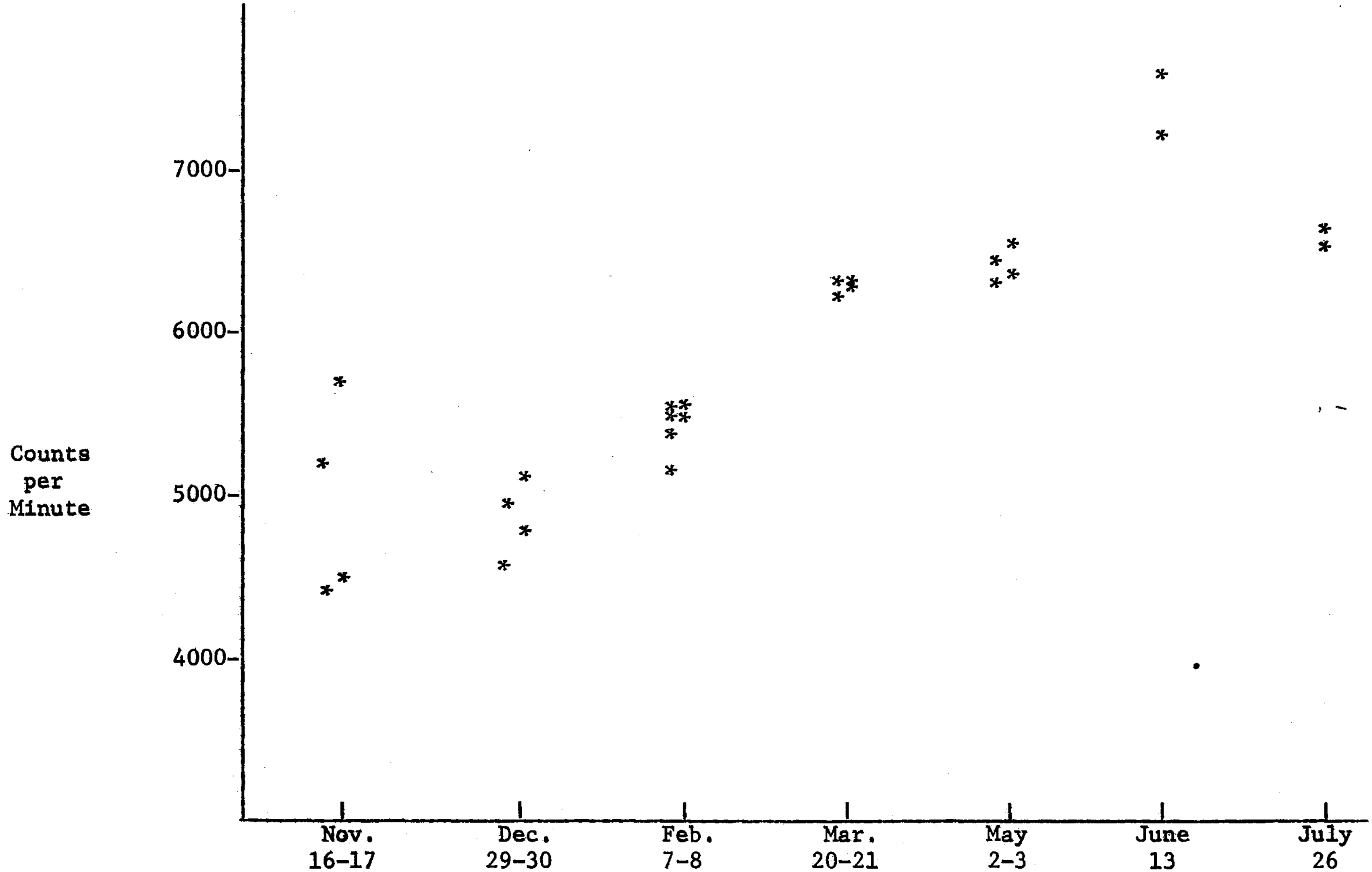

Figure 1. Net ^{40}K Counts per Minute of 619.03 gm. of KCl
Plotted Over Days of the Study

can be predicted nearly as well as fat-free lean by measurements such as ^{40}K count and live weight. For obvious reasons, separable lean is a more practical end-product to study than is fat-free lean, but the latter variable is theoretically better suited for ^{40}K studies because of the presence of potassium primarily in lean tissue.

TABLE V

CORRELATION COEFFICIENTS BETWEEN UNADJUSTED ^{40}K COUNT OR ADJUSTED ^{40}K COUNT AND LIVE WEIGHT OR FAT-FREE LEAN FOR GROUP I AND GROUP II AS A SINGLE POPULATION AND BY SEX

	Unadjusted Count vs. Live Weight	Adjusted Count vs. Live Weight	Unadjusted Count vs. Fat-Free Lean	Adjusted Count vs. Fat-Free Lean
Group I (20)[b]	0.51	0.90	0.70	0.93
All Group II (38)	0.63	0.66	0.63	0.64
Group II Steers (18)	0.51	0.57	0.60	0.87
Group II Heifers (20)	0.39[a]	0.57	0.36[a]	0.53
Pooled, within-sex (38)	0.45	0.57	0.46	0.69

[a]Not significantly different from zero ($P > 0.05$).

[b]Numbers in parentheses represent the number of animals measured.

In the weaning age cattle (Group I), ^{40}K count was highly correlated with both fat-free and separable lean. The pooled, within-slaughter day correlations of 0.92 and 0.93 compare quite favorably with similar correlations from previous studies using slaughter-weight

TABLE VI

CORRELATION COEFFICIENTS BETWEEN ^{40}K COUNT, LIVE WEIGHT, FAT-FREE LEAN AND SEPARABLE LEAN FOR GROUP I BY SLAUGHTER DAY AND GROUP II BY SLAUGHTER DAY

	Live Weight vs. ^{40}K Count	Live Weight vs. Fat-Free Lean	Live Weight vs. Separable Lean	^{40}K Count vs. Fat-Free Lean	^{40}K Count vs. Separable Lean	Fat-Free Lean vs. Separable Lean
Group I						
Nov. 18 (11)[b]	0.95	0.96	0.98	0.97	0.96	0.99+
Dec. 8 (9)	0.85	0.95	0.97	0.88	0.87	0.99+
Pooled within (20)	0.92	0.95	0.97	0.92	0.93	0.99+
Across Day (20)	0.90	0.93	0.95	0.93	--	0.99+
Group II						
May 16 (10)	0.27[a]	0.82	0.82	0.39[a]	0.26[a]	0.96
May 30 (8)	0.79	0.89	0.86	0.86	0.90	0.99
June 13 (10)	0.77	0.94	0.95	0.91	0.88	0.99
July 26 (10)	0.72	0.91	0.93	0.79	0.72	0.99
Pooled within (38)	0.57	0.88	0.88	0.67	0.60	0.98
Across Day (38)	0.63	0.91	0.90	0.64	0.60	0.98

[a]Not significantly different from zero ($P > 0.05$).

[b]Numbers in parentheses represent the number of animals.

cattle. It is important to note that the correlations between live weight and fat-free or separable lean are equally as high.

In the slaughter-weight cattle (Group II), live weight is as highly or more highly correlated with fat-free lean and separable lean than ^{40}K count. Live weight is especially more closely associated with lean tissue weights than ^{40}K count when several different counting days are involved. Pooling the within-day correlations had virtually no advantage over the across-day correlations, which indicates that the adjustment of the individual ^{40}K counts for differences in counting efficiency has been adequate.

The low correlations found on May 16 may be partially due to an erratic pattern in counting efficiency that occurred on that day. The counting efficiency of the ^{40}K counter ranged from 9.3% to 10.3% on the two standard source counts obtained that day. Such variation is unusual and would be expected to affect the net ^{40}K counts of the animals measured on that day.

Table VII presents the correlation coefficients between live weight, ^{40}K count, fat-free lean, and separable lean for Group II by sex and weight division. Grouping the cattle by sex resulted in a slightly higher correlation (pooled-within sex) between ^{40}K count and fat-free lean than the correlation using Group II as a single population. Only small differences occurred between the correlations for the steers and the correlations for the heifers. ^{40}K count was somewhat more highly correlated with fat-free lean in the steers than it was in the heifers ($r = 0.87$ and 0.53, respectively). Because the steers averaged more than 100 pounds heavier than the heifers, Group II was divided into weight divisions irregardless of sex. The resulting pooled, within-weight correlation between ^{40}K count and fat-free lean was virtually the same as the within-sex correlation (0.70 and 0.69, respectively). Grouping the animals so that they are more homogeneous for live weight tends to reduce the correlations between live weight and fat-free lean while slightly increasing the relationship between ^{40}K count and fat-free lean. This trend is consistent with previous work by Frahm et al. (1971) who reported a high correlation of 0.87 between ^{40}K count and fat-free lean in a population of bulls where only 4% to 10% of the variation in fat-free lean could be accounted for by live weight.

TABLE VII

CORRELATION COEFFICIENTS BETWEEN LIVE WEIGHT, ^{40}K COUNT, FAT-FREE LEAN, AND SEPARABLE LEAN FOR GROUP II BY SEX AND WEIGHT DIVISION

	Live Weight vs. ^{40}K Count	Live Weight vs. Fat-Free Lean	Live Weight vs. Sep. Lean	^{40}K Count vs. Fat-Free Lean	^{40}K Count vs. Sep. Lean
Steers (18)[a]	0.57	0.75	0.73	0.87	0.78
Heifers (20)	0.57	0.83	0.86	0.53	0.52
Pooled, within-sex (38)	0.57	0.80	0.79	0.69	0.63
Above mean wt. (16)	0.55	0.55	--	0.75	--
Below mean wt. (21)	0.66	0.73	--	0.69	--
Pooled, within-wt. (37)	0.61	0.67	--	0.70	--

[a]Numbers in parentheses represent the number of animals measured.

Correlation coefficients of Group II by weight division for average daily gain, average daily fat-free lean change, and average daily ^{40}K count change are presented in Table VIII. These correlations were calculated and presented as a partial evaluation of the ^{40}K counter as a monitor and predictor of muscle change in the growing cattle. The correlation between average ^{40}K count change and average fat-free lean change for Group II was even lower than the comparable correlation between ^{40}K count and fat-free lean (r = 0.47 and 0.64, respectively). Average daily gain is as highly correlated or more highly correlated with daily fat-free lean change than is daily ^{40}K count change. This parallels the slaughter data discussed previously, in that weight continues to be more closely associated with fat-free lean than is ^{40}K count.

TABLE VIII

CORRELATION COEFFICIENTS BETWEEN AVERAGE DAILY GAIN, AVERAGE DAILY ^{40}K COUNT CHANGE, AND AVERAGE FAT-FREE LEAN CHANGE FOR GROUP II

	Avg. Daily Gain vs. Avg. Count Change	Avg. Daily Gain vs. Avg. Fat-Free Lean Change	Avg. Count Change vs. Avg. Fat-Free Lean Change
Above Mean Slaughter Weight (16)[b]	0.28[a]	0.85	0.29[a]
Below Mean Slaughter Weight (21)	0.44	0.56	0.60
Pooled-Within Weight Division (37)	0.37	0.63	0.50
Across All Weights (37)	0.34	0.77	0.47

[a]Not significantly different from zero (P > 0.05).

[b]Numbers in parentheses represent the number of animals measured.

Linear Prediction Equations

Linear prediction equations for fat-free lean and separable lean are presented for both Group I and Group II in Tables IX, X, XI, and XII. Prediction equations for average daily fat-free lean change are presented for Group II in Tables XIII and XIV. In each case, the standard deviations of the predicted variables are listed as a comparison to the standard errors of estimate. Coefficients of determination are also given for each regression equation.

For the 20 steer calves slaughtered at weaning in Group I (Table IX), both ^{40}K count and live weight were of considerable value in predicting fat-free lean and separable lean. Regression equations using weight alone produced slightly smaller standard errors of estimate than did those with ^{40}K count alone, whether the predicted variable was fat-free lean or separable lean. Combining the two variables did reduce the standard error of estimate and account for more of the variation in fat-free and separable lean, but the improvement was small.

Table X presents the prediction equations for Group II as a single population of 38 animals. In this case, weight alone as a predictor of fat-free or separable lean was more precise than ^{40}K count alone. Adding ^{40}K count to weight in the regression model had little or no effect on the standard error of estimate. It is again important to note the heterogeneity of Group II and realize that as a single population it is more variable in live weight than any of the subdivisions discussed hereafter. Weight alone accounted for 82% and 81% of the variation in fat-free lean and separable lean, respectively; ^{40}K count alone could account for only 41% and 54% of the variation in fat-free and separable

TABLE IX

LINEAR PREDICTION EQUATIONS FOR GROUP I (20 STEER CALVES) USING ^{40}K COUNT AND LIVE WEIGHT

Predicted Variable	β_o a/	$\beta_{(ct)}$ b/	$\beta_{(wt)}$ c/	R^2	Standard Error of Estimate	Std. Dev. f/
$\hat{Y}_{FFL}$ d/	- 3.995	+0.0039(ct)		0.87	7.34	19.71
$\hat{Y}_{FFL}$	- 3.267		+0.352(wt)	0.87	7.30	19.71
$\hat{Y}_{FFL}$	- 7.592	+0.0020(ct)	0.186(wt)	0.91	6.11	19.71
$\hat{Y}_{SEP}$ e/	- 8.211	+0.0043(ct)		0.86	8.53	22.10
$\hat{Y}_{SEP}$	- 3.527		+0.401(wt)	0.90	7.20	22.10
$\hat{Y}_{SEP}$	-13.132	+0.0018(ct)	+0.254(wt)	0.93	6.36	22.10

a/ β_o = Regression coefficient, Y-intercept.

b/ ct = ^{40}K counts in counts per minute.

c/ wt = Live weight (pounds).

d/ $\hat{Y}_{FFL}$ = Predicted pounds of fat-free lean.

e/ $\hat{Y}_{SEP}$ = Predicted pounds of separable lean.

f/ Standard deviation of the predicted variable.

TABLE X

LINEAR PREDICTION EQUATIONS FOR GROUP II (38 STEERS AND HEIFERS) USING ^{40}K COUNT AND LIVE WEIGHT

Predicted Variable	β_o a/	$\beta_{(ct)}$ b/	$\beta_{(wt)}$ c/	R^2	Standard Error of Estimate	Std. Dev. f/
$\hat{Y}_{FFL}$ d/	150.678	0.0021(ct)		0.41	18.04	23.15
$\hat{Y}_{FFL}$	-10.234		0.312(wt)	0.82	9.86	23.15
$\hat{Y}_{FFL}$	- 8.164	+0.00024(ct)	0.296(wt)	0.83	9.91	23.15
$\hat{Y}_{SEP}$ e/	93.223	0.0040(ct)		0.54	19.38	28.22
$\hat{Y}_{SEP}$	-28.664		0.378(wt)	0.81	12.40	28.22
$\hat{Y}_{SEP}$	-34.573	0.0012(ct)	0.315(wt)	0.84	11.69	28.22

a/ β_o = Regression coefficient, Y-intercept.

b/ ct = ^{40}K counts in counts per minute.

c/ wt = Live weight (pounds).

d/ $\hat{Y}_{FFL}$ = Predicted pounds of fat-free lean.

e/ $\hat{Y}_{SEP}$ = Predicted pounds of separable lean.

f/ Standard deviation of the predicted variable.

TABLE XI

LINEAR PREDICTION EQUATIONS FOR GROUP II (BY SEX) USING ^{40}K COUNT AND LIVE WEIGHT

Predicted Variable	β_o a/	$\beta_{(ct)}$ b/	$\beta_{(wt)}$ c/	R^2	Standard Error of Estimate	Std. Dev. f/
			18 Steers			
$\hat{Y}_{FFL}$ d/	132.287	+0.0027(ct)		0.76	7.20	14.26
$\hat{Y}_{FFL}$	40.991		+0.256(wt)	0.57	9.65	14.26
$\hat{Y}_{FFL}$	48.985	+0.0020(ct)	+0.130(wt)	0.86	5.68	14.26
$\hat{Y}_{SEP}$ e/	150.370	+0.0031(ct)		0.62	11.74	18.37
$\hat{Y}_{SEP}$	24.779		+0.319(wt)	0.53	12.97	18.37
$\hat{Y}_{SEP}$	-34.573	+0.0012(ct)	0.315(wt)	0.73	10.07	18.37
			20 Heifers			
$\hat{Y}_{FFL}$	142.341	0.0021(ct)		0.28	15.38	17.65
$\hat{Y}_{FFL}$	-52.768		0.365(wt)	0.69	10.07	17.65
$\hat{Y}_{FFL}$	-51.585	0.0003(ct)	0.344(wt)	0.70	10.28	17.65
$\hat{Y}_{SEP}$	153.639	0.0026(ct)		0.27	19.51	22.24
$\hat{Y}_{SEP}$	-107.762		0.477(wt)	0.74	11.59	22.24
$\hat{Y}_{SEP}$	-106.908	0.0002(ct)	0.462(wt)	0.75	11.88	22.24

a/ β_o = Regression coefficient, Y-intercept.

b/ ct = ^{40}K counts in counts per minute.

c/ wt = Live weight (pounds).

d/ $\hat{Y}_{FFL}$ = Predicted pounds of fat-free lean.

e/ $\hat{Y}_{SEP}$ = Predicted pounds of separable lean.

f/ Standard deviation of the predicted variable.

TABLE XII

LINEAR PREDICTIONS FOR GROUP II (BY WEIGHT) USING ^{40}K COUNT AND LIVE WEIGHT

Predicted Variable	β_o a/	$\beta_{(ct)}$ b/	$\beta_{(wt)}$ c/	R^2	Standard Error of Estimate	Std. Dev. e/
			16 Cattle Above Mean Weight			
$\hat{Y}_{FFL}$ d/	183.911	0.0018(ct)		0.56	7.53	11.01
$\hat{Y}_{FFL}$	87.832		0.206(wt)	0.30	9.54	11.01
$\hat{Y}_{FFL}$	129.819	0.0015(ct)	0.073(wt)	0.59	7.57	11.01
			21 Cattle Below Mean Weight			
$\hat{Y}_{FFL}$	129.9512	0.0023(ct)		0.47	10.94	14.70
$\hat{Y}_{FFL}$	- 2.4795		0.302(wt)	0.53	10.36	14.70
$\hat{Y}_{FFL}$	19.5010	0.0012(ct)	0.201(wt)	0.61	9.71	14.70

a/ β_o = Regression coefficient, Y-intercept.

b/ ct = ^{40}K counts in counts per minute.

c/ wt = Live weight (pounds).

d/ $\hat{Y}_{FFL}$ = Predicted pounds of fat-free lean.

e/ Standard deviation of the predicted variable.

lean. Live weight appears to be a more useful measurement in predicting fat-free or separable lean in widely variable, slaughter-weight cattle populations, than is ^{40}K count.

TABLE XIII

LINEAR PREDICTION EQUATIONS FOR GROUP II (37 STEERS AND HEIFERS) PREDICTING DAILY FAT-FREE LEAN CHANGE USING DAILY ^{40}K COUNT CHANGE AND AVERAGE DAILY GAIN

Predicted Variable	β_o a/	$\beta_{(ctc)}$ b/	$\beta_{(adg)}$ c/	R^2	Standard Error of Estimate	Std. Dev. e/
$\hat{Y}_{FFLC}$ d/	0.3762	0.0016(ctc)		0.22	0.0806	0.0898
$\hat{Y}_{FFLC}$	0.2338		0.0068(adg)	0.59	0.0583	0.0898
$\hat{Y}_{FFLC}$	-0.0059	0.0008(ctc)	0.2099(adg)	0.64	0.0557	0.0898

a/ β_o = Regression coefficient, Y-intercept.

b/ ctc = Average daily ^{40}K count change in counts per minute.

c/ adg = Average daily gain in pounds.

d/ $\hat{Y}_{FFLC}$ = Predicted pounds of average daily fat-free lean change.

e/ Standard deviation of the predicted variable.

Prediction equations for the Group II cattle by sex and weight division are presented in Tables XI and XII, respectively. Live weight does not account for as much of the variation in the predicted

TABLE XIV

LINEAR PREDICTION EQUATIONS FOR GROUP II (BY WEIGHT) PREDICTING DAILY FAT-FREE LEAN CHANGE USING DAILY ^{40}K COUNT CHANGE AND AVERAGE DAILY GAIN

Predicted Variable	β_o a/	$\beta_{(ctc)}$ b/	$\beta_{(adg)}$ c/	R^2	Standard Error of Estimate	Std. Dev. e/
			16 Cattle Above Mean Weight			
$\hat{Y}_{FFLC}$ d/	0.5134	0.0006(ctc)		0.08	0.051	0.0518
$\hat{Y}_{FFLC}$	0.1012		0.196(adg)	0.72	0.029	0.0518
$\hat{Y}_{FFLC}$	0.1003	0.0001(ctc)	0.192(adg)	0.72	0.030	0.0518
			21 Cattle Below Mean Weight			
$\hat{Y}_{FFLC}$	0.3088	0.0020(ctc)		0.36	0.0724	0.0880
$\hat{Y}_{FFLC}$	-0.0012		0.2362(adg)	0.31	0.0748	0.0880
$\hat{Y}_{FFLC}$	0.0475	0.0015(ctc)	0.1548(adg)	0.47	0.0678	0.0880

a/ β_o = Regression coefficient, Y-intercept.

b/ ctc = Average daily ^{40}K count change in counts per minute.

c/ adg = Average daily gain in pounds.

d/ $\hat{Y}_{FFLC}$ = Predicted pounds of average fat-free lean change per day.

e/ Standard deviation of the predicted variable.

variables in these equations as it did when Group II was treated as a single population. ^{40}K count accounted for more of the variation in both predicted variables than did weight when only the 18 steers were considered. Live weight and ^{40}K count together in the regression models lower the standard errors of estimate for both separable and fat-free lean. A comparison of the equations derived for the steers with those for the 20 heifers shows that ^{40}K count was much less precise as an estimator of either fat-free or separable lean in the heifers than it was for the steers. Adding ^{40}K count to a regression model already containing weight did not improve the precision of the equations predicting either fat-free or separable lean in the case of these 20 heifers.

Dividing Group II into the 16 heaviest and 21 lightest cattle further reduced the effectiveness of live weight as a predictor variable of fat-free lean (Table XII). The use of ^{40}K alone in the regression models can account for only about one-half of the variation in fat-free lean for both weight groups. The equation using both weight and count is no more precise than count alone in the case of the heavier cattle. However, combining these two independent variables produced the smallest standard error of estimate for the light-weight cattle.

As the variability of live weight has been reduced, by sub-dividing Group II, ^{40}K count has become a more competitive estimator lean tissue when compared to live weight. This suggests that the ^{40}K counter may be most useful as a selection tool when the cattle in question are very uniform in live weight.

The two remaining tables (Tables XIII and XIV) contain linear prediction equations that use average daily gain and average daily ^{40}K

count change to predict the pounds of fat-free lean change per day. Average daily gain is a much more precise predictor of fat-free lean change than is ^{40}K change in Group II (as a single population) and in the heavy cattle of Group II. Average daily gain and ^{40}K count change together in the model had little effect on the standard error of estimate of average daily gain alone. Both average ^{40}K count change and average daily gain could account for only about one-third of the variation in fat-free lean change in the light-weight Group II cattle; therefore, together these two variables produced a prediction equation with the smallest standard error. Average daily gain accounted for only 31% of the variation in fat-free lean change in the light-weight cattle, whereas it accounted for 72% of the variation found in the heavier cattle.

Upon completion of the above statistical analysis and learning (via Group II) that ^{40}K count could account for only 41% of the variation in fat-free lean and that daily ^{40}K count change (for the entire feedlot period) could account for only 22% of the variation in daily fat-free lean, efforts to monitor muscle growth in smaller time periods seemed futile. Consequently, the interim six-week counts were not analyzed.

CHAPTER V

SUMMARY

A total of 58 cattle were used to evaluate the ^{40}K counter as a predictor of lean tissue and a monitor of muscle growth. Twenty steers were ^{40}K counted and slaughtered at weaning (Group I) to determine the usefulness of the device to predict lean tissue in young cattle. The remaining 38, consisting of 18 steers and 20 heifers, were ^{40}K counted at weaning, placed in the feedlot, ^{40}K counted at six-week intervals, and slaughtered after a final evaluation by the ^{40}K counter.

The high pooled, within-slaughter day correlation between ^{40}K count and fat-free lean (0.93) found in Group I suggested that lean tissue could be predicted in very young cattle as well as it had been estimated in slaughter weight cattle of previous studies. With evidence that lean can be predicted at the beginning of a feedlot period and at a desirable slaughter weight, monitoring the muscle changes between these two points seems feasible.

Linear prediction equations from Group II of this study revealed that live weight was a more precise estimator of fat-free or separable lean than ^{40}K count in a widely diverse beef cattle population. Dividing Group II into more homogeneous subdivisions (by sex or by weight) generally made ^{40}K count more competitive as a predictor of lean tissue when compared to live weight. ^{40}K count alone accounted for much more of the variation in fat-free and separable lean in the 18 Group II steers than it did in the 20 heifers (R^2 = 0.76 and 0.28, respectively). Only about one-half of the variation in fat-free lean could be accounted for by ^{40}K count in each case when Group II was divided strictly into weight divisions at the mean slaughter weight. Nonetheless, a regression equation with ^{40}K count and weight as predictor variables was no more precise than the equation using ^{40}K count alone in the case of the heavier cattle. Combining these two predictor variables did provide the equation with the smallest standard error of estimate for the light-weight cattle.

In an effort to evaluate the ^{40}K counter as a monitor of muscle growth, prediction equations were developed to predict daily fat-free lean change. Average daily gain as the lone predictor variable was the most precise predictor of fat-free lean change in the cattle above the mean slaughter weight. Average daily gain and average daily ^{40}K count change together provided the equation with smallest standard error of estimate for those cattle below the mean slaughter weight, and for all Group II as a single population.

Fat-free lean and separable lean were very highly correlated in both Group I and Group II. Live weight and ^{40}K count can be used as effectively to predict separable lean as they are used to predict fat-free lean. This is substantiated by the very similar coefficients of determination found for these two dependent variables throughout the study.

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