ANALYSIS OF A PERMIAN POTASSIUM-40 COUNTER AS A PREDICTOR OF LEAN IN BEEF CATTLE

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CHAPTER I

INTRODUCTION

The quest for a method of estimating the amount of muscling in a meat animal has resulted in the development and evaluation of many different tools designed for this purpose. Early methods were largely attempts to estimate carcass composition from analysis of a small portion of the carcass. In more recent years researchers have sought for an efficient way of estimating body composition that would not require the slaughter of the animal.

The value of such a tool in a breeding program is obvious. At present the most reliable means of sire evaluation is the progeny test. This method requires two years from the time a sire is ready to enter the breeding herd until he has been evaluated. The number of sires which may be tested is also limited due to the number of progeny required in addition to the time interval. If reliable, a non-destructive method of evaluation would enable the breeder to make selection from all of his bull calves and begin using the superior sires on his breeding herd immediately. This would, therefore, result in a higher selection differential and a shorter generation interval, thereby increasing the rate at which genetic improvement could be made.

One non-destructive method of evaluation proposed by Anderson (1959) is the use of potassium-40 (K^{40}) gamma rays. Potassium emits a relatively constant number of K^{40} gamma rays, and muscle tissue in animals of the same physiological age possesses approximately the same percent of potassium. The use of K^{40} as an estimate of lean tissue, therefore, is based on these two principles. If a given proportion of the K^{40} gamma rays being emitted can be detected, it would be possible to estimate the amount of potassium in the live animal and consequently arrive at an estimate of the amount of muscle tissue in this animal.

The purpose of this study was to evaluate a Permian K^{40} counter designed specifically for cattle weighing approximately 1000 pounds. The data from 31 head of Angus calves were examined to determine:

(1) The correlation between two independent counts on the same animal on the same day;

(2) The association between radioactive count and fat-free lean;

(3) The standard error of estimate when predicting fat-free lean from K^{40} count and live weight; and

(4) The association between variation in K^{40} count and several animal measurements.

CHAPTER II

REVIEW OF LITERATURE

The large volume of literature on live animal and carcass evaluation amply illustrates the importance placed on this field of study in animal science research. The search for a non-destructive method of evaluating meat animals has resulted in the study of potassium-40 (K^{40}) as a possible predictor of lean in meat animals.

One of the two major principles on which the K^{40} technique is based is the constant portion of potassium which is in the form of K^{40} gamma emitters. E. C. Anderson (1959) reported that 0.01% of all naturally occurring potassium was in the form of the K^{40} isotope. Forbes (1963) and Ward et al. (1967) agreed with this figure by reporting that K^{40} comprised 0.012% of all naturally occurring potassium. It would appear, therefore, that this principle has a sound basis.

The second principle, that a high percent of potassium is in muscle, has resulted in some conflicting reports in the literature. Anderson (1959) stated that there was no potassium in fat and only a minute quantity in bone. This statement was not supported by experimental evidence and this article has been quoted by many of the K^{40} papers in the literature even though no such evidence was presented.

Kirton and Pearson (1963), in studies involving 10 lamb carcasses, 20 lots of ground beef, and 15 lots of ground lamb, reported that the presence of potassium in fat could not be ignored. Values for the potassium content of fat of 0.70 and 0.82 grams of potassium per kilogram of weight as determined by K^{40} count and flame photometry, respectively, indicated that there was a detectable amount of potassium in the samples used in this study.

Ward *et al*. (1967), on data obtained from limited observations, reported that the potassium content of fat-free-lean tissue decreased as fat increased. A more reliable study, based on the evaluation of 90 steers by Lohman and Norton (1968), found that 53.4% of total body potassium was in the lean and 5% was in adipose tissue. Breidenstein (1964) reported that fat accounted for 12% of the total K^{40} count indicating a significant contribution to the net animal count. Values this large for the amount of potassium in fat indicate that fat should not be omitted as a source of potassium, which is contrary to the statement of Anderson (1959) that there is no potassium in fat. Significant negative correlations between K^{40} count and percent separable fat have been reported (Judge *et al*., 1963; Kirton *et al*., 1961; Kulwich *et al*., 1961b; Ward *et al*., 1967). These reports also indicated that although there is potassium in fat, there is only a relatively small amount. In contrast, Kirton *et al*. (1963b), working with

24 pigs, reported a significant positive correlation between percent ether extract and potassium expressed as a percentage of empty body weight.

Since this second principle suggests that most of the body potassium is found in the muscle tissue, other sources of potassium also influence the reliability of this principle. External sources of potassium were recognized by most researchers in this field, and reports indicated that one good washing was sufficient to remove the largest majority of this potassium source (Kirton et al., 1961; Twardock et al., 1966).

The most important internal source is the gastro-intestinal (GI) tract. Values for the percent of total body potassium contained in the GI tract of 16, 19, and 21 percent were reported by Lohman and Norton (1968), Kirton et al. (1963), and Lohman et al. (1966), respectively. Breidenstein (1964), as reported by Hillier et al. (1966), presented data (Table I) to demonstrate the importance of the non-lean sources of potassium and also the value of controlling the GI tract contribution by feeding a standardized oat diet. Although it appears that only about 55% of the total body potassium is in the lean, Lohman and Norton (1968) believe that because this is a large percentage when compared to the other tissues, potassium is a good quantitative index of muscle.

Gillett et al. (1965) reported significant differences between breeds, between muscles within an animal, and be-

TABLE I

PERCENT OF LIVE COUNT ACCOUNTED FOR BY SOME LIVE AND CARCASS VARIABLES ON TWO DIFFERENT RATIONS

Source of Count	Regular Feed	Low Radiation Diet
Live Count	100.0%	100.0%
Hide	5.0	5.0
GI Tract	15-30.0	10.0
Organs	10.0	8.0
Blood-Fat-Feet	2.0	2.0
Carcass Components	55-70.0	75.0
Lean	40-55.0	60.0
Fat	12.0	12.0
Bone	3.0	3.0

Breidenstein (1964)

tween the same muscle of different animals. This work was based on data from six muscles of each of six Hampshire and six Yorkshire barrows weighing from 186 to 220 pounds. Due to this limited number, care should have been taken in making reference to the swine population as a whole. These workers, however, felt that the variation in potassium content from muscle to muscle indicated that the potassium-to-muscle ratio is not constant. This could, therefore, be an important source of error in the K^{40} method of evaluation.

Gillett et al. (1967), working with beef cattle, reported a difference in amount of potassium per unit of muscle weight in seven muscles of beef cattle. Using seven Hereford, seven Angus, and two Shorthorn, and comparing grams of potassium per kilogram of muscle, these workers reported a significant difference of 0.51 grams from the largest to the smallest. Since this would amount to only about five grams of total potassium, it is doubtful whether the K^{40} counter would be sensitive enough to detect so small a difference consistently.

Ward et al. (1967) presented results in contrast to the results of Gillett et al. (1965). To determine if there was a difference in the potassium concentration of eight wholesale cuts, these researchers used a one-year-old Hereford heifer, three four-year-old Holstein cows, and a fat seven-year-old Guernsey. On the analysis of this questionable data, no significant difference was found in potassium content between muscles within animals.

Lohman and Norton (1968) reported potassium content as a percentage of six body components. These components, along with the coefficient of variation (CV) associated with each one, are presented in Table II. According to the authors, the large CV's for most components suggested considerable variation from animal to animal in amount of potassium per unit of component weight for these components. These workers further concluded that the CV reported for standard trimmed lean of 5.7% indicated that grams of potassium per kilogram of lean did not vary greatly from animal to animal.

Even though there is some conflicting evidence on the validity of the principles of evaluation by K^{40} technique, Lohman _et_ _al_. (1966) concluded that body potassium can be measured precisely enough to be practical as a measure of lean muscle mass in cattle. Anderson (1959) also concluded that potassium would be a measure of lean cell mass since the concentration of potassium in muscle was held constant by homeostatic processes.

Kirton _et_ _al_. (1961) used three 100-second counts to estimate the amount of potassium in each of ten lambs. The analysis of the association between percent separable lean and grams of potassium per kilogram of live weight yielded a correlation coefficient of 0.58.

In further studies with sheep, Judge _et_ _al_. (1963) reported a correlation of 0.73 between pounds of edible portion and K^{40} measurement in 27 live lambs and 38 lamb

TABLE II

POTASSIUM CONCENTRATION AS A PERCENTAGE OF SIX BODY COMPONENTS*

Component	GM-K Per KG	K as %(mean)	CV
Standard Trimmed Lean	3.32gm	53.4%	5.7%
Carcass Bone	3.07	12.4	14.3
GI Tract	2.71	16.4	33.6
Head & Organs	2.39	7.7	9.6
Blood, Mesenteric Fat and Feet	0.66	2.7	21.2
Adidose Tissue	0.77	3.8	24.7

*Lohman and Norton (1968).

carcasses. These workers also reported a correlation of 0.91 between carcass weight and pounds of edible portion and concluded that simple measures were as good as K^{40} measurement for predicting pounds of edible portion.

In swine, Kulwich *et al*. (1961a) counted 34 hams for K^{40} content and found that K^{40} activity was highly correlated ($r = 0.96$) with pounds of separable lean. Evidence from this data also illustrated that correlations between K^{40} count and pounds of fat-free lean were of the same magnitude. Correlations between count and percent separable or fat-free lean resulted in somewhat lower values. In another study involving 24 market-weight pigs, Kirton *et al*. (1963) reported a correlation of 0.77 between percent protein and percent potassium as determined by K^{40} count. A standard error of 18% of the range in percent protein was reported and these workers concluded that percent potassium was not a precise enough measure to separate individuals but may be of some benefit in distinguishing between groups.

Sixteen beef rounds were counted for a period of 42 to 51 minutes (Kulwich *et al*., 1961b). Correlation between pounds of separable lean and K^{40} count was 0.975, and, after adjusting for efficiency due to sample weight, the correlation coefficient was 0.982. Fat-free lean and K^{40} count were also highly correlated ($r = 0.983$). One other important result was the high correlation of 0.984 between pounds of separable lean and pounds of round. The coefficients of variation for fat-free lean and for separable lean were 23.5% and 23.8%, respectively. These workers therefore concluded that even though the correlation was very high, rounds differing by one or two percent could not be differentiated due to the large standard deviations in relation to the mean.

In an extensive study involving 21 steers in each of two years, Lohman et al. (1966) reported that whole body potassium accounted for 51% of the variation in carcass lean muscle mass. When used together in a prediction equation, live weight and whole body potassium, as determined by the K^{40} count, reduced the standard error of estimate for carcass lean muscle mass from 22.4 pounds to 14.7 pounds. This was not significantly lower than the standard error of 15.6 pounds obtained when weight alone was used in a prediction equation. Potassium-40 count, on the otherhand, did significantly reduce the standard error of estimate to 11.0 pounds. In the second year whole body potassium accounted for 88% of the variation in carcass lean muscle mass. Also the use of K^{40} count in a prediction equation with carcass weight significantly reduced the standard error for carcass lean mass from 15.2 pounds to 9.7 pounds. The major difference in the two years was standardized oat ration which was fed to steers in the second group for seven days prior to counting.

In most of the studies reported, some method of calibration was used to adjust the count for size and shape.

Anderson (1959) pointed out why it would be necessary and later work has reported the improvement made by instrument calibration (Kulwich et al., 1961a,b; Kirton et al., 1961; Lohman et al., 1966; Twardock et al., 1966; Ward et al., 1967). The reporting of the repeatability of unadjusted counts was missing from the literature.

Since the importance of K^{40} as a predictor of lean in beef cattle will depend on the amount of improvement this method makes over less expensive methods of evaluation, a brief review of less expensive and more easily obtained measures was included.

The correlation between carcass traits and live appraisal by different graders has ranged between 0.12 and 0.49 (Wilson et al., 1964; Gregory et al., 1964). Live animal weight taken shortly before slaughter was shown to be as good a predictor of rib eye area in lambs as any non-cutting measurement available in 1960 (Bailey et al., 1960). Orme et al. (1959) reported a high repeatability for live animal measurement and a high relationship between live weight and various primal cuts. A correlation of 0.90 between carcass weight and boneless roast and steak meat was reported from the data collected on 152 Hereford steers (Fitzhugh et al., 1965). Correlations between round weight and carcass lean of 0.93 (Thornton and Hiner, 1965) and round weight and round lean of 0.98 (Kulwich et al., 1961b) have been reported.

From this brief review of easy to obtain measures it appears evident that the value of the K^{40} method would be in live animal evaluation instead of carcass evaluation. Easier and less expensive carcass measures had nearly as high an association with carcass composition as did K^{40} count. The literature would indicate that, if the external and non-lean internal sources of potassium could be controlled, K^{40} determination would be an effective method of predicting lean in meat animals. Lacking in the literature was the report of the performance of K^{40} machines designed for the livestock they were measuring. Also lacking were enough studies designed to measure the type of cattle normally marketed.

CHAPTER III

MATERIALS AND METHODS

Counter

The Permian K^{40} Counter used in this study was designed for 1000-pound cattle that had been grown out under feed lot or range conditions (Figure 1). The counting chamber, mounted on a mobile trailer, was a six-inch thick steel box surrounding the detector banks. The scintillation detectors were phospho-light tubes and were arranged in a horseshoe shape so that they surrounded the back and sides of the animal being counted (Figure 2). A circular detector plate was located in the rear of the chamber so that the animal was surrounded by detectors except for the head and underline. A schematic diagram of the path of a K^{40} gamma ray through the counter was presented along with a more detailed explanation of the operation of this counter by Ward (1968).

The facilities at the Oklahoma State University Evaluation Center were inadequate at the time of this experiment and the cattle could not be handled with a minimum of excitement.

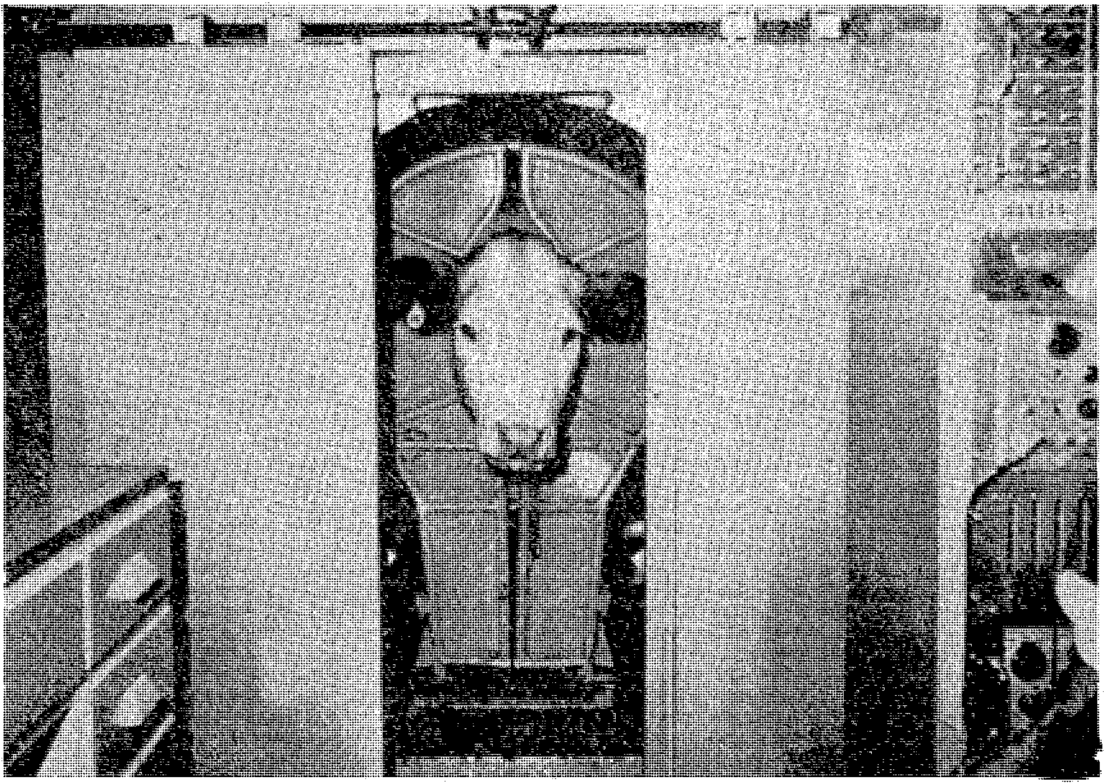

Figure 1. A 1,000 Pound Steer in the K^{40} Counting Chamber

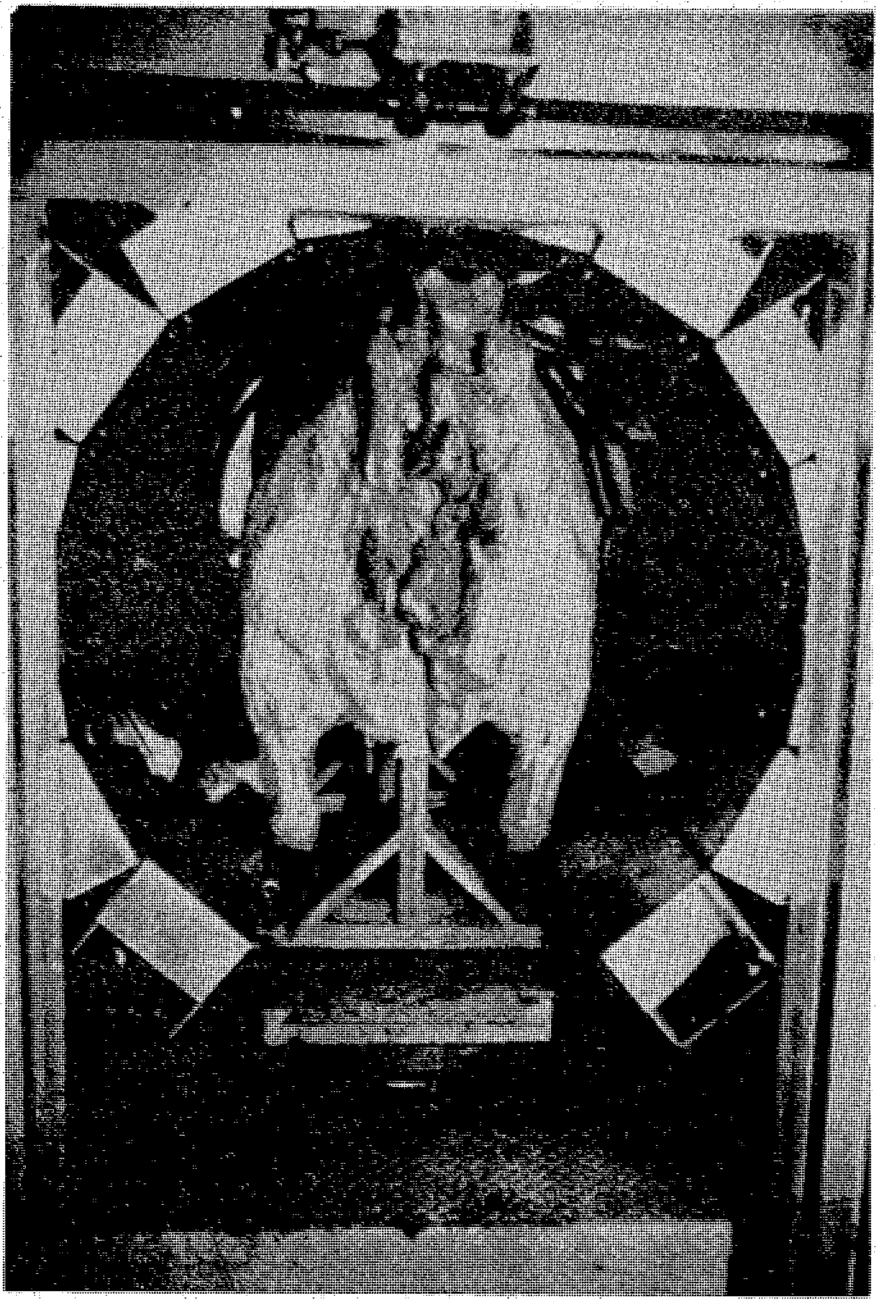

Figure 2. Carcass in Counter Showing Position of Detectors

Animals

To evaluate the performance of the K^{40} counter, 16 Angus steers and 16 Angus heifers were selected from the progeny test herd at Stillwater in the fall of 1967. These calves were selected at random from the group remaining after the calves for the progeny test had been selected. Although only six of the eleven bulls which sired progeny to test calves in 1967 had male progeny in this remainder, it appeared that the steer sample was a representative one. Since only a few heifers were used for the progeny test, all sires had progeny available for selection so the heifers should have been a random sample subject only to sampling error.

The calves were weaned at an average age of 205 days. The average adjusted weaning weight of the 16 steers was 457.5 pounds. When compared to the herd mean of 463 pounds, the steer sample appeared to be a representative one. The 16 heifers had a mean adjusted weaning weight of 450 pounds as compared to the herd heifer mean of 446 pounds.

The calves were taken to the Fort Reno Livestock Research Station to be fed out as finished yearlings. The steer calves were allotted randomly to the two groups of progeny test steer calves, while the heifers were fed together in a pen between the two larger steer pens. For the entire fattening phase the calves were fed a corn base fattening ration that was mixed at the Research Station. One of the K^{40} steers died from bloat so that 16 heifers and 15 steers were available at the conclusion of the feeding period.

The 160 day feeding period for the progeny test calves ended on March 14. At this time the mean adjusted yearling weight of the progeny test steers was 870 pounds, while the mean adjusted weight of the 15 K^{40} steers was 855 pounds, again indicating the steers were a relatively representative sample. On March 30, after 175 days of feed lot performance, the K^{40} calves were weighed and the seven heaviest, regardless of sex, were cut out to begin the evaluation phase of the experiment. The 24 remaining calves were continued on the same feeding program for an additional two weeks at which time the eight heaviest were weighed off-feed for evaluation. The procedure was repeated for the remaining 16, with the last 8 being weighed off-feed on May 11 after 217 days of feeding. The 31 animals were grouped in this manner in order to have groups small enough to handle effectively and to allow the slower gaining animals to reach as near 1000 pounds as possible.

This grouping procedure resulted in off-feed weights and sex distributions shown in Table III. As can be seen from the table, all but four of the steers were evaluated in Groups I and II, and all but four of the heifers were evaluated in Groups III and IV. The weight groupings were such that there was a heavy group, a light group, and two groups close together. This method of grouping produced some interesting results which will be discussed in more

TABLE III

AVERAGE WEIGHT, WEIGHT RANGE, AND SEX DISTRIBUTION OF GROUPS USED FOR EVALUATION

	Average Weight (Lbs.)	Range (Lbs.)
Group I 5 ♂ 2 ♀	992	950 - 1050
Group II 6 ♂ 2 ♀	932	911 - 966
Group III 2 ♂ 6 ♀	912	880 - 956
Group IV 2 ♂ 6 ♀	812	740 - 870

detail later.

Counting Procedure

Since each of the groups was weighed off-feed on Friday, the same day of the week was used for similar activities for each group. Following is the day by day routine procedure which was followed for each group.

<u>Friday</u>

At 8:00 a.m. the cattle were weighed and the group sorted out for evaluation was hauled by truck to the Oklahoma State University Evaluation Center, a distance of about 90 miles. Upon arrival at the center, the cattle were placed in concrete, slatted-floor holding pens. About 1:30 p.m. each animal was herded into a squeeze chute and 100 mg of propiopromazine hydrochloride, a tranquilizer, was administered intramuscularly. After a minimum of one hour, they were washed in a small washroom. Groups I and II were washed with water only, while Groups III and IV were washed with soap and water. The washing and the slippery concrete slats in the holding pens caused many bad falls and seemed to make the animals easily excitable, thereby making handling difficult. The cattle remained in the holding pens overnight without feed or water so that they had been shrunk at least 24 hours by 8:00 a.m. Saturday.

Saturday

Due to the muddiness of the feedlot pens, most of the cattle needed to have the mud balls clipped from their brisket, abdomen, and flank regions. This task was begun at 7:00 a.m. on Saturday and all animals were run into the squeeze chute to expose them to the same additional stress.

At 8:00 a.m. the counting began with a potassium-chloride standard source counted first. The animal counting continued without a stop until all animals had been counted twice. The KCl source was also counted in the middle and at the end of the counting day.

In this study, 10 minute counts were used for background and animal counts. A ten minute background count was taken before and after each animal count to estimate the amount of natural radiation in the air at the time of the sample count. The background count was obtained with the animal crate in the counting chamber so that, as nearly as possible, the calf was the only additional K^{40} source introduced to the counter. A simple average of the two background counts was used to subtract from the count obtained when the animal was in the counter. The figure remaining after this subtraction was used as the amount of gamma radiation introduced by the animal and was called "net count". This net count figure was the count analyzed in the evaluation of the data.

The animals in a group were coded and counted in a random order until all had been counted once. After counting the standard source, the cattle were recoded and counted in another random order so that the two counts on the same animal on the same day would be independent. After the second count the animals were returned to the holding pens and remained without feed and water until Monday morning.

Monday

When counting began on Monday, the calves had been shrunk a minimum of 72 hours. The counting procedure was the same on Monday as it was on Saturday. After their second count the calves were immediately hauled to the Meat Laboratory for slaughter.

On each counting day notes were taken relative to the weather conditions and temperament of the animals. A yardstick was used to measure the distance from the topline of the animals to the top of the counting crate. Measurements were taken at the shoulders, the last rib, and the hips, and an average distance was computed for analysis.

Slaughter floor data were obtained and the measurements taken are shown in Table IV. The carcasses were not split and were mounted on racks so that they assumed the same position as a live animal (Figure 3). The carcasses were chilled in this position at 40° F for a minimum of 40 hours.

TABLE IV

WEIGHTS AND MEASUREMENTS TAKEN ON SLAUGHTER FLOOR

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1. Slaughter weight
2. Head weight
3. Shank weight
4. GI Tract weight
5. Hide weight
6. Kidney, Heart, and Pelvic Fat weight
7. Heart weight
8. Liver weight
9. Hide thickness*

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*Hide thickness was the average of nine measurements made with a swine backfat probe.

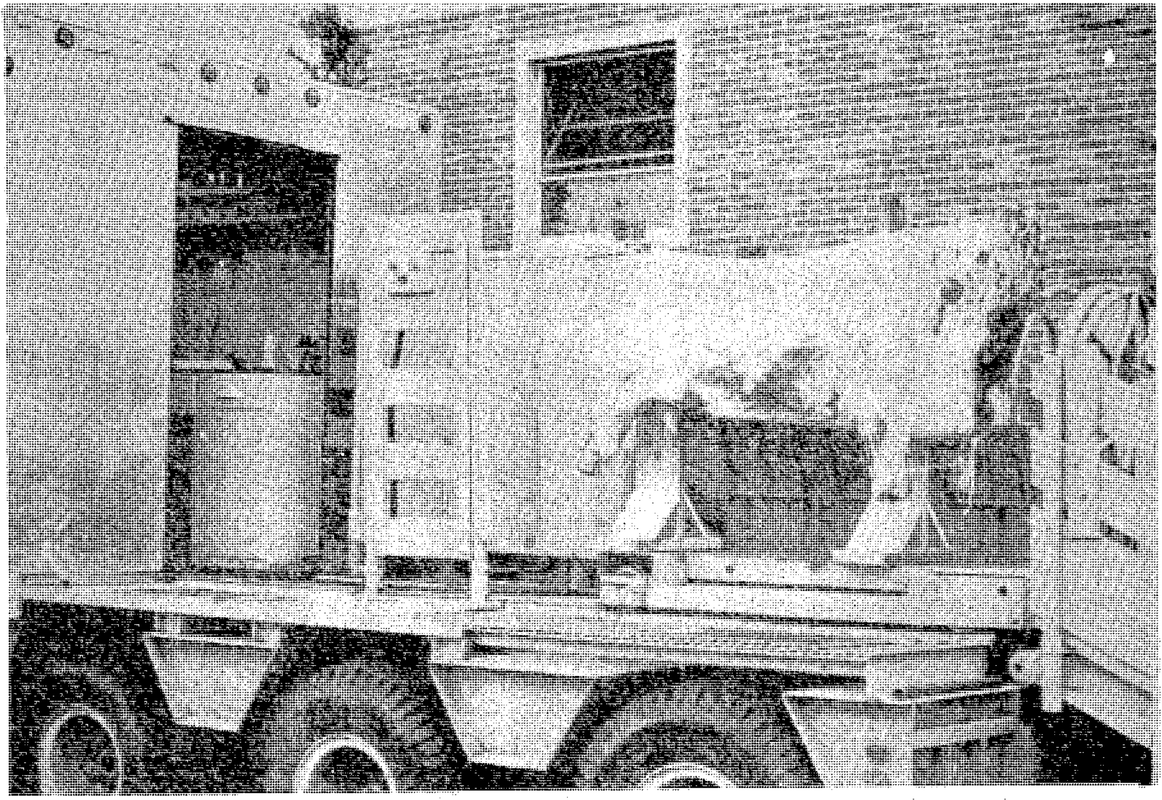

Figure 3. Unsplit Carcass Mounted on Rack for Counting

Wednesday

The mounted carcasses were returned to the Evaluation Center for counting. Ten minute counts were again used, but the order of counting was different from that of the live animals. The carcasses were not coded and usually only one or two carcass counts separated duplicate counts on the same carcass. It was, therefore, left up to the operator to be unbiased so that duplicate carcass counts would be independent. After the second count the carcass was returned to the Meat Laboratory.

Thursday to Saturday

After being returned to the laboratory, the carcasses were split and the right half of each was separated and the lean was sampled for ether extract. From this separation and sampling procedure, which is described in detail below, fat-free lean was determined for use in the evaluation of the association between K^{40} count and lean tissue.

Separation and Sampling

To arrive at an estimate of the amount of lean in these cattle, the right side of each carcass was separated into bone, trimmed fat, and separable lean. Since it had been shown (Brungardt and Bary, 1963) that there were essentially no differences in carcass fat, muscle, and bone between the right and left side of 35 beef carcasses, the values obtained for the right side were doubled to arrive at total carcass bone, trimmed fat, and separable lean.

The procedure used to separate the lean and fat was to trim as much of the fat as possible without trimming any lean. This fat without any lean was termed "trimmed fat". The lean portion with its associated fat content was labeled separable lean.

The separable lean was sampled using a procedure similar to that described by Munson _et_ _al_. (1966). The procedure is illustrated in Figure 4. The separable lean was first ground through a one inch plate. This coarse bulk was mixed by hand as it was placed in the hopper and then ground through a three-eighth inch plate. The ground bulk, as it was now called, was mixed by hand, placed in the hopper and ground through a one-eighth inch plate.

As the ground bulk emerged from this final plate, nine grab samples were obtained at estimated uniform intervals. These intervals were spaced so that, as nearly as possible, one sample would be obtained from each ninth part of the bulk. Care was taken to avoid sampling from the very first part of the bulk or the very last part. As each sample was obtained it was placed on a plastic tray. After all nine samples had been placed on the tray, three were taken at random to fill bottle "A", three to fill bottle "B", and three to fill bottle "C". The procedure used to fill the bottle was to take enough of one of the grab samples to fill bottle "A" one-third of the way, and enough of a second sample to fill bottle "A" two-thirds of the way, and finally

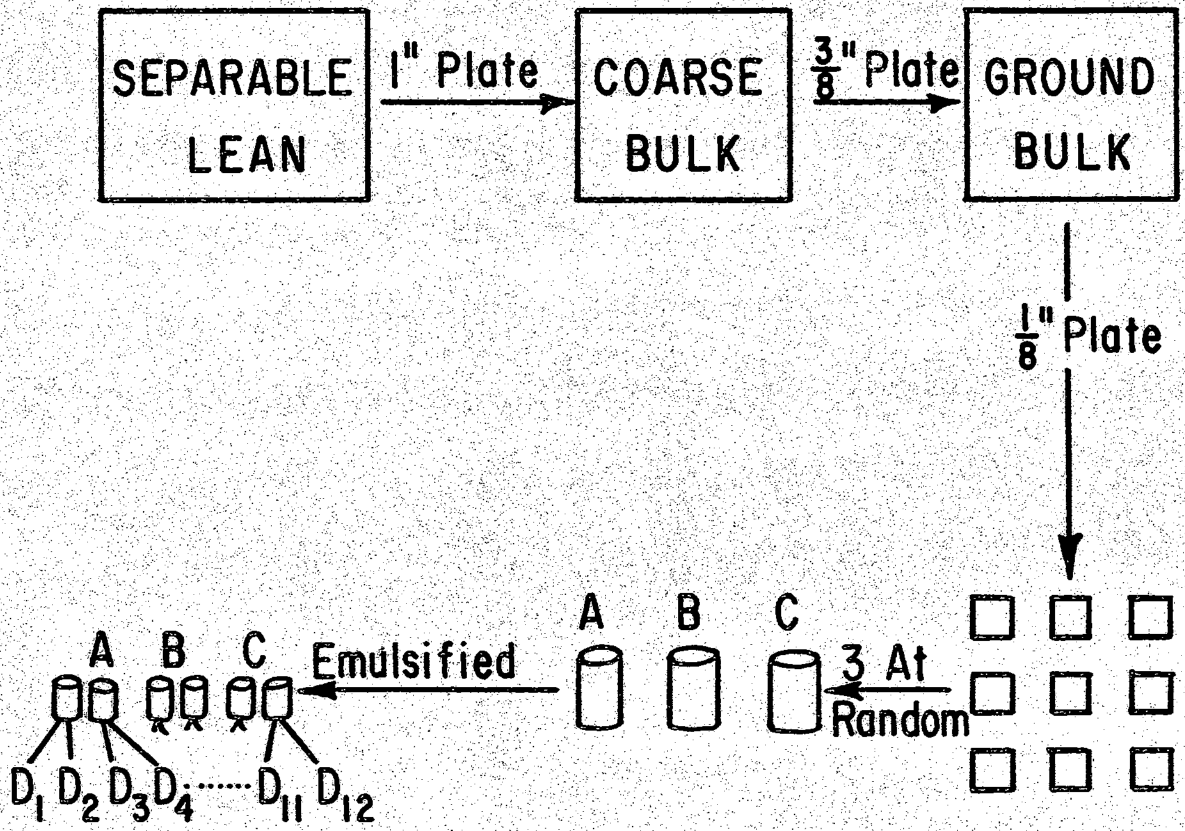

Figure 4. Schematic diagram of sampling procedure.

acquire enough of a third grab sample to fill bottle "A" full. Bottle "A" was then capped and the three samples which had been used were discarded. Bottles "B" and "C" were then filled in a similar manner.

The three sample bottles were stored in a low temperature cooler (30°) until they were emulsified. Each of the bottles was emulsified using a high speed omni-mixer without an ice pack. The sample was mixed until it had a pasty consistency, and half of each sample was transferred to a uniquely numbered sub-bottle. There were, therefore, 12 estimates of the composition of the separable lean from each animal. The sub-bottles were taken to the Biochemistry laboratory where duplicate determinations for moisture, ash, ether extract, protein, and potassium were made using procedures described by Leverton and Odell (1959), except that potassium determination was by atomic spectrophotometer rather than flame photometry.

Statistical Procedures

Chemical Analysis

The data from the chemical analyses were examined using a heirarchal (nested) design. The heirarchy was animals, bottles in animals, sub-bottles in bottles, and determinations in sub-bottles. The degrees of freedom associated with each classification are presented in Table V. Missing observations were encountered in the potassium determinations and the degrees of freedom are shown in parentheses.

TABLE V

DEGREES OF FREEDOM AND EXPECTED MEAN SQUARES FOR CLASSIFICATIONS IN NESTED DESIGN ANALYSIS OF SAMPLING PROCEDURE

Source	df[a]	Expected Value of Mean Square[a]
Total	371 (329)	
Animal	30 (30)	$\sigma_e^2 + 2\sigma_D^2 + 4\sigma_{SB}^2 + 12\sigma_B^2$ (3.58) (10.62)
Bottle/A	62 (62)	$\sigma_e^2 + 2\sigma_D^2 + 4\sigma_{SB}^2$ (3.53)
Subbottle/B	93 (72)	$\sigma_e^2 + 2\sigma_D^2$
Determination/SB	186 (165)	σ_e^2

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[a] Degrees of freedom and coefficients of expected value components in parentheses are for potassium. All others are for moisture, ash, ether extract, and protein.

In this design the corrected sum of squares for each classification was calculated. The corrected sum of squares (SS) for each classification was subtracted from the corrected sum of squares of the next lower classification to arrive at the sum of squares associated with the lower classification. For example, bottle SS - animal SS equals the sum of squares associated with bottle within animal. Since a balanced design was used for all chemical determinations and since there were no missing observations except in the potassium data, the expected value of the mean square for each component had the same coefficients for moisture, ash, ether extract, and protein. These coefficients are presented in Table V with the coefficients for potassium components in parentheses. Algebraic manipulation was used to derive the variance component associated with each classification. The percentage variation associated with each classification was used to evaluate the effectiveness of the sampling procedure in obtaining a representative sample.

Count Data

Since the purpose of this study was to evaluate the ^{40}K counter as a predictor of lean in beef cattle, the count data was examined thoroughly to estimate repeatability and the association between count and weight of fat-free-lean tissue. Since the first characteristic an effective method of prediction should possess is repeatability, the independent counts on the same animal on the same day were examined. The correlation between count 1 and count 2 on the same animal on the same day, or the agreement between independent estimates, was used as a measure of repeatability.

The association between the K^{40} counts per minute and fat-free-lean were studied using simple and multiple linear correlation as described by Steel and Torrie (1960). Since group was confounded with length of feeding, time, and weight, repeatability and correlation analyses were executed on each group and then pooled within group to adjust for the effect of the grouping. Pooling within group was accomplished by adding the corrected sum of squares and cross-products for each group and then using these "pooled" values in the standard equations.

The count data were further analyzed by simple linear regression (Steel and Torrie, 1960) to study the effectiveness of K^{40} count when used in a prediction equation. The equations studied were:

$$(1.)\quad \hat{Y}_{FFL} = B_0 + B_1 (x)$$

where,

$\hat{Y}_{FFL}$ is the estimated value of pounds of fat-free lean,

B_0 is the coefficient of regression common to all observations, or the y-intercept when weight (x) equals zero,

B_1 is the regression coefficient for weight,

x is the weight of the individual in pounds,

$$(2.)\quad Y_{FFL} = B_0 + B_2(Y)$$

where,

B_2 is the regression coefficient for K^{40} count,

Y is the K^{40} count in counts per minute,

$$(3.)\quad Y_{FFL} = B_0 + B_3(x) + B_4(Y)$$

where B_3 and B_4 are the regression coefficients for weight and count, respectively.

The abbreviated Doolittle technique was used to study the amount of variation in count associated with six variables. The model used was:

$$Y = B_0 + B_1(x_1) + B_2(x_2) + B_3(x_3) + B_4(x_4) + B_5(x_5) + B_6(x_6)$$

where,

Y is an individual K^{40} count in counts per minute,

B_0 is the common regression coefficient,

$B_1(x_1)$ is the coefficient and value for weight,

$B_2(x_2)$ is the coefficient and value for pounds of fat-free-lean,

$B_3(x_3)$ is the coefficient and value for gastrointestinal (GI) tract weight,

$B_4(x_4)$ is the coefficient and value for hide weight,

$B_5(x_5)$ is the coefficient and value for hide thickness,

$B_6(x_6)$ is the coefficient and value for average distance from the detectors.

Since the reduction of the total sum of squares for each variable is adjusted for only those variables preceding it in the equation, a valid F test can be made on only the last variable in the equation (Tanner, 1969). Separate analyses did not, however, need to be made with each variable last in the equation. In this procedure the beta value and the corresponding inverse element are sufficient to derive the adjusted sum of squares for a particular variable. For example, the sum of squares removed by the i^{th} variable after adjusting for the other five variables may be obtained by the following formula:

$$\left[B_i\right]^2 \left[C_{ii}\right]^{-1}$$

where,

$\left[B_i\right]^2$ is the squared value of the regression coefficient associated with variable i.

$\left[C_{ii}\right]^{-1}$ is the inverse of the diagonal element in the inverse matrix corresponding to the i^{th} variable.

In addition, the analysis was employed separately with fat-free lean and GI tract weight each first in the equation to observe the relationship between adjusted and unadjusted sum of squares in this type of data.

Throughout the analysis of the data the assumption was made that errors were normally distributed with mean zero and variance σ^2 and all x_i were assumed to have a linear association with Y.

CHAPTER IV

RESULTS AND DISCUSSION

Chemical Determinations

The mean squares for each source in the analysis of variance of the chemical determinations is presented in Table VI. The amount of variation in each chemical component associated with a particular source is shown in Table VII.

Ether Extract

Since the ether extract percentage was used to determine the amount of fat in the separable lean, this chemical component was of the greatest concern. The component analysis showed that the largest part of the variation (85.4%) was due to the animal differences as would be expected. The values of 4.6% and 1.3% for bottle and sub-bottle, respectively, indicate that the sampling and emulsifying procedures maintained the representative nature of the separable lean. The 8.7% associated with determination was larger than was expected and that has been reported. Munson *et al*. (1966) reported values of 2.7 and 2.4% for determination error. These were confirmed by Mandigo *et al*. and most of the literature indicates a figure around 3%.

TABLE VI

MEAN SQUARES FROM ANALYSIS OF VARIANCE FOR COMPONENTS OF CHEMICAL DETERMINATIONS

Source	% Moisture	% Ash	% Ether Extract	% Protein	% K
Animal	106.2616	0.03199	110.7167	9.8828	0.00502
Bottle	4.4563	0.00162	3.0823	0.5420	0.00133
Sub-bottle	3.2747	0.00235	1.1681	0.4165	0.00214
Determination	1.0254	0.00069	0.8998	0.1913	0.000054

TABLE VII

PERCENT OF VARIATION IN CHEMICAL COMPONENTS ASSOCIATED WITH EACH CLASSIFICATION

Source	% Moisture	% Ash	% Ether Extract	% Protein	% K
Animal	77.6%	63%	85.4%	69.9%	16.9%
Bottle	2.7	0	4.6	2.8	0
Sub-bottle	10.3	21	1.3	10.1	49.8
Determination	9.4	16	8.7	17.2	33.0

In this study the large determination error appeared to be due to careless technician work. No re-runs were used in the analysis of this data and this showed up in the large value for determination error. In many reports which indicate a 3% determination error, if duplicate determination disagrees by more than some laboratory upper limit, usually one to two percent, a third determination, or as many as necessary, is obtained until two agree within the acceptable range. This method forces an error of less than 3% and does not allow the evaluation of the technique and technician being employed. The data in this study suggested that in studies involving chemical determinations a method of sampling such as was used would produce precise estimates. This method would also allow the analysis of the amount of variation associated with different steps of the process.

Potassium

From the analysis of the potassium data it is apparent that in this trial a large majority of the variation in percent potassium was introduced in the laboratory. The potassium determinations were run by an experienced technician in the soils lab. The 33% determination error would, therefore, appear to have a large equipment-technique error associated with it. The 20 missing observations may indicate difficulties which contributed to this error.

Since only 16.9% of the variation in percent potassium was associated with animal, statements made relative to the amount of potassium in a particular animal or the association between potassium and count could be very misleading. This figure was in agreement with reports that suggested the constancy of potassium in muscle. Since percent potassium is per unit of lean weight, it would appear that in this sample of cattle the amount of potassium per unit of fat-free lean was relatively constant. One of the widely used methods of discussing the validity of K^{40} has been to compare potassium as determined by K^{40} to potassium as determined by flame photometry (Kirton and Pearson, 1963; Lohman, 1966) or some other method of determination. These reports should include an analysis of the sources of variation in the chemical technique.

Kirton _et al_. (1963) suggested that percent potassium was not precise enough for accurate distinction between the composition of individual animals. This data suggests that the atomic absorption spectrophotometer technique for determining percent potassium might not be precise enough for estimating percent potassium if there is a relatively constant amount of potassium per unit of lean weight.

Moisture, Ash, Protein

From Table VII it was observed that the three bottles appeared to be an adequate representative sample of the separable lean. The emulsification process, however, appeared to be somewhat inefficient for these three components. Determination errors once again were relatively large, indicating the small variations being examined and the inefficiency of current procedures to detect these small variations.

Count Data

Repeatability

The intraclass correlation coefficients between count 1 and count 2 for each counting period are presented in Table VIII. Since the number of observations in each group was small (7 or 8), care was taken in interpreting individual group differences. From these data, however, several trends appeared to develop.

The first trend observed from this data was that this ^{40}K counter repeated itself to about the same extent on the different weight groups in this study. Although the figures for Group I, the heaviest group, were consistently lower, the difference was not significant and was due largely to one animal which ranked low on one count and high on the second count for each count period. This observation was in contrast to the results reported by Lohman *et al*. (1966) on the repeatability of adjusted counts. These workers found a decrease in repeatability as the size of the animal decreased. The calibration of the counts in this study, however, could give an advantage to the heavier animals.

A second observed trend was noted from one counting period to the next. The amount of fill remaining after 24

TABLE VIII

INTRACLASS CORRELATION COEFFICIENTS BETWEEN COUNT 1 AND 2 ON EACH DAY FOR EACH GROUP AND POOLED-WITHIN GROUP

	SATURDAY (24 hr. shrink)	MONDAY (72 hr. shrink)	CARCASS
GROUP I	0.87	0.79	0.63
GROUP II	0.96	0.98	0.96
GROUP III	0.92	0.94	0.84
GROUP IV	0.92	0.95	0.94
POOLED	0.91	0.92	0.88

hours of shrinkage appeared to stay as constant from count 1 to count 2 as the fill remaining after 72 hours without feed and water, since the repeatability for Saturday counts was essentially the same as the repeatability for Monday counts. This trend was observed in both individual group estimates as well as the pooled-within group estimates.

The values for the carcass counts were generally in line with the live counts except for Group I where, again, the disagreement between the two counts of only one carcass was largely responsible for this low figure. Since the carcass potassium content was expected to vary less between duplicate counts than the potassium content of the live animal, it was surprising that repeatability of carcass counts on a pooled basis was lower than the pooled repeatability estimates of live counts. This difference, however, was not significant. From this limited study, this K^{40} counter appeared to repeat itself at a level high enough to justify further investigation.

Correlation

The association between K^{40} counts per minute and fat-free lean for the Saturday, Monday, and carcass counts is shown in Tables IXa, IXb, and IXc, respectively. These correlation coefficients are based on the assumption that there is a linear response between K^{40} count and fat-free lean.

Although Groups I and II were washed with water only,

TABLE IXa

CORRELATION BETWEEN THE TWO SATURDAY COUNTS, THE AVERAGE OF THE TWO COUNTS AND POUNDS OF FAT-FREE LEAN

	COUNT 1	COUNT 2	AVG./ 2 COUNTS
GROUP I	0.70	0.69	0.72
GROUP II	0.94	0.95	0.95
GROUP III	0.65	0.36	0.53
GROUP IV	0.94	0.88	0.92
POOLED	0.82	0.74	0.80

TABLE IXb

CORRELATION BETWEEN THE TWO MONDAY COUNTS, THE AVERAGE OF THE TWO COUNTS AND POUNDS OF FAT-FREE LEAN

	COUNT 1	COUNT 2	AVG./ 2 COUNTS
GROUP I	0.66	0.74	0.74
GROUP II	0.89	0.92	0.91
GROUP III	0.49	0.63	0.57
GROUP IV	0.92	0.87	0.90
POOLED	0.75	0.80	0.79

TABLE IXc

CORRELATION BETWEEN THE TWO CARCASS COUNTS, THE AVERAGE OF THE TWO COUNTS AND POUNDS OF FAT-FREE LEAN

	COUNT 1	COUNT 2	AVG./ 2 COUNTS
GROUP I	0.37	0.77	0.60
GROUP II	0.97	0.95	0.97
GROUP III	0.71	0.69	0.73
GROUP IV	0.83	0.86	0.86
POOLED	0.77	0.81	0.82

and Groups III and IV were washed with soap and water, the association between K^{40} count and fat-free lean did not appear to be affected. The pooled coefficient for Groups I and II was 0.85 while the pooled coefficient for Groups III and IV was 0.77 for the average counts on Saturday. Since sex is confounded in these same groups, it appeared that the association between K^{40} count and lean was the same in heifers as it was in steers. The scatter diagram in Figure 5 presents further evidence that sex did not have a significant effect on this correlation. This figure illustrates the distribution of the 31 animals on a deviation from the mean basis. It was observed that the sexes were evenly distributed throughout the diagram indicating a similar association in both steers and heifers.

No obvious trend developed in which the association between count and fat-free lean increased or decreased as live weight changed. Although the lighter group had higher coefficients than the heavier group, it must be kept in mind that only seven and eight animals were used in these two groups so that one extreme animal in either group could have been responsible for this discrepancy.

An examination of the Saturday and Monday counts suggested that there was no detectable difference in the K^{40} count - fat-free lean association from the 24-hour shrinkage period to the 72-hour period. The individual group estimates indicated the same degree of association within each group and the pooled estimates were surprisingly

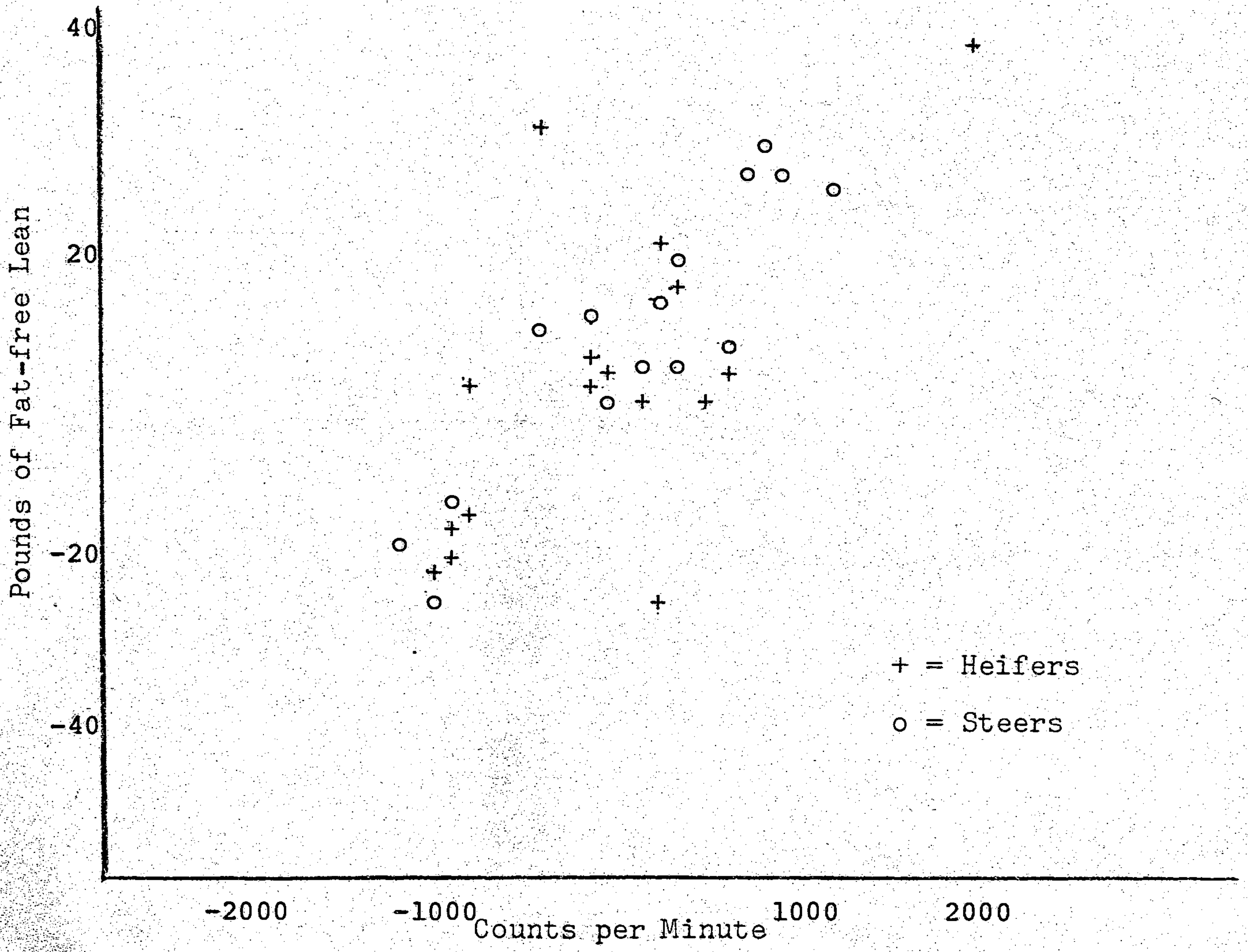

Figure 5. The distribution of sexes for Saturday counts on deviation from mean basis.

similar. It had been expected that the association after 72 hours of shrinkage would be higher than after 24 hours since there would be less non-lean potassium, but this was not borne out in the data.

It was further expected that the association would be even higher between carcass K^{40} count and fat-free lean than for the live counts. Table IXc, however, points out that this was not the case. As in the case of both the 24 and 72-hour counts, the pooled correlation coefficients for each carcass count were 0.80. There was, therefore, no advantage for more than a 24-hour shrinkage period in this data.

The pooled estimates of correlation for each count also pointed out that one count was as good as another for ranking this group of cattle. A correlation coefficient of 0.96 between the average of the Saturday counts and the average of the Monday counts further illustrated that the animals were ranked by K^{40} count nearly the same on Monday as on Saturday.

The association between a variable and the average of two estimates is expected to be larger than the association between the variable and one estimate if errors associated with the two estimates are independent. Since the pooled correlation for the average of the two counts for each counting period was no higher than the pooled value of the individual counts, it would appear that there may have been an extraneous bias that prevented the two counts from being completely independent.

To further study K^{40} count as a predictor of lean, the association between K^{40} count and fat-free lean expressed as a percent of live weight was examined. These correlation coefficients are presented in Table X. The pooled coefficients for this association seem to center around 0.70, about 0.10 lower on the average than the K^{40} count - pounds of fat-free lean association. This was considered logical since using a percentage basis reduced the effective variation and thereby reduced the probability of obtaining a large correlation.

The estimates of the association between K^{40} count and live weight are given in Table XI. It was interesting to note that the additional 48 hours of shrinkage did not influence this association. The pooled correlations of around 0.33 indicated that although there was an association between count and weight it was not of large magnitude.

As these correlation studies were conducted, an interesting trend was observed. In all associations considered thus far, Groups I and III had lower coefficients of correlation while Groups II and IV had higher coefficients (Tables IX and XI). This trend was obvious in the association between count and pounds of fat-free lean, was rather obscure in the count-percent association, and was strikingly evident in the correlation between count and live weight. It should be noted that these are on group estimates based on small numbers, but this trend suggested that

TABLE X

CORRELATION BETWEEN TWO COUNTS ON SATURDAY AND MONDAY, THE AVERAGE OF THE TWO COUNTS FOR EACH DAY, AND PERCENT FAT-FREE LEAN OF LIVE WEIGHT

SATURDAY

	COUNT 1	COUNT 2	AVG./ 2 COUNTS
GROUP I	0.82	0.68	0.78
GROUP II	0.75	0.89	0.82
GROUP III	0.72	0.43	0.60
GROUP IV	0.63	0.75	0.71
POOLED	0.71	0.69	0.73

MONDAY

	COUNT 1	COUNT 2	AVG./ 2 COUNTS
GROUP I	0.68	0.73	0.74
GROUP II	0.73	0.79	0.76
GROUP III	0.55	0.73	0.65
GROUP IV	0.78	0.66	0.72
POOLED	0.68	0.72	0.71

TABLE XI

CORRELATION BETWEEN TWO COUNTS ON SATURDAY AND MONDAY AND LIVE WEIGHT TAKEN IMMEDIATELY PRIOR TO EACH COUNT

	Saturday		Monday	
	Count 1	Count 2	Count 1	Count 2
GROUP I	-0.18	-0.02	-0.05	-0.02
GROUP II	0.60	0.66	0.79	0.69
GROUP III	0.08	-0.03	0.09	0.06
GROUP IV	0.73	0.49	0.45	0.51
POOLED	0.35	0.33	0.29	0.32

further study of this phenomenon might lend itself to a better understanding of this evaluation method.

The only occasion in this analysis whereby this I-III: II-IV pattern did not hold was in the correlation between weight and fat-free lean. The coefficients of this association are shown in Table XII. From this data there appeared to be a higher association in the lighter animals. These differences are not large, however, and the low correlations for Group I were largely due to the heaviest animal in this Group which also had the lowest pounds of fat-free-lean in Group I.

Of particular interest was the low (0.46) correlation between carcass weight and fat-free lean. This was in contrast to the correlation of 0.90 between carcass weight and weight of boneless roast and steak meat reported by Fitzhugh <u>et</u> <u>al</u>. (1965). It should be remembered that there is a correlation between carcass weight and fat also and therefore, a measure of association between carcass weight and boneless meat is actually multiple correlation between carcass weight, fat, and fat-free lean.

The correlation coefficients for count to pounds of fat-free lean tissue are in general agreement with the coefficients reported for lambs of 0.73 by Judge <u>et</u> <u>al</u>. (1963), and lower than those of 0.96 for separable lean of hams reported by Kulwich <u>et</u> <u>al</u>. (1961a), and for fat-free lean of beef rounds of 0.98 by Kulwich <u>et</u> <u>al</u>. (1961b). In both of these studies by Kulwich <u>et</u> <u>al</u>. (1961a&b), longer

TABLE XII

CORRELATION BETWEEN WEIGHTS TAKEN PRIOR TO LIVE AND CARCASS COUNTS AND POUNDS OF FAT-FREE LEAN

	WT 11	WT 12	WT 21	WT 22	CARCASS WT
GROUP I	0.48	0.48	0.54	0.53	0.61
GROUP II	0.59	0.57	0.51	0.45	0.40
GROUP III	0.61	0.64	0.63	0.64	0.28
GROUP IV	0.69	0.69	0.61	0.61	0.61
POOLED	0.56	0.55	0.52	0.51	0.46

counting periods and adjustment of the count for several variables could have accounted for the higher coefficients. Another factor was the small numbers used in each study. The most detailed study with beef cattle in the literature (Lohman _et al_., 1966) also indicated a real association between K^{40} counts per minute and fat-free lean tissue, although no correlation coefficients were presented.

The analysis of the count data seems to indicate that there is a real association between K^{40} count and pounds of fat-free lean. The magnitude of this association has not been determined, but the data from these 31 Angus cattle pointed toward 0.80 as the coefficient of the association. This data also illustrated a real association between live and carcass weight and fat-free lean. The magnitude of this association appeared to be approximately 0.55.

Prediction Equations

Since the purpose of this study was to evaluate the K^{40} counter as a predictor of lean, the count and weight data were used in the prediction equation $Y_{FFL} = B_{(0)} + B_i(x)$. Each of the variables were considered alone and then they were both used in a prediction equation together to arrive at the standard error of estimate associated with each equation.

The standard error of estimate is the standard deviation of the dependent variable when the independent variable is held constant. In this data the standard error is the standard (or average) deviation in fat-free lean, holding weight constant, or for a fixed count when each of these is used separately in the equation.

The value of a new tool rests in its ability to improve the accuracy with which we make predictions. In other words, how far will the predicted value "miss" the actual value. In this population of cattle the value for the mean and standard deviation for fat-free lean was 228 ± 18 pounds. Therefore, a prediction based on the mean alone would miss the true value by 18 pounds on the average. Tables XIII and XIV present the standard errors for the three prediction equations examined in this study.

When used alone in the prediction equation, weight consistently reduced the standard error of estimate by three pounds. This demonstrated that the knowledge of the animal's live weight in addition to the mean lean weight resulted in an average miss in the vicinity of 15 pounds. This value was in line with the correlations between weight and fat-free lean (Table XI) which, although they were significant, were not sufficiently large enough to effectively reduce the standard error of estimate to any great extent.

From Table XIII it could be observed that when K^{40} count was used in a prediction equation, the standard error of estimate was reduced six to eight pounds. This indicated that there was a higher linear association between count and fat-free lean than between weight and fat-

TABLE XIII

STANDARD ERROR OF ESTIMATE IN POUNDS DERIVED FROM USING WEIGHT AND COUNT ALONE IN THE PREDICTION EQUATION $Y_{FFL} = B_0 + B(x)$

PERIOD	X = WEIGHT	X = COUNT
DAY 1 COUNT 1	14.8[a]	10.1
DAY 1 COUNT 2	14.9	12.0
DAY 1 AVG. COUNT		10.7
DAY 2 COUNT 2	15.3[a]	11.8
DAY 2 COUNT 2	15.4	10.7
DAY 2 AVG. COUNT		10.8
CAR. COUNT 1	15.1[b]	11.4
CAR. COUNT 2		10.4
AVG. CAR COUNT		10.1

[a] Live weights taken immediately prior to corresponding live count

[b] Cold carcass weight

TABLE XIV

VALUES FOR POOLED MULTIPLE CORRELATIONS BETWEEN FAT-FREE LEAN, COUNT AND WEIGHT, AND THE STANDARD ERRORS OF ESTIMATE ASSOCIATED WITH PREDICTION EQUATIONS USING BOTH COUNT AND WEIGHT

Day	Count	Multiple R	SEE (lb.)
Sat.	1	0.870	8.79
Sat.	2	0.808	10.50
Mon.	1	0.814	10.40
Mon.	2	0.840	9.60

free lean. The correlations in Tables IX and XI illustrate this difference. It should be observed at this point that without an extremely high correlation between two variables, only a small improvement in prediction accuracy will be obtained. It is, therefore, essential that as the expense of the measurement increases, the association between the measurement and the variable being measured must increase sufficiently, so that the cost of the measurement will be offset by the increased accuracy of the predicted value.

In an equation involving both count and weight, the standard error of estimate was reduced nine to ten pounds. These values are shown in Table XIV along with the multiple correlation between fat-free lean, count, and weight. By knowing both the weight and the K^{40} count of a group of cattle similar to those used in this study, the predicted fat-free lean value would "miss" on the average 8 to 9.5 pounds. The multiple correlation values again demonstrate the necessity of a high correlation in order to predict with any degree of accuracy.

Lohman et al. (1966) reported the only standard errors based on the prediction equations for this type of data. The standard deviation of the carcass lean muscle mass reported in this study was 22.4 pounds. In contrast to the three pound reduction reported in this study, these workers reported a 6.8 pound reduction in the error of estimate when weight was used alone. When K^{40} count was used alone the SEE was reduced to 9.7 pounds, slightly lower than the figures reported here. Carcass weight and K^{40} count used together reduced the error of estimate to six pounds in the Illinois study compared to the error of estimate of eight pounds found in the present study for predictions based on live weight and K^{40} count.

The difference in the observed values appeared to be due to the calibration techniques used by these workers. This calibration would tend to adjust the count in direct relation to fat-free lean since the counter was calibrated on the basis of the animal's weight. Since the relationships between count, weight, and fat-free lean are all positive, adjustments made between any two would have affected the relationship between the adjusted variable and the third associated variable.

Sources of Variation

Six sources of variation were examined using a multiple linear regression model to analyze the amount of variation in count associated with each one. This procedure fits a six dimensional surface to the data to allow the examination of the effect of each of these variables singularly and in combination on the variation in K^{40} count. Variation in count from animal to animal may be caused by many things. These six variables were associated with a certain proportion of this variation with remaining variation due to sources unaccounted for by this model.

The comparisons made in the discussion were, therefore, the contribution of each of these variables to the reduction in sum of squares associated with all six variables. The value for F obtained for each source adjusted for the other five sources is exhibited in Table XV. The values in Table XVI show the percentage of the variation which was accounted for that was associated with each source adjusted and three unadjusted. The adjusted values were the values obtained when the source was last in the equation and the unadjusted values were obtained when weight, fat-free lean, and GI tract weight were each used first in the equation. Since this type of comparison had not been reported in the literature, interpretation of these results was made with careful qualification.

Weight

The significant F values for live weight on Saturday indicated that when these six variables are used in a prediction equation, weight is associated with a significant amount of the total reduction in sum of squares. As was expected, the amount of reduction in sum of squares associated with weight would not be as large after 72 hours of shrinkage. This analysis was the only time a difference between shrinking periods was observed in the association between count and weight. These results suggested that live weight after 24 hours of shrinkage was an important variable in the regression equation but could have been omitted in the equations for the Monday counts. The F

TABLE XV

VALUES OF F FOR SOURCES OF VARIATION ADJUSTED FOR ALL OTHER SOURCES FOR EACH COUNT

Source	Saturday (a) Count 1	Count 2	Monday (a) Count 1	Count 2	Carcass (b) Count 1	Count 2
Weight	5.67*	7.55*	0.07	0.09	0.89	0.22
Fat-Free Lean	24.6**	21.0**	22.0**	31.2**	42.1**	48.9**
GI Tract Wt	2.88	2.78	0.89	0.67	0.37	0.63
Hide Weight	0.1	0.08	0.18	0.0	0.0	0.33
Hide Thickness	0.0	0.08	0.78	0.10	1.90	1.88
Avg. Distance	1.36	5.52*	0.55	0.06	0.04	0.20

(a) weight = live weight prior to each count

(b) weight = cold carcass weight used for both counts

* ($P \leqslant .025$)

** ($P \leqslant .001$)

TABLE XVI

PERCENT REDUCTION IN SUM OF SQUARES FOR ALL SOURCES ADJUSTED AND THREE UNADJUSTED

Source	Saturday (a)		Monday (a)		Carcass (b)	
	Count 1	Count 2	Count 1	Count 2	Count 1	Count 2
Weight[1]	25.7%	5.1%	52.6%	56.2%	33.4%	40.5%
Weight[2]	9.9	14.4	0.10	0.10	1.10	0.20
FFL[1]	81.0	48.2	95.4	98.0	95.0	96.0
FFL[2]	43.0	40.2	32.2	33.9	51.8	42.2
GI Tract[1]	31.0	20.0	38.5	35.0	18.9	19.5
GI Tract[2]	5.0	5.3	1.3	0.7	0.5	0.5
Hide Weight	0.2	0.2	0.3	0.0	0.0	0.3
Hide Thickness	0.0	0.2	1.1	0.1	2.3	1.6
Avg. Distance	2.4	10.6	0.8	0.0	0.0	0.1

(a) Live weights taken before each live count

(b) Cold carcass weight used for both counts

(1) Variable unadjusted

(2) Variable adjusted for all other variables

values for carcass weight were also non-significant, which indicated that when animals were alike in fat-free lean, carcass weight did not add to the reduction in count which could be accounted for by these six variables.

Fat-Free-Lean

Since the K^{40} technique was developed as a tool for predicting fat-free lean, it was not surprising that the F values were highly significant for all counts. This significance indicated that there was a real association between count and fat-free lean. The pooled correlations, all around 0.80, and all of which were significant, substantiated this conclusion.

The percentages in Table XV illustrated that fat-free lean was associated with a larger portion of the variation accounted for by these variables than any of the other five. The larger percentages for the unadjusted variable indicated that, of the variation accounted for by these six variables, 48 to 98% of this reduction was attributed to fat-free lean when the other sources varied as they did in this experiment. However, when the other five variables were at their average value, the portion of the accounted for variation attributable to fat-free lean was 32 to 51%.

These results suggested that in animals similar in weight, size, and fill, a smaller quantity of the variation accounted for could be credited to fat-free lean. This further indicated that small differences in fat-free lean would probably not be predicted as reliably in more uniform cattle. On the otherhand, in a population with variation in weight, fill, and size similar to the variation in this study, fat-free lean accounted for 95 to 98 percent of the reduction in count variation attributed to these six sources for the Monday and carcass counts. After 72 hours of shrinkage, therefore, the reduction in the total count sum of squares due to all six variables would not be significantly greater than the reduction due to fat-free lean alone. This suggested that 72-hour count and carcass count should have been more reliable as predictors of lean. The pooled estimates of correlation, which were very similar for the three periods, did not agree with this conclusion. The larger superiority of the 72-hour and carcass count over the 24-hour count in reduction accounted for, but the failure of a difference in predictability indicated that some extraneous sources of variation were present but were not accounted for by this model.

The only reports of similar values were 60 percent by Breidenstein (1964) and 77 percent by Lohman _et al_. (1966). Cattle in both of these studies had been fed an oat ration for seven days prior to counting. These values were in closer agreement with the association exhibited in this study after 24 hours of shrinkage. These workers attributed the total count variation to live and carcass components.

Gastro-Intestinal Tract

The F values for GI tract weight approached significance for the Saturday counts. The percent reduction for the GI tract weight adjusted was only five percent. The validity of these values is questionable as the GI tract weight was measured after 72 hours of shrinkage, thereby neglecting to consider fill differences after 24 hours. Since GI tract weight did seem to have a small effect on the Saturday count, it was expected that GI tract weight after 24 hours would have accounted for a larger portion of the total reduction in sum of squares. Had this weight been taken after 24 hours, the results for Saturday may have been closer to the 10.0 and 16.4 percent reported for cattle fed a low radiation diet for seven days as reported by Breidenstein (1964) and Lohman and Norton (1968), respectively.

Hide Weight, Hide Thickness, Average Distance

All F values and percent reductions for these variables were non-significant except for count 2 on Saturday and this was attributed to chance. In order for the K^{40} method to be reliable the variation associated with these variables was expected to be negligible. Since the adjusted values were so low, the unadjusted values were not calculated. It would appear, therefore, that in this group of calves these sources of variation could have been omitted from the equation and the same amount of reduction in sum of squares obtained from weight, fat-free lean, and GI tract weight.

SUMMARY

The purpose of this study was to evaluate the Permian Potassium-40 (K^{40}) counter as a predictor of lean in beef cattle. The K^{40} counter is based on the principle that there is a constant proportion of potassium in the muscle of an animal and that this potassium gives off a constant percentage of K^{40} gamma rays. If these gamma rays could be counted, then it should be possible to estimate the amount of lean in the sample being counted.

Sixteen Angus heifers and fifteen Angus steers were counted in the potassium-40 (K^{40}) whole body counter at the OSU Live Animal Evaluation Center during the spring of 1968. The 31 head were divided into four groups and each group was counted after shrinking periods of 24 and 72 hours. The animals were slaughtered and the carcasses were counted after chilling about 40 hours. The right side was separated into lean, fat and bone; and chemical determinations were made to obtain an estimate of the amount of fat-free lean (FFL).

The separable lean from the right side was sampled so that it could be analyzed using a hierarchal (nested) design. This analysis indicated that 85.4% of the variation in ether extract was associated with animal and, therefore, that the sampling procedure used was an adequate means of obtaining an estimate of fat-free lean. Further analysis of moisture, ash, protein, and potassium components suggested that the samples obtained in this manner were sufficiently representative of the total bulk. However, the data indicated that more efficient procedures are necessary to detect small variations in ash and percent potassium.

The count data was first analyzed to see how the two independent counts on the same animal on the same day agreed. The intraclass correlation between counts one and two, after 24 and 72 hours of shrinkage and after slaughter, suggested that there was essentially no difference in the extent to which the two counts agreed. The pooled within group coefficients of this correlation (repeatability) were 0.91, 0.92, and 0.88 for the 24-hour counts, 72-hour counts, and carcass counts, respectively.

Each live and carcass count and the average of the two counts for each counting period was examined to observe the relationship between count and pounds of FFL. Significant positive relationships were observed between all live and carcass counts and pounds of fat-free lean. The 72-hour counts were not, however, more closely associated with fat-free lean than the 24-hour counts. Similarly the carcass counts were not more closely associated with fat-free lean than the live counts as had been expected. The pooled correlations for both live count periods and the carcass counts were all in the vicinity of 0.80.

Other relationships were studied between count and various animal traits. The pooled correlations between live count and percent fat-free lean of live weight were approximately 0.70 on the average. Relationships between live count and live weight indicated a small positive correlation existed and that in a small group there could be either a negligible or a large association. Live and carcass weights, when correlated with fat-free lean, resulted in pooled coefficients ranging from 0.46 to 0.56 which indicated that weight could be used to aid in predicting fat-free lean.

Simple and multiple linear regression models were used to determine the standard error of estimates associated with prediction equations using weight alone, count alone, and weight and count together. When live or carcass weight was used alone in the equation $Y = B_o + B_1 (x)$, the standard error of estimate was reduced on the average three pounds to a value of 15.0 pounds. When count was used in this equation, the standard error associated with the predicted Y value ranged between 10.1 and 12.0 pounds, a reduction of 6 to 8 pounds. When weight and count were used together in a prediction equation, the standard error of estimate was from 8.8 to 10.5 pounds. These values showed that count and weight used together resulted in a more accurate prediction than either used alone.

The count data was further examined to study the amount of variation in count associated with six animal measurements. This analysis indicated that in a group of animals with variation in weight, fat-free lean, gastrointestinal tract weight, hide weight, hide thickness, and average distance from the detectors similar to the variation in the animals used in this study, fat-free lean would account for 95 to 98% of the variation in count associated with these six variables after 72 hours of shrinkage. When the other five variables were adjusted to their average value, fat-free-lean was associated with only 32 to 53 percent of the variation accounted for. It was suggested that this might have indicated that, in a group of animals widely variable, more of the variation in count can be attributable to fat-free lean and, therefore, the counter would detect differences in fat-free lean more precisely than in a group of animals very similar in size and shape.

From the analysis of this data it appeared as if the ^{40}K counter was of some benefit in detecting the meatier animal. Certain trends which developed suggested that some extraneous sources of variation might have been influencing the effectiveness of the counter and that the control of these factors might have improved the ability of this counter to predict fat-free lean.

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