NET ENERGY OF MILO AND CORN FOR CATTLE AS DETERMINED BY THE COMPARATIVE SLAUGHTER TECHNIQUE

By

CURTIS W. ABSHER

Bachelor of Science

Virginia Polytechnic Institute

1962

Submitted to the faculty of the Graduate School of the
Oklahoma State University of Agriculture and
Applied Science in partial fulfillment
of the requirements for the degree of
MASTER OF SCIENCE
May, 1965

NET ENERGY OF MILO AND CORN FOR CATTLE

AS DETERMINED BY THE COMPARATIVE

SLAUGHTER TECHNIQUE

Thesis Approved:

Thesis Adviser

Dean of the Graduate School

ACKNOWLEDGMENTS

The author expresses his appreciation to Dr. Robert Totusek, Professor of Animal Science, for his counsel and guidance during the course of this study and in the preparation of this thesis.

Appreciation is also extended to Professors A. D. Tillman, and J. V. Whiteman of the Animal Science Department, for their assistance with the plan of operational procedure for this trial and with interpreting and reporting the results.

The author is grateful for the privilege of association with and assistance by fellow colleagues in the Graduate School of Oklahoma State University.

Grateful acknowledgment is also extended to the students who cared for the experimental animals and assisted with collection of data.

Special recognition is extended to the wife of the author, Barbara, for her understanding and assistance during the course of this study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURE

INTRODUCTION

A basic consideration of nutritionists is that of evaluating feeds for productive purposes. Any means of evaluation should be indicative of the absolute response that might be expected from a feed and a reflection of its relative feeding value. Net energy is theoretically the best measure of feeding value since deducted from the gross chemical energy of a feed are all of the major losses, namely: fecal loss, urinary loss, combustible gases and heat production.

Corn is generally considered to be superior to milo in feedlot rations because less corn than milo is required to produce a unit of gain. Since the main use of grain in fattening rations is to supply energy, it seems appropriate to compare these grains on their efficiency of furnishing energy to steers.

Even though net energy is theoretically superior to other measures of feeding value, it has been used little because it is (1) relatively difficult to determine, and (2) there is considerable variation in reported values. Both of these difficulties could be results of the fact that the relationship between intake and energy retention has not been firmly established. The ultimate usefulness of net energy values is dependent upon this relationship. The purposes of this investigation are to estimate the net energy of milo and corn and to compare the grains on an energy basis. It is hoped that this investigation will yield information pertinent to the relationship between net energy values and successive feed increments above maintenance.

LITERATURE REVIEW

Words and symbols are necessary and important tools of any scientific discipline. Harris (1963) has proposed a list of symbols and abbreviations to be used by animal nutritionists in reporting experimental results. Some of the proposed abbreviations will be used throughout this paper. Those used are: NE_m, net energy for maintenance; NE_{m+p}, net energy for maintenance plus production; and NE_p, net energy for production above maintenance. The units of energy used will be kilocalorie, kcal. (1 kcal.=1000 calories), or megacalorie, megcal. (1 megcal.=1000 kcal.=1 therm).

Historical Aspects

The concept of using net energy values in practical production situations is not new even though it has been relatively obscure in this country. Early in this century Armsby (1914) and Kellner (1915) published text books of animal nutrition with the feeding standards being based on the principle of net energy. Kellner (1915) felt that net energy values were too complicated for the average farmer and, therefore, gave feeds values according to their producing ability as compared to one pound of starch. The Scandinavian feed unit system used in Europe is similar to Kellner's starch equivalent system with the exception that barley is the reference standard rather than starch (Morrison, 1959; Maynard and Loosli, 1962).

Armsby and Fries (1916) presented tables of net energy values based on digestible energy and energy expenditure values obtained from other workers as well as their own obtained experimentally at the Pennsylvania Station. Morrison (1959) and Maynard and Loosli (1962) discuss a net energy system for feeding dairy cattle proposed by Møllgaard. Both Armsby and Møllgaard used Kellner's starch equivalent values to derive net energy values that they had not obtained experimentally.

Net Energy - Intake Relationships

The relationship between net energy and level of intake has not been definitely established. Armsby (1914) and Kellner (1915) assumed net energy to be constant over the whole range of feed intake. Armsby and Fries (1916) stated, "Tables show primarily the net energy values for maintenance or fattening. There seems good reason for believing, however, that they may be taken without serious error to represent also the net energy values for growth...." However, Armsby (1914) suspected that feed is used more efficiently for sparing tissue (maintenance) than for fattening. Forbes *et al.* (1926) observed that the net energy for production was approximately 20 percent less than the net energy of a feed for maintenance. Forbes *et al.* (1928), Forbes *et al.* (1930), and Mitchell *et al.* (1932) used respiratory chambers to further establish this relationship.

Blaxter (1956) reviewed much of the literature pertaining to net energy values and is apparently of the opinion that the relationship between intake and energy retention is curvilinear. Kleiber (1961), on the other hand, states that the "law of diminishing returns does not properly fit the conditions of animal feeding..." and that "there is neither sufficient empirical evidence for the theory that partial efficiency decreases with increasing food intake, nor is the theoretical strength of this argument impressive."

Lofgreen and Otagaki (1960) studied the NE_p of various increments of molasses. Molasses, when fed as 10 percent of the ration, had a higher NE_p than molasses at levels of 25 or 40 percent of the ration. Companion digestion trials failed to show that the loss in energy was due to fecal loss, thus implicating other losses, such as heat increment. If the heat increment truly was greater when molasses was fed at the higher levels the relationship between energy retention and intake could well be curvilinear.

Marston (1948), Lofgreen et al. (1963), and Garrett et al. (1964) have published experimental evidence that the NE_p values of successive feed increments above maintenance are, for practical purposes, equal. Marston (1948) used a respiration apparatus to measure the various energy losses while Lofgreen et al. (1963) and Garrett et al. (1964) used the actual energy stored as a measure of the NE_p of feeds.

Armstrong (1960) used sheep in estimating the feeding value of a grass cut at different stages of maturity. He concluded that metabolizable energy was constant regardless of intake and that the availability of the metabolizable energy was linearly related to intake.

Forbes et al. (1928) and Forbes et al. (1930) reported that the heat production from a ration fed at levels from fasting to three times the maintenance requirement was a gentle, reversed "S" curve. The curve was prominent from fasting to maintenance and slight from maintenance to full feed. The heat increment per unit of feed was therefore relatively more constant when maintenance was used as a base line rather than when fasting was used. It was recommended that the maintenance base line be used for more meaningful results in such experiments. Kriss (1943) reviewed the work of Forbes et al. (1928), Forbes et al. (1930), and other workers in this field and concluded that the gentle curve above maintenance could practically be taken as a straight line. Therefore, if the heat production was linearly related to intake, energy retention and intake would be similarly related.

Methods of Determination

According to the "Law of Hess" only the initial and final chemical states of matter need to be known in order to determine energy exchanges, since the intermediate steps are of no consequence in the final balance of energy (Maynard and Loosli, 1962). This principle underlies the use of respiration chambers for indirect determination of net energy values. Of the workers previously mentioned, Mitchell et al. (1932), Marston (1948), and Armstrong (1960) used this method. Kleiber (1961) explained the calculations used in this procedure.

Armsby and Fries (1916), Forbes et al. (1928), and Forbes et al. (1930) had the unique opportunity to use a respiration calorimeter to directly measure heat losses and derive net energy values. The respiration calorimeter operates in the same manner as a bomb calorimeter and was described by Braman (1933).

The technique that is receiving the most attention currently is the direct net energy determination technique used and improved at the California Station (Garrett et al., 1959; Garrett et al., 1964; Lofgreen et al., 1962; and Lofgreen et al., 1963). This technique involves estimating the initial composition of a group of animals, observing the final composition after a period on feed, and calculating the energy stored per unit of feed. Rathbun and Pace (1945) used specific gravity to estimate the fat content of eviserated carcasses and whole bodies of guinea pigs. They concluded that the fat content of the carcass was equivalent to the total body fat, and specific gravity was an adequate measure of body composition. DaCosta and Clayton (1950) experimentally justified the use of this technique. Kraybill _et al._ (1952) extended the use of specific gravity for estimating body composition to cattle and Reid _et al._ (1955) made certain modifications. Since the contents of the digestive tract of ruminants can cause considerable variation in live weight, Lofgreen _et al._ (1962b) developed a method for reducing this source of error. Equations were also developed to estimate empty body weights from hot carcass weights.

Lofgreen and Otagaki (1960) explained in detail the use of the above procedures in determining net energy values of feeds. This technique can be used for determining the NE_{m+p} of a feed by use of a reference standard (Lofgreen _et al._, 1962a) or the NE_p by the increment method (Lofgreen _et al._, 1963; Garrett _et al._, 1964).

Net Energy of Milo

Garrett _et al._ (1964) specifically compared the NE_{m+p} and the NE_p of milo to the NE_{m+p} and NE_p of barley. He concluded that there was no difference in the two grains when used as a source of energy in balanced rations. The mean net energy values obtained for milo were 179.9 and 116.8 kcal. per kg. air dry feed for NE_{m+p} and NE_p, respectively. It was pointed out that for producing live weight gain milo is generally considered to be less efficient than barley. Hale _et al._ (1962) summarized a series of trials at the Arizona Station in which 8.7 percent less barley than milo was required to produce a unit of gain.

EXPERIMENTAL PROCEDURE

Forty-six Hereford steers, which were 14 to 18 months old, were obtained from the Oklahoma Agricultural Experiment Station beef herd. The steers were of similar breeding and since weaning had been fed rations consisting primarily of hay and pasture. They were placed in drylot and fed a balanced ration containing 30% milo and 60% cottonseed hulls for about 70 days prior to the beginning of the feeding test.

One week before the beginning of the trial, all steers were weighed and given a condition score to indicate the apparent relative fat covering. In an effort to obtain a representative slaughter group, each steer was represented on a scatter diagram with respect to his weight and condition score. The diagram was segmented by diagonal lines and nine steers for the slaughter group were selected. The steers were randomly selected within blocks with the number selected being proportional to the number in the block. These steers were used to estimate the composition of the steers remaining on feed.

All cattle were shrunk for 24 hours before the initial weights were taken. The nine steers in the slaughter group were then killed and the carcass data were collected. The empty body weights of the steers were determined by subtracting the weight of the contents of the rumen and reticulum from the shrunk live weight. The specific gravity of the total carcass was determined after a 24-hour chill by weighing each quarter in air and in water. The weights in air were read to the nearest 0.5 lb. on a platform scale while those in water were read to the nearest gram on a gram balance. The water tank used to obtain the in-water weights was placed in the cooler with the carcasses and filled with water at least 24 hours before the specific gravities were taken so that the carcasses and water would have the same temperature.

The specific gravity of the empty body was estimated by the equation $Y = 0.9955X - 0.0013$ where X was the specific gravity of the carcass and Y, the specific gravity of the empty body (Kraybill _et al._, 1952). By use of another formula derived by Kraybill _et al._ (1952) the percent body water was determined. The formula is: % body water =

$$100\left[4.008 - \frac{3.620}{\text{Body Specific Gravity}}\right].$$

The formulas of Reid _et al._ (1955) were used for estimating percent body fat and percent protein of the dry matter and the total empty body. These formulas are as follows:

$$\%\ \text{body fat} = 337.88 + 0.2406X - 188.91 \text{ Log } X$$

$$P = 80.93 - 0.00101Z$$

$$\%\ \text{fat free dry matter} = 100 - [\%\ \text{moisture} + \%\ \text{fat}]$$

$$P_1 = P[\%\ \text{fat free dry matter}]$$

where X is the percent body water, Z is the age in days of the animals, P is the percent protein in fat free dry matter, and P_1 is the percent protein in the whole body.

The caloric content of the empty body was estimated by multiplying the kg. of fat by 9367 kcal. per kg. (Blaxter and Rook, 1953) and adding it to the product of the kg. of protein multiplied by 5686 kcal. per gm. as used by Lofgreen and Otagaki (1960). From this information the kcal. per kg. of empty body weight was determined on each of the steers slaughtered initially.

A correlation of 0.73 ($P < .05$) was calculated between condition score and kcal. per kg. of empty body weight by the method of Steel and Torrie (1960), and a regression equation was derived to estimate the caloric content of the steers on test. The equation was $\hat{Y} = 1382 + 138.9X$ (standard error of $\hat{Y} = \pm 184$ kcal.) with the independent variable (X) being initial condition score and the dependent variable (Y) considered as the kcal. per kg. of empty body weight. From the regression equation, the kcal. per kg. of empty body weight with respect to condition score were as follows: score 4, 1938 kcal./kg.; score 5, 2077 kcal./kg.; score 6, 2216 kcal./kg.; score 7, 2354 kcal./kg.; and score 8, 2493 kcal./kg. The empty body weights of the steers on test were estimated by the equation $\hat{Y}' = 53.1 + .835\ X'$ (standard error of $\hat{Y}' = \pm 10.5$ lb.) with $\hat{Y}'$ and X' being estimated empty body weight and live shrunk weight, respectively. The initial caloric content of each animal on test was taken as the product of empty body weight and kcal. per kg. of empty body weight.

The experimental design is shown in Table I. Steers were fed at three different planes of nutrition, namely, maintenance, intermediate, and high level. Steers on the basal maintenance treatment were initially fed at a rate described by the equation: lb. of daily feed = $.0662W^{0.75}$. This formula was developed from the equation of Garrett _et al._ (1959) for TDN required for maintenance (TDN required = $0.036W^{0.75}$) and the calculated TDN value of the basal ration (54.4%). All other treatments were fed 0.0331 lb. basal per lb. $W^{0.75}$, with either corn or milo added to obtain the desired plane of nutrition. The composition of the basal ration is given in Table II while proximate analyses of corn, milo, and the basal ration are listed in Table III. Because of the expected superiority of corn over milo for producing gain, corn was fed at a rate of only 90% that

TABLE I

EXPERIMENTAL DESIGN

Treatment	No. Animals	Feeding Regime
Basal Maintenance	7	Basal, fed to maintain body wt.
Milo Maintenance	5	Basal, $\frac{1}{2}$ amount of basal maintenance plus corn to maintain body wt.
Corn Maintenance	5	Basal, $\frac{1}{2}$ amount of basal maintenance plus corn to maintain body wt.
Milo Intermediate	5	Basal, $\frac{1}{2}$ amount of basal maintenance plus milo to equal $\frac{1}{2}$ gain of high milo
Corn Intermediate	5	Basal, $\frac{1}{2}$ amount of basal maintenance plus corn to equal $\frac{1}{2}$ gain of high milo
Milo High	5	Basal, $\frac{1}{2}$ amount of basal maintenance plus milo, maximum intake
Corn High	5	Basal, $\frac{1}{2}$ amount of basal maintenance plus corn to equal gain of high milo

TABLE II

COMPOSITION OF BASAL RATION

Ingredient	%
Dehydrated alfalfa pellets (17% protein)	35.0
Cottonseed hulls	23.0
Cottonseed meal (41% solvent)	40.0
Salt	1.0
Dicalcium phosphate (28% Ca, 18% P)	1.0
Added per ton	
Santoquin	114 gm.
Vit. A. supplement (30,000 I. U./gm.)	200 gm.

TABLE III

PROXIMATE ANALYSES OF FEEDS

	Dry Matter %	Ash %	Crude Protein %	Fat %	Fiber %	N.F.E. %
Basal	90.82	8.1	20.3	2.0	24.3	36.1
Corn	88.27	1.3	9.3	4.3	2.1	71.3
Milo	87.87	1.5	8.9	3.0	0.7	73.8

of milo. During the course of the experiment it was necessary to increase the level of basal in order to maintain body weight of the basal maintenance group. At the same time the amount of corn fed in relation to the amount of milo was reduced to 85% in an attempt to equalize gain between the corn and milo groups.

All steers were weighed bi-weekly and the feed was adjusted in accordance with the body weight. The cattle were not shrunk for the interim weights. However, the waterers were covered for seven hours before weighing in order to prevent a last minute fill on water.

The steers were fed individually twice daily in stalls measuring 3.0 m. X 0.75 m. The basal ration and the finely ground grain (ground thru 1/8 in. screen) were weighed to the nearest one eighth of a pound at each feeding and fed together. The steers were allowed from one to two hours in which to eat their ration; no water was available while in the stalls. They were then turned together in a paved lot and had free access to water. Feed refusals were removed from the feed trough and added to the next feeding. The amount of feed at the next feeding was adjusted accordingly in order to prevent a buildup of spoiled feed. After the first month on feed a third feeding was started for those steers that habitually left feed. They were returned to the feeders at noon and given an hour in which to eat feed that had been left from the morning feeding.

An outbreak of a respiratory infection reduced feed intake and slowed gains considerably during the trial. In an attempt to remedy this situation 16 grams of cottonseed meal containing approximately 75 mg. chlortetracycline were added to each steer's ration for the last 40 days.

At the end of the trial all steers were slaughtered. Time and facilities made it necessary to kill on six different days during a two-week period. The slaughter groups were balanced so that the average time on feed was 122 days for each treatment. The caloric content of the animals was estimated in the same manner as previously described for the initial slaughter group. The initial estimated caloric content of each animal was subtracted from the final total caloric content in order to determine the energy gained.

In determining the net energy of the basal, the net energy required for maintenance was assumed to be 35 kcal. per lb. of metabolic size, $W^{0.75}$ (Garrett *et al.*, 1959). The sum of kcal. gained per day per $W^{0.75}$ plus the 35 kcal. for maintenance was divided by the feed consumed per day per $W^{0.75}$ and, thus, the net energy of the basal was determined.

The NE_{m+p} values at various levels of grain intake were determined for both milo and corn. Energy and feed data from each steer were put on a daily basis and divided by his mean metabolic size in order to equalize steers with respect to time on feed and weight. The daily energy supplied by grain was calculated by adding 35 kcal. for maintenance (Garrett *et al.*, 1959) to the amount of energy gained and correcting for basal consumed. NE_{m+p} was calculated for each steer by dividing the amount of grain fed into the energy transformed. Treatment differences with respect to NE_{m+p} values were statistically analyzed by the method of Steel and Torrie (1960) for disproportionate sub-class numbers.

NE_p is the relationship of an increment of feed above maintenance and the energy it produces $\left(\frac{\Delta \text{ stored energy}}{\Delta \text{ feed}}\right)$. NE_p values were calculated for the increments of grain between maintenance and intermediate, maintenance and high, and intermediate and high levels of intake. To obtain NE_p values for the increments of grain fed above maintenance, the average daily energy gain and average daily grain intake per unit of metabolic size for the maintenance group were subtracted from the respective values of each steer on the high and intermediate levels. Energy gain above maintenance was divided by grain fed above maintenance to derive a NE_p value on each steer. NE_p values for the increments of grain above intermediate level were calculated in the same manner.

The NE_p values obtained by comparing both high and intermediate levels to maintenance were statistically analyzed by a "t" test for unpaired observations with equal variation assumed (Steel and Torrie, 1960). The NE_p values for the increment of grain from intermediate to high were obtained from data on the same steers upon which NE_p values for the increment between high and maintenance were calculated, i.e., the same data were used, but corrected for different levels, maintenance and intermediate. This was considered the basis for pairing NE_p values of the increments between high and maintenance and high and intermediate. The difference between pairs was analyzed by a "t" test based upon paired observations and equal variances (Steel and Torrie, 1960).

RESULTS AND DISCUSSION

The data obtained from the initial slaughter group are listed in Table IV. It can be seen that there was a wide range in the slaughter group, particularly with respect to condition score, percent fat, and energy content. Condition score was correlated with specific gravity, percent fat, and kcal. per kg. empty body weight. The simple correlations obtained by the method of Steel and Torrie (1960) are listed in Table V. The negative correlation is as expected since a steer with a high condition score should be fatter and, thus have a lower specific gravity. These correlations indicate that visual appraisal can be used to account for a sizeable portion of variation in body composition providing there is considerable variation in the cattle.

TABLE IV

INITIAL SLAUGHTER GROUP DATA

Item of Interest	Mean	Range
Shrunk wt.	333 kg.	284 kg.--378 kg.
Condition score	5.6	4--8
Empty body wt.	302.2 kg.	264.2 kg.--378.8 kg.
Empty body wt. as % of live wt.	90.8%	88.2%--93.2%
Specific gravity (empty body)	1.0701	1.0589--1.0897
Moisture, %	62.5	58.9--68.6
Fat, %	13.8	7.5--17.7
Protein, %	19.09	18.83--19.24
Kcal./kg. empty body wt.	2,154	1,671--2,446

TABLE V

CORRELATIONS ON SLAUGHTER GROUP DATA

Variables	r_{xy}
Condition score and specific gravity	-.75*
Condition score and % carcass fat	0.77*
Condition score and kcal./kg. empty body wt.	0.73*

*($P<.05$)

The net energy values for both NE_{m+p} and NE_p obtained in this investigation are listed in Table VI. The mean NE_m and NE_p values for milo are 169.1 $\pm$ 10.5 and 132.5 $\pm$ 14.6 kcal. per kg., respectively. Garrett et al. (1964) estimated the NE_m of air dry milo to be 179.6 $\pm$ 7.0 kcal. per kg. and NE_p to be 116.6 $\pm$8.0 kcal. per kg. The standard errors accompanying the means indicate that both sets of values are possibly estimates of the same true mean NE_{m+p} and NE_p values.

The NE_{m+p} values were statistically analyzed by the 3 X 2 factorial method with adjustments for disproportionate sub-class numbers (Steel and Torrie, 1960). Unequal numbers were caused by the death of a steer on high milo and the failure of another steer on the same treatment to eat the high level of milo. His data were considered with the milo intermediate group since his grain consumption was similar to that level. The completed analysis of variance table (Appendix, Table IX) illustrates that level of intake was a significant ($P<.05$) source of variation in NE_{m+p} values. This is in accordance with the report by Forbes et al. (1926) that NE_p was 20% less than NE_m of a feed. Therefore, NE_{m+p} values obtained at levels of intake slightly above maintenance would be expected to have values similar to NE_m, while lower NE_{m+p} values approaching the value of NE_p would be expected at high intake levels.

TABLE VI

MEAN NET ENERGY VALUES OF MILO AND CORN DETERMINED AT THREE LEVELS OF INTAKE (Expressed as megcal. per 100 kg. of feed)

Feed	Level	NE_{m+p}	NE_p Maintenance	NE_p Intermediate
	Maintenance	169.1 ± 10.5[a]	------	-------
Milo	Intermediate	144.8 ± 9.6	111.2 ± 20.6	-------
	High	148.4 ± 13.5	130.9 ± 29.2	158.4 ± 29.2
	Mean	154.6 ± 6.3	132.5 ± 14.6	
	Maintenance	170.7 ± 10.5	-------	--------
Corn	Intermediate	147.7 ± 10.5	121.0 ± 22.6	--------
	High	137.8 ± 10.5	118.1 ± 22.6	119.4 ± 22.6
	Mean	152.1 ± 6.1	119.5 ± 13.0	
Basal Maintenance		113.9 ± 3.5	------	-------

[a] Standard Error

Net energy can be thought of as the slope of a regression line between energy retained and the feed responsible for the energy, since net energy is an amount of energy gain per unit of feed. The failure of grain-level interaction to be significant indicates that the slopes of two such regression lines for milo and corn could be equal. Furthermore, the failure of grain to be a significant source of variation is evidence that one regression line could properly describe the relationship between energy retention and level of intake for both grains. Therefore, Figure 1 shows the regression of energy retained upon level of grain intake for both milo and corn. The major axes represent the total grain fed (X) and the energy furnished by that grain (Y). Since the basal was fed at a level to supply half of the energy requirement for maintenance, the base line (X-axis) is mid-way between fasting and maintenance. The imaginary axes, indicated by dotted lines, illustrate the relationship between a

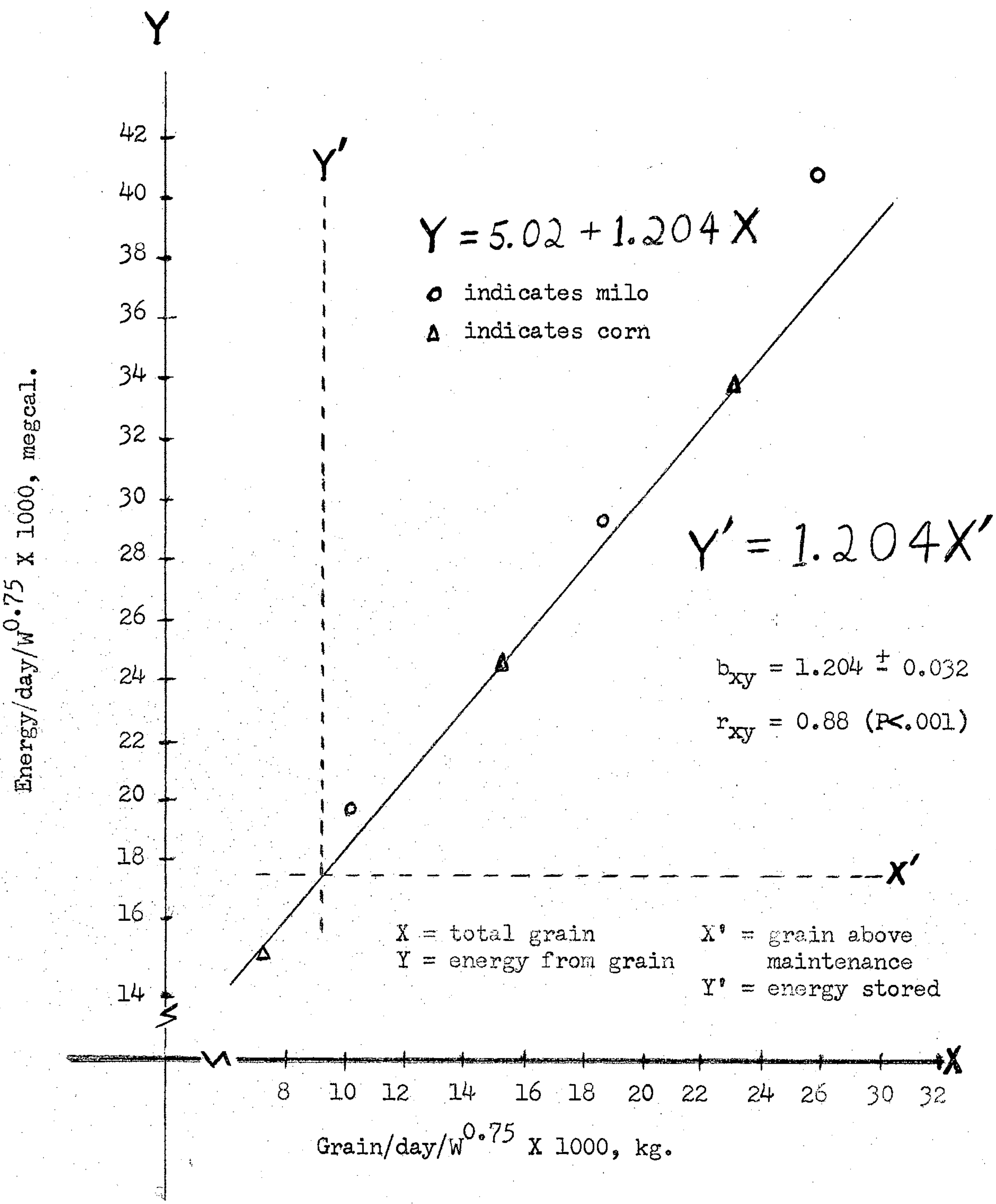

Figure 1. Feed intake and energy retention relationship

unit of feed above maintenance (X') and the amount of energy stored in the body (Y'). Theoretically, the regression line should pass through the origin of the X'-Y' axes. Thus the formula $Y' = 1.204X'$ describes the relationship between energy gain and feed intake above maintenance. The slope, 1.204 ± 0.032, necessarily is similar to the mean NE_p values obtained by the increment method, and means that for every kg. of grain fed above maintenance, 1.204 megcal. of energy was stored in the body.

Units of feed and energy are on the basis of amount per day per unit of metabolic size. This is necessary in order to put maintenance requirements for all sizes of cattle on an equivalent basis. Garrett _et al_. (1959) established the requirement for maintenance for cattle at 35 kcal. per lb. of metabolic size where metabolic size is taken as $(\text{weight in lbs.})^{0.75}$.

The line in Figure 1 is representative of the relationship between energy retention and intake above maintenance only since no points below maintenance were observed. The correlation between energy retained and grain fed was calculated to be 0.88($P<.001$) and indicates a high degree of association between the two factors. Furthermore, the slope of the regression line, $b=1.204 \pm 0.032$, is significantly ($P<.001$) greater than zero (Steel and Torrie, 1960).

NE_p values for the increments of feed above maintenance were compared by "t" tests. No significant differences were found between the NE_p values of the various increments. Therefore, there is no reason to believe that NE_p values of successive units of feed above maintenance are not equal within the range of this experiment.

The biggest problem encountered in this trial was the poor performance of the high level milo steers (note Table VII). High level corn steers were fed to equal gain of milo steers so the range of feed intake was kept narrow for both grains. Intake was improved slightly by the addition of a mid-day feeding.

There are several possible reasons for the low intake. Church and Ralston (1963) reported that individual feeding lowered performance of steers while Garrett et al. (1964) cites work exhibiting no difference in performance between individually-fed and group-fed steers. Possibly, individual feeding was responsible for low feed intake, but apparently the high level corn steers would have consumed more feed if it had been offered.

Another factor that could have lowered intake was the degree of fineness of the ration. Milo and corn were ground through a 1/8 inch screen. Totusek et al. (1964) noted only a slight decrease ($<5\%$) in feed intake when a ration containing finely ground milo was compared to one containing coarsely ground milo in the feedlot. Steers in the present trial did not have access to water during the feeding periods. The combination of these two factors might explain the low feed intake.

The environmental temperature during most of the feeding trial was uncomfortably hot and a reduction in intake was noted by steers fed ad libitum on another trial conducted concurrently at the same location. However, the ad libitum fed steers were consuming considerably more feed than the individually fed steers of this trial when the hot weather began.

An unidentified respiratory infection plagued the feedlot for a short period. Watery eyes and noses were observed along with chronic inappetence among all treatment groups.

Regardless of the cause, the range of feed intake was not large enough to permit the relationship between energy retention and feed intake to be properly studied. Furthermore, only two levels of feed above maintenance were fed. To properly test the relationship between intake and energy retention more levels of intake are needed.

The question of the relationship between energy and level of intake above maintenance is probably an academic question. Recent work indicates that, for practical purposes, this relationship can be taken as rectilinear (Lofgreen et al., 1963; Garrett et al., 1964). In order to statistically detect a curvilinear relationship (if there truly is one) it is probable that one or both of the following conditions would be required: (1) extremely wide ranges of performance, or (2) large numbers of animals. The California workers (Lofgreen et al., 1963; Garrett et al., 1964) obtained average daily gains similar to gains obtained in commercial feedlots. In one trial (Garrett et al., 1964) twelve animals per treatment were used. It seems that a range wider than these workers obtained (0.15 kg. to 1.15 kg. per day) would be difficult to produce.

The most practical approach to establishing a pattern of NE_p values appears to make use of large numbers of small animals (sheep or laboratory animals) and modifications of the comparative slaughter technique described in this paper. This would permit actual measurement of the caloric content of the tissue stored and should improve percision of the estimates of net energy values.

From the data presented in this investigation one must conclude that milo is equally as efficient as corn at supplying energy to steers when compared at low intake levels. Milo is generally considered to be, without exception, less efficient than corn at producing live weight gain on cattle. Data in Table VII indicate that this was also the situation in this trial when corn and milo were compared at the high level of intake. However, at the intermediate level more gain per kg. of feed was obtained on the milo ration than on the corn ration. Steers were fed for equal gain so corn was fed at the rate of approximately 88% of the rate of milo feeding. While this feeding regime allowed corn steers to outgain milo steers at the high level, the reverse was true at the maintenance and intermediate levels indicating that the efficiency of milo relative to corn is greater at maintenance than at high levels of production. Table VII summarizes the feedlot and carcass phases of this experiment. All maintenance groups lost weight on a live weight basis, but all gained weight when empty body weights were the means of comparison. Empty body weight gain appears to give a more accurate measure of the response to the treatments than live weight gains since it more closely follows the pattern of energy gain. Otherwise, a simultaneous loss in weight and gain in energy would be difficult to explain. The use of empty body weight gain could be adopted to feedlot ration comparisons for the purpose of reducing the variation among animals due to fill.

Table VII illustrates that the steers fed milo were fatter at the end of the trial than corn-fed steers. At the end of the trial the steers fed the high level of milo had 19.13% body fat while the high level corn-fed steers had only 15.34% fat. The intermediate groups had a similar relationship, but the difference was smaller. These data indicated that percent protein was essentially the same for corn and milo steers at the same level.

TABLE VII

MEAN FEEDLOT RESPONSE AND CARCASS COMPOSITION OF HEREFORD STEERS FED MILO AND CORN AT THREE LEVELS

Level:	Maintenance			Intermediate		High	
Item of Interest / Feed:	Basal	Milo	Corn	Milo	Corn	Milo	Corn
No. animals completing test	7	5	5	6	5	3	5
Condition score	5.3	5.0	6.2	5.3	5.8	5.0	5.6
Initial shrunk wt., kg.	334	336	317	336	332	342	337
Final shrunk wt., kg.	331	335	312	369	356	392	394
Daily wt. gain, gm.	-28	-10	-44	265	207	401	468
Initial empty body wt., kg.	306	304	289	305	301	311	305
Empty body wt., kg.	306	314	294	349	329	372	376
Empty body wt. gain/day, gm.	2	83	45	356	234	505	572
Initial kcal./ kg. empty body wt.	2117	2080	2253	2126	2190	2085	2158
Final kcal./kg. empty body wt.	2176	2191	2142	2459	2412	2875	2527
Daily energy gain, kcal.	184	459	-164	1,702	1,118	3,473	2,384
Daily feed intake, kg.	4.48	3.95	3.41	5.26	4.71	6.46	5.98
Basal	4.48	2.25	2.18	2.32	2.30	2.40	2.36
Test feed	---	1.70	1.23	2.94	2.41	4.06	3.62
Gain/kg. feed, gm.	--	--	--	50.4	43.9	62.1	78.2
Kcal/kg. feed	--	--	--	324	237	538	399
Final body composition							
Moisture, %	64.6	64.4	65.0	61.6	62.1	57.7	61.0
Body fat, %	11.5	11.7	11.1	14.7	14.0	19.1	15.3
Body protein, %	19.2	19.2	19.2	19.0	19.0	18.6	18.6

The above results indicate that there may have been a difference in the composition of the gain. Table VIII contains the composition of the gain produced by the two grains. At the intermediate level, composition of gain was essentially the same for both grains; while, at the high level the gain of the milo steers had more fat, but less moisture and protein. Similarly, the milo steers had significantly ($P<.10$) more energy per unit of live gain than the corn steers on the high level (8.46 vs. 5.31). These data present a sound explanation of why milo is less efficient than corn at producing gain, but has a similar net energy value.

TABLE VIII

COMPOSITION OF GAIN

Level:	Intermediate		High	
Component — Grain:	Milo	Corn	Milo	Corn
Energy, megcal./kg.	6.64±2.1[a]	6.58±2.6	8.46[d]±2.6	5.31±1.4
Water, %	52.3±19.2	54.5±23.5	28.2±17.6	53.9[c]±9.7
kg.	23.0	17.7	16.7	38.4
Fat, %	25.3±21.4	31.6±26.1	52.2[c]±19.9	23.2±10.9
kg.	10.9	4.0	32.8	16.3
Protein, %	17.8±1.3	17.8±1.6	15.6±2.0	18.2[b]±1.1
kg.	7.8	5.3	9.3	12.9
Ash, %	4.7±0.9	4.0±1.1	4.3±0.5	4.7±0.3
kg.	2.1	1.3	2.4	3.3
Total, %	100.0	100.0	100.0	100.0
kg.	43.8	28.3	61.2	70.9
Energy grain, megcal.	209.3	134.8	421.4	291.8

a (Standard Error) c ($P<.02$)
b ($P<.01$) d ($P<.10$)

The procedure used in this experiment is dependent upon obtaining an empty body weight and the specific gravity of the carcass of each steer. If cattle are slaughtered in commercial plants the carcasses can generally be used for specific gravity determination, but the amount of fill is difficult to obtain. Therefore, an accurate method of estimating empty body weights is needed. Lofgreen et al. (1962b) developed an equation to estimate the empty body weight when only the hot carcass weight is known. A similar equation was developed from the slaughter data obtained at the end of the trial. The regression equation calculated by using measured empty body weights and hot carcass weight was $\hat{Y} = 86.0 + 1.38X$ (standard error of $\hat{Y} = \pm 7.0$), where $\hat{Y}$ is the estimated empty body weight and X, the hot carcass weight. The correlation between the hot carcass weight and empty body weight was 0.96. The equation is similar to the one, $\hat{Y} = 70 + 1.45X$, which was developed by Lofgreen et al. (1962) on 104 steers of widely varying weights and amounts of fat. The similarities in the slopes of the two regression lines indicate that the amount of change in empty body weight per unit of carcass weight was essentially the same at both stations. The difference in the Y-intercepts (86 vs. 70) could be due to the difference in length of time that the cattle were shrunk before slaughter. The cattle in this trial were shrunk for 24 hours while those at the California Station were shrunk for only 12 hours. Therefore, it appears that empty body weights of cattle can be accurately estimated if hot carcass weights are known, providing that the shrinking time is kept constant.

SUMMARY

Net energy of milo and corn was determined at three levels of intake by the comparative slaughter technique. Values for the net energy of the grains for both maintenance plus production and production alone were determined. The initial body composition of the test steers was estimated by data collected from a representative slaughter group killed at the start of the feeding trial. Final body composition was determined by measuring specific gravities of the carcasses and using appropriate formulas to estimate the percentages of fat and protein in the animals.

The net energy for maintenance, NE_m, of milo and corn was 169 ± 11 and 171 ± 11 kcal. per 100 kg. of air dry grain, respectively, while mean net energy values for production, NE_p, were 133 ± 15 kcal. per 100 kg. milo and 120 ± 13 kcal. per 100 kg. corn

The gain from the high level of milo was found to contain more fat, less water and protein, and more energy per kg. than the gain from the high level of corn. The higher energy content per kg. gain was considered to be an explanation for milo being equal to corn on a net energy basis but inferior at producing live gain.

Even though grain did not significantly affect NE_{m+p} values, level of intake was a significant ($P < .05$) source of variation when NE_{m+p} values were compared over the range of feed intake for this trial. However, NE_p values for the various increments of grain above maintenance did not differ ($P > .05$) indicating that the relation-

ship between energy retention and level of intake above maintenance can be considered linear for practical purposes.

The use of empty body weights in cattle feeding experiments is discussed. An equation, $\hat{Y}=86.0 + 1.38X$ (standard error of $\hat{Y}=7.0$ lb.) was calculated from slaughter data on 33 steers to estimate body weight, Y, when only the hot carcass weight, X, is known.

LITERATURE CITED

Armsby, Henry P. 1914. The Principles of Animal Nutrition (3rd ed.). John Wiley and Sons, Inc., New York.

Armsby, Henry P. and J. August Fries. 1916. Net energy values for ruminants. Penn. Agr. Exp. Sta. Bul. 142.

Armstrong, D. G. 1960. Calorimetric determination of the net energy value of dried S.23 Ryegrass at four stages of growth. 8th International Grassland Congress Proceedings. p.485.

Blaxter, K. L. 1956. The nutritive value of feeds as sources of energy: A review. J. Dairy Sci. 39:1396.

Blaxter, K. L. and J. A. F. Rook. 1953. The heat of combustion of the tissues of cattle in relation to their chemical composition. British J. Nutr. 7:83.

Braman, Winfred W. 1933. The respiration calorimeter. Pa. Agri. Exp. Sta. Bul. 302.

Church, D. C. and A. T. Ralston. 1963. Comparison of performance of steer calves when fed *ad libitum* vs. twice daily in individual stalls. J. Animal Sci. 22:708.

Da Costa, Ester and Ruth Clayton. 1950. Studies of dietary restriction and rehabilitation. II. Interrelationships among the fat, water content and specific gravity of the total carcass of the albino rat. J. Nutr. 41:597.

Forbes, E. B., W. W. Braman, Max Kriss, C. D. Jefferies, R. W. Swift, R. B. French, R. C. Miller and C. V. Smythe. 1928. The energy metabolism of cattle in relation to the plane of nutrition. J. Agr. Res. 37:253.

Forbes, E. B., W. W. Braman, Max Kriss, R. W. Swift, R. B. French, C. V. Smythe, P. S. Williams and H. H. Williams. 1930. Further studies of the energy metabolism of cattle in relation to the plane of nutrition. J. Agr. Res. 40:37.

Forbes, E. B., J. August Fries, Winfred W. Braman and Max Kriss. 1926. The relative utilization of feed energy for maintenance, body increase, and milk production of cattle. J. Agr. Res. 33:483.

Garrett, W. N., J. H. Meyer and G. P. Lofgreen. 1959. The comparative energy requirements of sheep and cattle for maintenance and gain. J. Animal Aci. 18:528.

Garrett, W. N., G. P. Lofgreen and J. H. Meyer. 1964. A net energy comparison of barley and milo for fattening cattle. J. Animal Sci. 23:470.

Hale, W. H., F. Hubbert, Jr., M. Cadena and B. Taylor. 1962. Milo-barley studies with fattening steers. J. Animal Sci. 21:998. (Abstr.).

Harris, Lorin E. 1963. Symposium on feeds and meats terminology. III. A system for naming and describing feeds, energy terminology and the use of such information in calculation diets. J. Animal Sci. 22:535.

Kellner, O. 1915. The Scientific Feeding of Animals. Authorized translation by William Goodwin. The MacMillan Co., New York.

Kleiber, Max. 1961. The Fire of Life. John Wiley and Sons, Inc., New York.

Kraybill, H. F., H. L. Bitter and O. G. Hankins. 1952. Body composition of cattle. II. Determination of fat and water content from measurement of body specific gravity. J. Appl. Physiol. 4:575.

Kriss, Max. 1943. Evaluation of feeds on the basis of net available nutrients. J. Animal Sci. 2:63.

Lofgreen, G. P., D. L. Bath and H. T. Strong. 1963. Net energy of successive increments of feed above maintenance for beef cattle. J. Animal Sci. 22:598.

Lofgreen, G. P., D. L. Bath and V. R. Young. 1962a. Determination of the net energy of dried beet pulp using barley as a reference standard. J. Animal Sci. 21:766.

Lofgreen, G. P., J. L. Hull and K. K. Otagaki. 1962b. Estimation of empty body weight of beef cattle. J. Animal Sci. 21:20.

Lofgreen, G. P. and K. K. Otagaki. 1960. The net energy of blackstrap molasses for fattening steers as determined by a comparative slaughter technique. J. Animal Sci. 19:392.

Marston, Hedley R. 1948. Energy transactions in the sheep. 1. The basal heat production and heat increment. Australian J. of Sci. Res., Series B. 1:93.

Maynard, Leonard A. and John K. Loosli. 1962. Animal Nutrition (5th ed.). McGraw-Hill Book Co., New York.

Mitchell, H. H., T. S. Hamilton, F. J. McClure, W. T. Haines, Jessie R. Beadles and H. P. Morris. 1932. The effect of the amount of feed consumed by cattle on the utilization of its energy content. J. Agr. Res. 45:163.

Morrison, Frank B. 1959. Feeds and Feeding (22nd ed.). The Morrison Publishing Co., Clinton, Iowa.

Rathbun, Edith N. and Nello Pace. 1945. Studies on body composition. I. The determination of total body fat by means of the body specific gravity. J. Biol. Chem. 158:667.

Reid, J. T., G. H. Wellington and H. O. Dunn. 1955. Some relationships among the major chemical components of the bovine body and their application to nutritional investigations. J. Dairy Sci. 38:1344.

Steel, R. G. D. and J. H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Co., New York.

Totusek, Robert, Dwight Stephens and Lowell Walters. 1964. Improving the utilization of milo for fattening calves: value of fine grinding and supplemental vitamin A. Okla. Agri. Exp. Sta. Misc. Pub. MP-74:63.

APPENDIX

Key to Tables X through XVI

a) Initial condition score: Indicates relative visible fat covering; range from 4 to 8 with 8 being fattest.

b) Shrunk weights taken after twenty-four hours without feed or water.

c) Predicted by equation: Empty body wt. = 53.1+0.835 (live wt.) X 0.4536, kg.

d) Predicted by equation: Composition = 1382+138.9 (Condition score), kcal./kg.

e) Empty body wt. (c) X composition (d), kcal.

f) Final empty body wt. =(shrunk live wt.) - (fill from rumen and reticulum)

g) Specific gravity of empty body = 0.9955(carcass sp. gr.) - 0.0013

h) Percent body water = $100 \times 4.008 - \frac{3.620}{\text{Body sp. gr.}}$

i) Percent protein = 80.93 - 0.00101 (age in days) X 100(% moisture+% fat)

j) Percent body fat = 337.88 + 0.2406(% body water) - 188.91 Log (% body water)

k) kg. protein X 5686 kcal. per kg.

l) kg. fat X 9367 kcal. per kg.

m) 35 kcal. per lb. of $(\text{mean weight})^{0.75}$ considered as maintenance

n) lb. basal per day per $W.^{0.75}$ X 516.8 kcal. per lb.

TABLE IX

ANALYSIS OF VARIANCE OF NE_{m+p} VALUES FOR CORN AND MILO
(adjusted for disproportionate sub-class numbers)

Preliminary Analysis of Variance

Source	df.	Mean Square
Total	28	------
Treatments	5	912
A, Level	2	2,189*
B, Grain	1	34.3
A X B interaction	2	74
Error	23	553

* ($P < .05$)

Completed Analysis of Variance

Source	df.	Mean Square
A, adjusted for B	2	2,058*
B, adjusted for A	1	9.1
A B, adjusted for A and B	2	115.4
Error	23	553

* ($P < .05$)

TABLE X

NEm+p CALCULATIONS FOR
BASAL MAINTENANCE GROUP

Item of Interest	Animal No. 30	20	28	34	09	03	36	Mean
Initial condition score[a]	6	6	5	6	4	6	4	5.3
Initial shrunk wt.[b], lb.	830	808	795	708	715	653	645	736
Empty body wt.[c], kg.	338.38	330.22	325.68	292.34	294.84	271.48	268.53	305.6
Kcal./kg. empty body wt.[d]	2216	2216	2077	2216	1938	2216	1938	2117
Initial energy[e], kcal.	749,850	731,768	676,437	647,825	571,400	601,600	520,411	642,756
Final shrunk wt.[b], lb.	840	772	800	705	677	672	635	728.7
Final empty body wt.[f], kg.	341.78	332.26	332.48	288.26	283.27	281.23	282.13	305.9
Carcass specific gravity	1.0860	1.0702	1.0841	1.0800	1.0927	1.0818	1.0888	1.0834
Body specific gravity[g]	1.0779	1.0641	1.0779	1.0738	1.0865	1.0756	1.0826	1.0769
Moisture[h], %	65.4	61.6	65.0	62.7	67.6	64.3	66.4	64.6
Protein[i], %	19.22	18.98	19.22	19.14	19.20	19.20	19.23	19.17
Fat[j], %	10.63	15.73	11.04	13.44	8.46	11.76	9.62	11.53
Protein, kg.	65.69	63.06	63.90	55.17	54.39	54.00	54.25	58.64
Fat, kg.	36.33	52.26	36.71	38.74	23.96	33.07	27.14	35.46
Protein energy[k], kcal.	373,513	358,559	363,335	313,697	309,262	307,044	308,466	333,410
Fat energy[l], kcal	340,303	489,519	343,863	362,878	224,433	309,767	254,220	332,140
Final energy, kcal.	713,816	848,078	707,198	676,575	533,695	616,811	562,686	665,551
Energy gain, kcal.	-36,034	116,310	30,761	38,750	-37,705	15,211	42,275	22,795
Mean weight, lb.	835	790	797.5	706.5	696.0	662.5	640.0	732.5
$(\text{Mean weight})^{0.75}$, lb.	155.3	149.0	150.1	137.0	135.5	130.6	127.2	140.7
Days on feed	125	124	127	118	120	125	127	123.7
Total basal, lb.	1,361.25	1,286.50	1,337.13	1,128.25	1,140.13	1,135.00	1,159.38	1,221.8
Basal/day/$W^{0.75}$	0.0701	0.0696	0.0701	0.0697	0.0701	0.0695	0.0717	0.0701

TABLE X (Continued)

Item of Interest	Animal No. 30	20	28	34	09	03	36	Mean
Energy/day/$W^{0.75}$, kcal.	-1.856	6.295	1.614	1.778	-2.319	0.932	2.617	1.294
Gain + maintenance, kcal.	33.144	41.295	36.614	36.778	32.681	35.932	37.617	36.294
Energy from basal, kcal.	33.144	41.295	36.614	36.778	32.681	35.932	37.617	36.294
NEm+p megcal./100 lb.	47.28	59.33	52.23	52.76	46.62	51.70	51.84	51.68
NEm+p megcal./100 kg.	104.2	130.8	115.1	116.3	102.8	114.0	114.3	113.9

TABLE XI

NE_{m+p} CALCULATIONS FOR MILO MAINTENANCE GROUP

Item of Interest	07	41	13	23	22	Mean
			Animal No.			
Initial condition score[a]	6	4	5	5	5	5
Initial shrunk wt.[b], lb.	838	765	748	665	690	741
Empty body wt.[c], kg.	341.56	309.35	307.31	276.01	285.31	303.9
Kcal./kg. empty body wt.[d]	2216	1938	2077	2077	2077	2081
Initial energy, kcal.	756,897	599,520	638,283	573,273	592,589	632,114
Final shrunk wt.[b], lb.	865	765	700	690	673	738.6
Final empty body wt.[f], kg.	370.59	323.87	306.18	286.44	283.95	314.0
Carcass specific gravity	1.0789	1.0819	1.0880	1.0737	1.0883	1.0821
Body specific gravity[g]	1.0727	1.0757	1.0818	1.0675	1.0821	1.0759
Moisture[h], %	63.4	64.3	66.2	61.7	66.3	64.4
Protein[i], %	19.17	19.20	19.23	19.07	19.22	19.18
Fat[j], %	12.70	11.76	9.82	14.52	9.73	11.71
Protein, kg.	71.04	62.18	58.88	54.62	54.57	60.26
Fat, kg.	47.06	38.09	30.07	41.59	27.63	37.89
Protein energy[k], kcal.	403,933	353,555	334,792	310,569	310,285	342,627
Fat energy[l], kcal.	440,811	356,789	281,666	389,574	258,810	345,530
Final energy, kcal.	844,744	710,344	616,458	700,143	569,095	688,157
Energy gain, kcal.	87,847	110,824	-21,825	126,870	-23,494	56,044
Mean weight, lb.	851.5	765.0	724.0	677.5	681.5	739.9
$(\text{Mean weight})^{0.75}$, lb.	157.6	145.4	139.6	132.8	133.4	141.76
Days on feed	127	117	120	120	127	122.2
Total basal, lb.	702.00	596.50	590.38	563.75	586.50	607.83
Total grain, lb.	523.38	446.38	443.25	424.00	441.50	455.7
Basal/day/$W^{0.75}$, lb.	0.0350	0.0350	0.0352	0.0353	0.0346	0.0350

TABLE XI (Continued)

Item of Interest	Animal No. 07	41	13	23	22	Mean
Energy/day/$W^{0.75}$, kcal.	4.389	6.514	-1.303	7.962	-1.387	3.235
Gain + maintenance [m],	39.389	41.514	33.697	42.962	33.613	38.235
Basal correction[n], kcal.	-18.088	-18.088	-18.191	-18.243	-17.881	-18.098
Energy from grain	21.301	23.426	15.506	24.719	15.732	20.137
Grain/day/$W^{0.75}$, lb.	0.0261	0.0262	0.0264	0.0265	0.0260	0.0262
NE_{m+p} megcal./100 lb.	81.61	89.41	58.73	93.28	60.51	76.71
NE_{m+p} megcal./100 kg.	179.9	197.1	129.5	205.6	133.4	169.1

TABLE XII

NEm+p CALCULATIONS FOR
CORN MAINTENANCE GROUP

Item of Interest	Animal No. 19	18	21	40	02	Mean
Initial condition score[a]	7	6	7	7	4	6.2
Initial shrunk wt.[b], lb.	755	753	708	680	598	699
Empty body wt.[c], kg.	310.03	309.35	292.34	281.68	250.61	288.8
Kcal./kg. empty body wt.[d]	2354	2216	2354	2354	1938	2253
Initial energy[e], kcal.	730,446	685,520	688,168	663,075	485,682	650,578
Final shrunk wt.[b], lb.	738	740	712	677	568	687.0
Final empty body wt.[f], kg.	311.39	305.27	303.45	301.64	249.94	294.3
Carcass specific gravity	1.0795	1.0826	1.0834	1.0833	1.0915	1.0840
Body specific gravity	1.0733	1.0764	1.0772	1.0771	1.0853	1.0779
Moisture[h], %	63.5	64.5	64.7	64.7	67.3	64.9
Protein[i], %	19.18	19.21	19.21	19.21	19.22	19.21
Fat[j], %	12.59	11.55	11.35	11.35	8.74	11.12
Protein, kg.	59.72	58.64	58.29	57.94	48.04	56.53
Fat, kg.	39.20	35.26	34.44	34.24	21.84	33.00
Protein energy[k], kcal.	339,568	333,427	331,437	329,447	273,155	321,407
Fat energy[l], kcal.	367,186	330,280	322,599	320,726	204,575	309,073
Final energy, kcal.	706,754	663,707	654,036	650,173	477,730	630,480
Energy gain, kcal.	-23,692	-21,813	-34,132	-12,902	-7,952	-20,098
Mean weight, lb.	746.5	746.5	710.0	678.5	583.0	692.9
(Mean weight)$^{0.75}$, lb.	142.7	142.7	137.5	133.0	118.7	134.9
Days on feed	120	118	127	127	120	122.4
Total basal, lb.	626.38	586.38	618.00	599.75	505.13	587.13
Total grain, lb.	345.50	337.75	347.25	340.25	287.00	331.55
Basal/day/$W^{0.75}$,lb.	0.0365	0.0348	0.0354	0.0354	0.0354	0.0355

TABLE XII (Continued)

Item of Interest	19	18	Animal No. 21	40	02	Mean
Energy/day/$W^{0.75}$, kcal.	-1.383	-1.295	-1.955	-0.764	-0.351	-1.150
Gain + maintenance[m], kcal.	33.617	33.705	33.045	34.236	34.649	33.85
Basal correction[n], kcal.	-18.863	-17.985	-18.295	-18.295	-18.295	-18.347
Energy from grain, kcal.	14.754	15.720	14.750	15.941	16.354	15.504
Grain/day/$W^{0.75}$, lb.	0.0201	0.0200	0.0198	0.0201	0.0201	0.0200
NEm+p megcal./100 lb.	73.40	78.60	74.49	79.31	81.36	77.43
NEm+p megcal./100 kg.	161.8	173.3	164.2	174.8	179.4	170.7

TABLE XIII

NEm+p CALCULATIONS FOR
MILO INTERMEDIATE GROUP

Item of Interest	Animal No. 08	33	29	05	26	11	Mean
Initial condition score[a]	6	6	4	5	5	6	5.33
Initial shrunk wt.[b], lb.	810	750	748	743	648	748	741
Empty body wt.[c], kg.	330.90	308.22	307.31	305.49	269.43	307.31	321.4
Kcal./kg. empty body wt.[d]	2216	2216	1938	2077	2077	2216	2123
Initial energy,[e] kcal.	733,274	683,016	595,567	634,503	559,606	680,999	647,828
Final shrunk wt.[b], lb.	870	820	835	785	718	850	813
Final empty body wt.[f], kg.	369.68	343.37	374.21	337.93	310.03	356.07	348.55
Carcass specific gravity	1.0590	1.0744	1.0806	1.0819	1.0733	1.0685	1.0729
Body specific gravity[g]	1.0529	1.0682	1.0745	1.0757	1.0672	1.0623	1.0668
Moisture[h], %	57.0	61.9	64.9	64.3	61.6	60.0	61.6
Protein[i], %	18.53	19.09	19.21	19.20	19.06	18.93	19.00
Fat[j], %	19.89	14.30	11.15	11.76	14.63	16.40	14.69
Protein, kg.	68.50	65.55	71.89	64.88	59.09	67.40	66.22
Fat, kg.	73.53	49.10	41.72	39.74	45.36	58.40	51.31
Protein energy[k], kcal.	389,491	372,717	408,767	368,908	335,986	383,236	376,518
Fat energy[l], kcal.	688,756	459,920	390,791	372,245	424,887	547,033	480,605
Final energy, kcal.	1,078,247	832,637	799,558	741,153	760,873	930,269	857,123
Energy gain, kcal.	344,973	149,621	203,991	106,650	201,267	249,270	209,295
Mean weight, lb.	840.0	785.0	791.5	764.0	683.0	799.0	777.1
(Mean weight)$^{0.75}$, lb.	156.0	148.3	149.2	145.3	133.6	150.4	147.13
Days on feed	117	120	124	127	125	125	123.0
Total basal, lb.	631.25	622.88	643.88	649.50	589.63	642.88	630.00
Total grain, lb.	801.00	756.63	834.88	847.75	789.63	752.25	797.02
Basal/day/W$^{0.75}$, lb.	0.0346	0.0349	0.0347	0.0351	0.0353	0.0333	0.0347

TABLE XIII (Continued)

Item of Interest	08	33	29	Animal No. 05	26	11	Mean
Energy/day/$W^{0.75}$, kcal.	18.901	8.407	11.026	5.780	12.052	13.259	11.571
Gain + maintenance[m], kcal.	53.901	43.407	46.026	40.780	47.052	48.259	46.571
Basal correction[n], kcal.	-17.881	-18.036	-17.933	-18.140	-18.243	-17.209	-17.907
Energy from grain, kcal.	36.020	25.371	28.093	22.640	28.809	31.050	28.664
Grain/day/$W^{0.75}$, lb.	0.0428	0.0425	0.0451	0.0459	0.0473	0.0400	0.0439
NE_{m+p} megcal./100 lb.	84.16	59.70	62.29	49.32	60.91	77.63	65.67
NE_{m+p} megcal./100 kg.	185.5	131.6	137.3	108.7	134.3	171.1	144.8

TABLE XIV

NE_{m+p} CALCULATIONS FOR
CORN INTERMEDIATE GROUP

Item of Interest	Animal No. 38	25	31	14	04	Mean
Initial condition score[a]	6	6	5	6	6	5.8
Initial shrunk wt.[b], lb.	810	745	688	688	723	731
Empty body wt.[c], kg.	330.90	306.18	284.63	284.63	298.01	300.9
Kcal./kg. empty body wt.[d]	2216	2216	2077	2216	2216	2188
Initial energy[e], kcal.	733,274	678,495	591,177	630,740	660,390	658,815
Final shrunk wt.[b], lb.	835	817	757	735	785	785.8
Final empty body wt.[f], kg.	338.38	339.06	323.64	314.34	330.22	329.1
Carcass specific gravity	1.0666	1.0743	1.0823	1.0784	1.0731	1.0749
Body specific gravity[g]	1.0605	1.0681	1.0761	1.0722	1.0670	1.0687
Moisture[h], %	59.5	61.9	64.4	63.2	61.5	62.1
Protein[i], %	18.97	19.08	19.20	19.15	19.06	19.02
Fat[j], %	16.97	14.30	11.66	12.92	14.74	14.12
Protein, kg.	64.19	64.69	62.14	60.20	62.94	62.83
Fat, kg.	57.42	48.49	37.74	40.61	48.67	46.58
Protein energy[k], kcal.	364,984	367,827	353,328	342,297	357,877	357,263
Fat energy[l], kcal.	537,853	454,206	353,511	380,394	455,892	436,371
Final energy, kcal.	902,837	822,033	706,839	722,691	813,769	793,634
Energy gain, kcal.	169,563	143,538	115,662	91,951	153,379	134,819
Mean weight, lb.	822.5	781.0	722.5	711.5	754.0	758.3
$(\text{Mean weight})^{0.75}$	153.6	147.7	139.4	137.7	143.9	144.5
Days on feed	118	120	120	127	118	120.6
Total basal, lb.	628.50	627.25	596.13	614.50	583.25	609.93
Total grain, lb.	653.25	657.00	637.25	657.38	603.50	641.68
$\text{Basal/day/W}^{0.75}$	0.0347	0.0354	0.0356	0.0351	0.0343	0.0350

TABLE XIV (Continued)

Item of Interest	38	25	Animal No. 31	14	04	Mean
Energy/day/$W^{0.75}$, kcal.	9.355	8.099	6.915	5.258	9.032	7.732
Gain + maintenance[m], kcal.	44.355	43.099	41.915	40.258	44.032	42.732
Basal correction[n], kcal.	–17.933	–18.295	–18.398	–18.140	–17.726	–18.098
Energy from grain	26.422	24.804	23.517	22.118	26.306	24.634
Grain/day/$W^{0.75}$, lb.	0.0360	0.0371	0.0380	0.0376	0.0355	0.0368
NE_{m+p} megcal./100 lb.	73.39	66.86	61.89	58.82	74.10	67.01
NE_{m+p} megcal./100 kg.	161.8	147.4	136.4	129.7	163.4	147.7

TABLE XV

NEm+p CALCULATIONS FOR
MILO HIGH LEVEL GROUP

Item of Interest	Animal No. 24	16	10	Mean
Initial condition score[a]	6	5	4	5
Initial shrunk wt.[b], lb.	855	708	708	757
Empty body wt.[c], kg.	347.91	292.34	292.34	310.86
Kcal./kg. empty body wt.[d]	2216	2077	1938	2077
Initial energy[e], kcal.	770,969	607,190	566,555	648,238
Final shrunk wt.[b], lb.	985	793	815	864
Final empty body wt.[f], kg.	427.74	334.75	353.80	372.10
Carcass specific gravity	1.0509	1.0670	1.0655	1.0611
Body specific gravity	1.0449	1.0609	1.0594	1.0550
Moisture[h], %	54.4	59.6	59.1	57.7
Protein[i], %	18.05	18.87	18.82	18.58
Fat[j], %	23.10	16.87	17.43	19.13
Protein, kg.	77.21	63.17	66.59	68.99
Fat, kg.	98.81	56.47	61.67	72.32
Protein energy[k], kcal.	439,016	359,185	378,631	392,277
Fat energy[l], kcal.	925,553	528,954	577,663	677,390
Final energy, kcal.	1,364,569	888,139	956,294	1,069,667
Energy gain, kcal.	593,600	280,949	389,739	421,429
Mean weight, lb.	920	750.5	761.5	810.7
$(\text{Mean weight})^{0.75}$ lb.	167.0	143.4	144.9	151.8
Days on feed	120	127	117	121.3
Total basal, lb.	709.50	627.13	592.50	643.04
Total grain, lb.	1,255.63	1,045.63	955.25	1,085.5
Basal/day/$W^{0.75}$, lb.	0.0353	0.0344	0.0349	0.0348

TABLE XV (Continued)

Item of Interest	Animal No. 24	16	10	Mean
Energy/day/$W^{0.75}$, kcal.	29.621	15.427	22.989	22.679
Gain + maintenance[m], kcal.	64.621	50.427	57.989	57.679
Basal correction[n], kcal.	−18.243	-17.778	-18.036	−18.019
Energy from grain, kcal.	46.378	32.649	39.953	39.660
Grain/day/$W^{0.75}$, lb.	0.0626	0.0573	0.0563	0.0587
NEm+p megcal./100 lb.	74.09	56.98	70.96	65.92
NEm+p megcal./100 kg.	163.3	125.6	156.4	148.4

TABLE XVI

NEm+p CALCULATIONS FOR
CORN HIGH LEVEL GROUP

Item of Interest	Animal No. 70	27	3B	06	12	Mean
Initial condition score[a]	5	6	6	6	5	5.6
Initial shrunk wt.[b], lb.	878	755	705	698	673	742
Empty body wt.[c], kg.	356.52	310.03	291.21	288.49	278.96	305.1
Kcal./kg. empty body wt.[d]	2077	2216	2216	2216	2077	2160
Initial energy, kcal.[e]	740,492	687,026	645,321	639,294	579,400	658,306
Final shrunk wt.[b], lb.	973	885	875	837	770	868
Final empty body wt.[f], kg.	415.94	390.32	374.67	365.60	333.39	376.0
Carcass specific gravity	1.0663	1.0676	1.0735	1.0686	1.0809	1.0713
Body specific gravity[g]	1.0602	1.0615	1.0673	1.0625	1.0747	1.0652
Moisture[h], %	59.4	59.8	61.6	60.1	64.0	61.0
Protein[i], %	18.86	18.90	19.06	18.94	19.19	18.99
Fat[j], %	17.08	16.63	14.63	16.29	12.07	15.34
Protein, kg.	78.45	73.77	71.41	69.24	63.98	71.37
Fat, kg.	71.04	64.91	54.81	59.56	40.24	58.11
Protein energy[k], kcal.	446,067	419,456	406,037	393,699	363,790	405,810
Fat energy[l], kcal.	665,432	608,012	513,405	557,899	376,928	544,335
Final energy, kcal.	1,111,499	1,027,468	919,442	951,598	740,718	950,145
Energy gain, kcal.	371,007	340,442	274,121	312,304	161,318	291,838
Mean weight, lb.	925.5	820.0	790.0	767.5	721.5	804.9
$(\text{Mean weight})^{0.75}$	167.8	153.2	149.0	145.8	139.2	151.0
Days on feed	124	120	117	124	127	122.4
Total basal, lb.	719.75	629.88	604.50	621.88	611.00	637.4
Total grain, lb.	1,047.13	966.88	918.00	953.00	997.50	976.5
Basal/day/$W^{0.75}$, lb.	0.0345	0.0342	0.0346	0.0344	0.0345	0.0344

TABLE XVI (Continued)

Item of Interest	70	27	3B	06	12	Mean
			Animal No.			
Energy/day/$W^{0.75}$, kcal.	17.831	18.518	15.724	17.274	9.125	15.694
Gain + maintenance[m], kcal.	52.831	53.518	50.724	52.274	44.125	50.694
Basal correction[n], kcal.	-17.830	-17.675	-17.881	-17.778	-17.830	-17.798
Energy from grain	35.001	35.843	32.843	34.496	26.295	32.896
Grain/day/$W^{0.75}$, lb.	0.0502	0.0526	0.0526	0.0527	0.0563	0.0528
NEm+p megcal./100 lb.	69.72	68.14	62.44	65.46	46.71	62.49
NEm+p megcal./100 kg.	153.7	150.2	137.7	144.3	103.0	137.8

TABLE XVII

NE_p CALCULATIONS FOR MILO
BY INCREMENT METHOD
(All figures per unit $W^{0.75}$)

Animal	Maintenance Milo/day	kcal./day
07	0.0261	21.301
41	0.0262	23.426
13	0.0264	15.506
23	0.0265	24.719
22	0.0265	15.732
Mean	0.0262	20.137

	Intermediate		Increments Between Maintenance and Intermediate			
			ΔMilo	ΔEnergy	NE_p kcal./lb.	NE_p kcal./kg.
08	0.0428	36.020	0.0166	15.883	956.8	2,109
33	0.0425	25.371	0.0163	5.234	321.1	708
29	0.0451	28.093	0.0189	7.956	421.0	928
05	0.0459	22.640	0.0197	2.503	127.1	280
26	0.0473	28.809	0.0211	8.672	411.0	906
11	0.0400	31.050	0.0138	10.913	790.8	1,743
Mean	0.0439	28.663			504.6	1,112

	High		Increments Between Maintenance and High				Increments Between Intermediate and High			
			ΔMilo	ΔEnergy	NE_p kcal./lb.	NE_p kcal./kg.	ΔMilo	ΔEnergy	NE_p kcal./lb.	NE_p kcal./kg.
24	0.0626	46.378	0.0364	26.241	720.9	1,589	0.0187	17.715	947.3	2,088
16	0.0573	32.649	0.0311	12.512	402.3	887	0.0134	3.986	297.5	656
10	0.0563	39.953	0.0301	19.816	658.3	1,451	0.0124	11.290	910.5	2,007
Mean	0.0587	39.660			593.8	1,309			718.4	1,584

TABLE XVIII

NE_p CALCULATIONS FOR CORN BY INCREMENT METHOD (All figures per unit $W^{0.75}$)

Animal	Maintenance Corn/day	kcal./day
19	0.0201	14.754
18	0.0200	15.720
21	0.0198	14.750
40	0.0201	15.941
02	0.0201	16.354
Mean	0.0200	15.504

Animal	Intermediate		Increments Between Maintenance and Intermediate: Δ Corn	Δ Energy	NE_p kcal./lb.	NE_p kcal./kg.
38	0.0360	26.422	0.0160	10.918	682.4	1,504
25	0.0371	24.804	0.0171	9.300	543.9	1,199
31	0.0380	23.517	0.0180	8.013	445.2	981
14	0.0376	22.118	0.0176	6.614	375.8	828
04	0.0355	26.306	0.0155	10.802	696.9	1,536
Mean	0.0368	24.634			548.8	1,210

Animal	High		Increments Between Maintenance and High: Δ Corn	Δ Energy	NE_p kcal./lb.	NE_p kcal./kg.	Increments Between Intermediate and High: Δ Corn	Δ Energy	NE_p kcal./lb.	NE_p kcal./kg.
70	0.0502	35.001	0.0302	19.497	645.6	1,423	0.0134	10.367	773.6	1,705
27	0.0526	35.843	0.0326	20.339	623.9	1,375	0.0158	11.209	709.4	1,564
3B	0.0526	32.843	0.0326	17.339	531.9	1,173	0.0158	8.209	519.6	1,146
06	0.0527	34.496	0.9327	18.992	580.8	1,280	0.0159	9.862	620.3	1,368
12	0.0563	26.295	0.0363	10.791	297.3	655	0.0195	1.661	85.2	187
Mean	0.0529	32.896			535.9	1,181			541.6	1,194

VITA

CURTIS W. ABSHER

Candidate for the Degree of

Master of Science

Thesis: NET ENERGY OF MILO AND CORN FOR CATTLE AS DETERMINED BY THE COMPARATIVE SLAUGHTER TECHNIQUE

Major Field: Animal Science

Biographical:

Personal Data: Born in Blacksburg, Virginia, August 6, 1940, the son of William J. and Jean Absher; married June 15, 1963, to Barbara Louise Jones; father of a daughter, Karen Lynne.

Education: Received the Bachelor of Science Degree from Virginia Polytechnic Institute, with a major in Animal Husbandry, in June, 1962.

Experience: Assistant County Agent for Virginia Agricultural Extension Service, 1962-1963. International Farm Youth Exchange Delegate to India, winter 1962-1963. Graduate Assistant at Oklahoma State University, 1963-1965.

Professional Organizations: Alpha Zeta, American Society of Animal Science, and Block and Bridle.

Date of Degree: May, 1965.