ENERGY REQUIREMENTS OF MATURE BEEF COWS AS INFLUENCED BY BODY SIZE

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TABLE OF CONTENTS

LIST OF TABLES

Table		Page

LIST OF FIGURES

INTRODUCTION

Feeder calf producers are focusing attention on factors that may be related to efficiency of feed utilization. This interest is prompted by the increasing capital cost involved in supplying forage. Producers generally recognize that cow size has an influence on the amount of feed required to support the unit. The most frequent specific question in this regard is: What is the optimum cow size? Obviously this question is difficult to answer due to the relationships that may exist between mature size and the many production criteria that are associated with this characteristic. Certain factors other than feed requirements may be related to cow size such as growth rate and tissue development patterns of calves, age of puberty, reproductive efficiency, carcass desirability of offspring and salvage value of cows.

The study reported herein was designed with two major objectives: (a) to study the relationship between the energy requirements of mature beef cows of different sizes for maintenance and production, and (b) to establish levels of energy required during the lactation and dry periods for producing cows to attain weight change patterns that appear to be consistent with good reproductive performance and economy of feeding.

LITERATURE REVIEW

Any consideration of cow size in relation to economics of production must be divided into at least two segments. First, the effect of cow size upon productivity as measured by calf weaning weight. Secondly, those factors that contribute to the energy requirements of cows of various sizes. This review then is organized into two sections to permit separate treatment of the areas mentioned above.

Productivity as Related to Cow Size

Knox (1957) compiled data on large and small cows over a 5 yr. period and found that small cows averaging 934 lb. in weight weaned calves that weighed 417 lb. The large cows weighed an average of 1066 lb. and weaned calves that weighed 469 lb. The large cows weaned a 93.9 percent calf crop while the small cows weaned a calf crop of 81.6 percent. As a result, the large cows averaged 13 percent more pounds of calf per 1000 lb. of cow weight than the small cows. Moreover, the large cows produced 33 percent more calf weight and had a longer productive life than did small cows.

Several studies have indicated that a positive relationship exists between cow weight and calf weaning weight. Gregory *et al.* (1950) reported correlations between cow weight and calf weaning weight of 0.20 and -.11 for two groups of cows. Brinks *et al.* (1962) found similar correlations from analysis of data collected at Miles City, Montana, from 1926 through 1959. Their correlations between spring and fall cow weights and calf weaning weights were 0.21 and 0.09, respectively. Marchello *et al*. (1960) reported a highly significant ($P<.01$) correlation of 0.239 between heifer weights at 18 months of age and weaning weight of their first calves. A somewhat higher relationship was reported by O'Mary *et al*. (1959) who reported a significant ($P<.05$) correlation of 0.51 between cow weight and adjusted weaning weight of their calves. Marlowe and Stewart (1955) found that cow weight accounted for 12 percent of the total variation in calf weaning weight. These reports all indicate a positive relationship between cow weight and calf weaning weight.

Several additional studies have been conducted to evaluate the additional calf weight that might result from increasing cow weight. Oregon workers, Sawyer *et al*. (1963), studied 230 cow-calf records and reported increases of 19.8 and 14.6 lb. in weaning weight for each 100 lb. increase in cow weight at 18 months and 5.5 years of age, respectively. Neville (1962) reported an increase of 7.0 lb. in the weight of calves for each 100 lb. increase in cow weight. Marchello *et al*. (1960) reported a highly significant ($P<.01$) regression coefficient which indicated that an additional 18 lb. of calf could be expected for each 100 lb. increase in heifer weight at 18 months of age. Tanner *et al*. (1965) studied data collected from 518 Angus and 385 Hereford cows and reported that each 100 lb. increase in cow weight was associated with an increase in 200 day adjusted weaning weight of 8.5 lb. for Angus calves and 4.9 lb. for Hereford calves.

Several studies have indicated that the effect of cow weight on calf weaning weight may be curvilinear. In a study of the effect of cow weight on calf weight, Marlowe (1962) found that preweaning growth rate of calves increased as dam weight increased to approximately 1250 lb. for Angus cattle and approximately 1350 lb. for Hereford cattle. As dam weight increased above these levels, preweaning growth rate decreased for Angus cattle but remained approximately the same for Herefords. A definite curvilinear relationship between cow weight and calf weight has also been reported by Ellis (1963) from data including both Hereford and Hereford-Brahman crossbred cattle. Calf weight increased with increasing cow weight to approximately 1150 lb. but declined thereafter. Tanner et al. (1965) noted a similar relationship between these two variables in data collected from a group of Hereford cows. In the cow weight range from 600 to 900 lb. an additional 16 lb. of calf was associated with each 100 lb. increase in cow weight. However, in the range of cow weights from 900 to 1500 lb. this increase was much lower. Maddox (1963) has also reported this type of curvilinear relationship between calf weaning weight and cow weight.

Several workers have attempted to relate physical dimensions of beef cows to their productivity. O'Mary et al. (1959) correlated 15 body measurements with calf weaning weight and found that all of the measurements were positively correlated with weaning weight; however, only four of these were statistically significant ($P<.05$). Ewing (1964) has observed a correlation of 0.30 between wither height of the dam and calf weight at 210 days of age in data collected from a study of lifetime performance of beef cows. Tanner et al. (1965) reported that 20 percent of the total variation in calf weaning weight could be accounted for by considering either wither height or back length of the dams. When these two variables were considered together they accounted for 25 percent of the total variation in calf weaning weight, whereas cow weight alone accounted for only 12 percent of the variation associated with calf weaning weight.

A high positive relationship between milk production of cows and weaning weights of their calves has been reported by several workers. Montsma (1960) reported a correlation of 0.96 between average daily milk production and calf weaning weight. Pope et al. (1963) found correlations between average daily milk production of dams and 210 day adjusted weaning weights of their calves to range from 0.60 to 0.70. Gifford (1953) reported a correlation of 0.60 between accumulated milk of dams and weights of their calves at 8 mo. of age. Likewise, Schwulst et al. (1966) noted a correlation of 0.58 between milk consumption and gain of calves from birth to 5 wks. of age.

Other reports have presented estimates of the amount of milk required for each additional pound of calf gain. Drewery et al. (1959) reported that the quantities of milk required for each additional pound of calf gain were 12.5, 10.8 and 6.7 lb. in the first, third and sixth months of lactation, respectively. Data from Hereford cows used in a similar study by Gifford (1953) indicate that 6.71, 5.15 and 3.22 lb. of milk were required for each additional pound of calf gain in the first, third and sixth months of lactation, respectively. Montsma (1960) found that 8.06 lb. of milk were required for each additional pound of calf gain during the eight week period immediately after birth.

Pope et al. (1963) reported correlation coefficients between average milk production and various measures of cow size as follows:

spring weight	-.22 to -.37
summer weight gain	-.10 to -.24
fall weight	-.29
wither height	0.09
wither height X width at hooks	-.13
metabolic body size	-.16 to -.39.

There was little, if any, relationship between cow size and average daily milk production in this study; therefore, the larger cows had no advantage over the small cows in average daily milk production. Also, a negative relationship between milk production and cow weight was found in dairy cows by Mason _et al_. (1957), who reported a correlation of -.14 between these two variables. Therefore, it can be concluded that if the larger cow produces more pounds of calf without the benefit of extra milk yield, she must transmit a greater potential for growth to her calf.

Correlations between cow weight and calf weaning weight have been reported to range from -.11 to 0.58. Regression analyses indicate that from 4.9 to 18.0 lb. of additional calf may be expected at weaning for each 100 lb. increase in cow weight. However, several studies indicate that the relationship between cow weight and calf weaning weight may be curvilinear rather than linear as reported by most workers. A number of studies indicate that milk production of the dam has a great influence on weaning weights of their calves. However, most studies reveal negative correlations between cow weight and average milk production.

Factors Influencing Energy Requirements of Beef Cows

Factors such as body size, type and level of production, type of management, degree of condition, physical activity and temperament of the animal have been reported to influence energy requirements of ruminant animals. Each of these factors will be given consideration in this section of the review.

Brody (1945) states that basal metabolism may be expressed by the following equation:

$$Y = aW^b$$

where

Y = energy requirement for basal metabolism,

W = weight expressed in kgm.,

b = change in basal metabolic requirement for each unit change in metabolic body size,

a = the change in calories per 24 hr. for each unit change in metabolic body size.

In an analysis of a large volume of data involving species ranging in size from a mouse to an elephant, Brody (1945) found the basal metabolic requirement for energy to be proportional to weight to the 0.73 power regardless of species. An interspecies relationship predicting the caloric requirement for basal metabolism of $Y = 70.5\ W^{0.73}$ was developed from this study. Because of ease of calculation, Kleiber (1961) suggests that $W^{0.75}$ be used to calculate metabolic size. Brody (1945) also states that TDN required for maintenance is about twice the basal metabolic requirement.

In a study with identical twin calves, Winchester and Hendricks (1953) found that maintenance energy requirements varied with weight to the 0.6686 power. Green _et al._ (1959) studied the energy requirements of beef calves for growth and fattening and found that the energy requirement for maintenance varied with $W^{0.63}$ for light calves and $W^{0.73}$ for heavier calves. Thomas and Moore (1960) studied maintenance requirements of Holstein and Jersey cows and found that the maintenance requirements of Holsteins was proportional to $W^{0.90}$ whereas the maintenance requirements of Jersey cows was proportional to $W^{0.70}$. Luitingh (1961) conducted a study in South Africa and found that the maintenance requirements of steers ranging in age from 9 to 36 months varied with $W^{0.78}$.

In a study of large and compact cows, Knox (1957) estimated forage consumption by the amount of lignin voided in the feces and found a linear relationship between feed consumption and body size. However, Stonaker et al. (1952) reported that no apparent relationship existed between body size and efficiency of feed utilization by large, intermediate and compact cows. They concluded that about the same tonnage of similar aged breeding cattle may be maintained on a given land area, and this may be independent of their individual size characteristics. However, Holmes et al. (1961) have presented data which indicates that forage intake is not proportional to body weight. These workers reported that daily digestible organic matter (DOM) intakes from grazing of 1300 lb. cows, 790 lb. heifers and 450 lb. calves were 17.4, 15.3 and 11.0 lb., respectively.

Grazing animals have been reported to have a higher energy requirement for maintenance than similar animals kept in confinement. This increase in energy requirement for maintenance may be due to environment, locomotion and harvest of forage. Armstrong et al. (1959) stated that environment may influence energy utilization in three ways: (1) alter digestion and absorption processes, (2) change the energy requirement and (3) produce a change in the proportion of metabolizable energy that is subsequently lost as heat.

Reid et al. (1958) studied the maintenance requirements of dairy cows fed in barns and fed on pasture and found that a 1000 lb. cow required 3.4 lb. TDN per day more when grazing than when fed in a barn. These workers found that 40 to 50 percent more energy was required to support a grazing cow than a cow fed in a stall, and they attributed this difference to climate, quality and quantity of forage and distance walked. They discounted the idea that energy expended in harvest of the forage is a major factor in the increased maintenance requirements of grazing cows. They believe that a grazing animal will select forage that is enough superior to harvested forage to compensate for the additional energy required for grazing.

Sheep have also been used to study the influence of grazing on maintenance energy requirements. Coop (1962a, b) found that grazing sheep weighing 100 lb. required 1.47 lb. DOM daily to maintain their weight whereas sheep of the same size that were confined to small pens required only 0.92 lb. DOM daily. In similar experiments Langlands _et al_. (1963a, b) studied the maintenance requirements of both pen fed and grazing sheep and found that grazing sheep required 1.02 lb. DOM daily to maintain each 100 lb. of live weight whereas the same live weight could be maintained on 0.82 lb. DOM daily when pen fed.

Lambourne and Reardon (1963) studied maintenance requirements of mature wethers in several different environments and found that when wethers were allowed to graze for short periods on abundant forage live weights of 26, 33 and 46 kg. could be maintained on 420, 400 and 490 gm. DOM per day. However, when these same wethers were allowed to graze freely on sparse forage, the same live weights required 750, 780 and 560 gm. DOM daily for maintenance. They concluded that the increase in maintenance requirements of sheep on sparse forage may be attributed to the energy expenditure of locomotion required to obtain adequate amounts of forage. They further concluded that 10 percent of the total energy requirement for maintenance may be attributed to locomotion. These workers also noted that cold weather caused an increase in maintenance energy requirements and that the increase was greater for thin sheep than those in higher degrees of condition. A further example of the influence of forage abundance on maintenance energy requirements is afforded by Kromann et al. (1961) who found that steers grazing good irrigated pastures had no greater maintenance requirements than steers fed in dry lot.

Clapperton (1961) enclosed a treadmill within a respiration calorimeter to study the energy requirements of sheep for locomotion. The sheep were fed either a maintenance ration or a level of twice maintenance, and metabolism was measured during an 8 hr. period of locomotion and during the remainder of the 24 hr. period. Energy requirements increased with both speed and vertical motion. The average energy required for horizontal movement of 1 kg. body weight was found to be 0.58 ± 0.05 kcal. per meter.

McCandlish and Gaessler (1920) determined the maintenance energy requirements of fleshy and thin dairy cows. The cows were fed 150 days while in each condition, and there was a 23 percent change in body weight between trials. Fleshy cows required 7.39 lb. TDN to maintain 1000 lb. of live weight while the thin cows required only 5.42 lb. TDN. Eckles et al. (1927) found that calves in normal condition required 5.43 therms per 1000 lb. for maintenance whereas calves that were fat required 6.79 therms for each 1000 lb. maintained.

Armsby and Fries (1917) used a mature steer to determine the effect of condition on feed utilization and found that a 300 lb. increase in live weight resulted in a 36 percent increase in the maintenance energy requirement. In proportion, this increase was greater than the corresponding increase in live weight or computed surface area of the body. Rebhan and Donker (1960) used three sets of monozygous bovine animals to study the effect of condition on the energy required for maintenance and found an increase in the maintenance energy requirement as the condition of the animal increased. In contrast to the results of other workers, Trowbridge et al. (1915) found that condition had very little effect on maintenance energy requirements.

An extensive study of the maintenance requirements of cattle was conducted by Trowbridge et al. (1915) who found that a higher plane of nutrition resulted in increased maintenance requirements and that the increase was proportional to the increase in nutritional plane. They also concluded that the maintenance energy requirement decreased with age of the animal. They also found that the maintenance energy requirement was lowest during the spring, highest during the winter and intermediate during the remaining seasons. Activity resulted in an increased maintenance requirement.

Cochrane et al. (1925) found that excitable animals had a greater maintenance energy requirement than placid animals.

Metabolic rate and in turn maintenance requirements vary with metabolic size, and the average figure of $W^{0.75}$ has been suggested as a basis for metabolic body size. A number of factors including increased activity, grazing, cold climate, higher degree of condition, higher level of nutrition, younger age and excitable temperament increases the maintenance energy requirements. However, most of the research pertaining to energy requirements has been conducted with small numbers of non-producing animals. Very little research has been reported in which producing cows in semi-practical conditions were used as experimental animals. This study was conducted to determine the energy requirements of beef cows for maintenance and production when kept in semi-practical conditions.

MATERIALS AND METHODS

This trial conducted at the Fort Reno Livestock Research Station located at El Reno, Oklahoma, was initiated in February of 1965 and terminated in March of 1966. Twenty mature, commercial Hereford cows, served as experimental animals. Ten large cows were selected with an average weight of 1318 $\pm$ 27.6 lb. and 10 cows averaging 956 $\pm$ 27.6 lb. were selected as small cows. The cows were selected on the basis of previous performance such that the large cows had an average advantage in weaning weight of offspring similar to that reported in the literature. The cows were maintained on native grass pasture, which was supplemented with prairie hay and cottonseed cake, for approximately two weeks before being placed on test. All cows were then moved to a large dry lot for the entire experimental period. Individual feeding stalls were provided in an open shed adjacent to the dry lot, and cows were fed their daily feed allowances each morning. All cows had access to a mineral mixture consisting of 1 part trace mineral salt, 1 part dicalcium phosphate and 1 part calcium carbonate.

Cows within each size group were divided into two sub-classes as defined below:

1. Producing - Cows that produced a calf and were rebred during the study. The cows were fed to attain a set weight change pattern which is described later.
2. Maintenance - Cows that were open and were fed to maintain a constant body weight throughout the entire study.

The experimental period for each producing cow was divided into two phases as defined below:

1. A lactating phase during which each cow was nursing a calf and producing a fetus. This phase encompassed the period from calving to 266 days post-partum.

2. A non-lactating phase during which the cows were in the latter stages of pregnancy. This phase encompassed the period from 266 days post-partum until the following parturition.

An annual weight change pattern was developed for the producing cows which appeared to be consistent with economy and good reproductive performance in studies reported by Smithson _et al_. (1966). The weight change pattern for producing cows is described below and illustrated in Figure 1.

Period I. From calving to 56 days post-partum. During this period, the cows were allowed to lose not more than 15 percent of their pre-calving weight.

Period II. Fifty-six days post-partum to 266 days post-partum. During this period, the cows were fed to gain approximately 10 percent of their pre-calving weight in order to regain their previous fall weight.

Period III. Two hundred sixty six days post-partum to the following parturition. During this period, the cows were fed to gain 5 percent of their fall weight in order to regain their previous pre-calving weight.

Weight changes were controlled by adjusting feed levels on the basis of weekly weights taken after a 12 hr. shrink period during which the animals were without feed and water. Inasmuch as the cows were placed on test just prior to calving, the weight taken at this time was used as a base weight for development of the annual weight change pattern. Each cow remained on test from the time she calved in 1965 until she

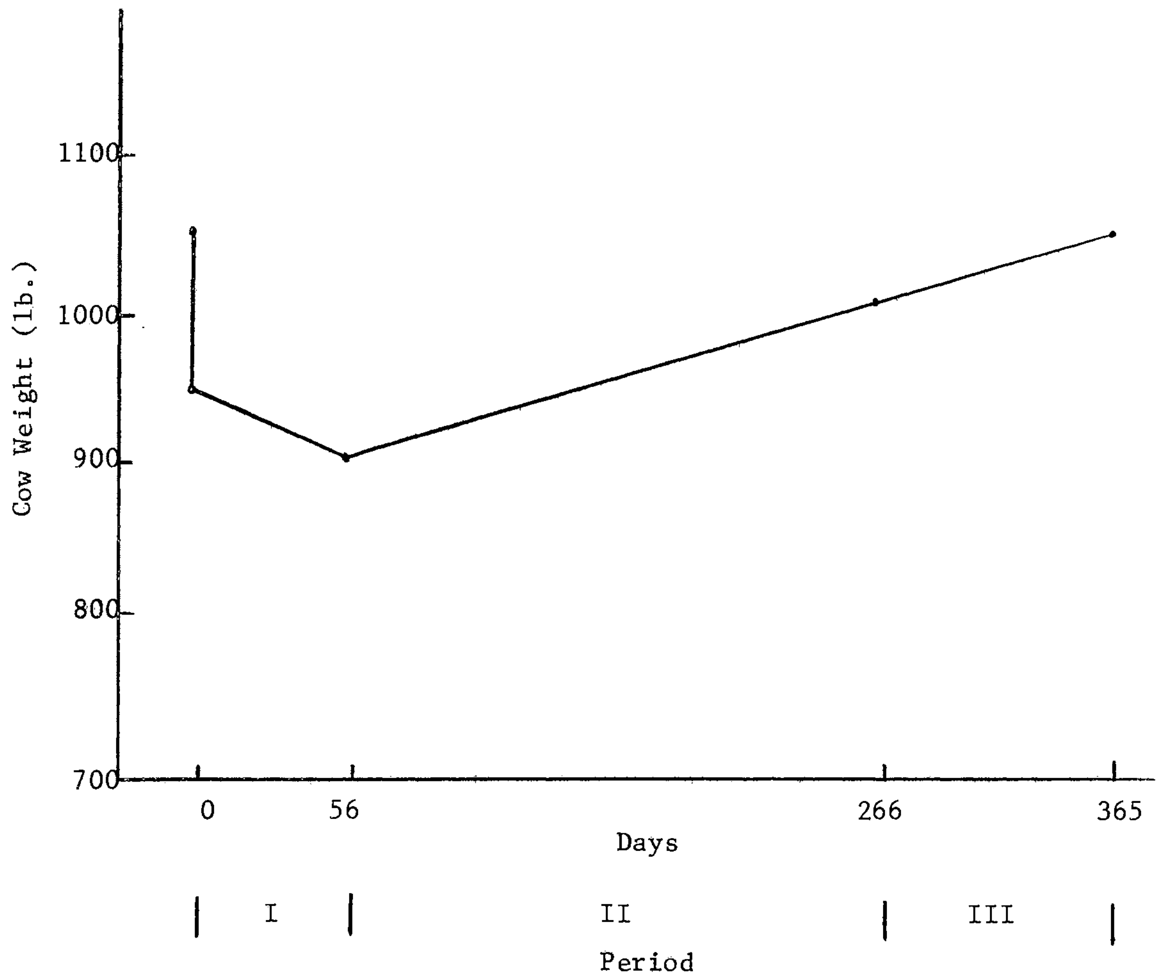

Figure 1. Weight Change Pattern for Producing Cows Illustrated for a 1000 lb. Cow

calved again in 1966; therefore, the experimental period encompassed one complete production year.

All cows were fed prairie hay, milo and cottonseed meal from the time of calving until 56 days post-partum, and at this time each cow was given a ration of alfalfa hay with allowances of milo and cottonseed meal when needed to attain the designated weight change. As the cows would not consume adequate amounts of alfalfa hay to achieve proper weight gains, a complete mixed ration, ration A (Table I), which supplied the nutrient requirements (N.R.C., 1963) of beef cows in production, was substituted for the alfalfa hay ration. The cows received this ration until their calves were weaned at 215 days of age. As each calf was weaned, the cow was fed a ration which supplied the nutrient requirements (N.R.C., 1963) of pregnant beef cows, ration B (Table I). All feeds and rations were sampled frequently and composites were combined for determination of proximate analysis and gross energy values which are presented in Table II. Digestible energy (DE) and total digestible nutrient (TDN) contents of the complete rations are presented in Table III.

There were five large producing cows and eight small producing cows during the lactating phase while during the non-lactating phase there were nine large producing cows and six small producing cows. This difference in numbers between the two phases warrants an explanation. Calves of three of the large cows died leaving only five large producing cows during the lactating phase. Two of the large cows that lost calves were rebred and were used as producing cows during the non-lactating phase, and two additional large producing cows were placed on test during the summer and were also used as producing cows during the

TABLE I

COMPOSITION OF RATIONS FED TO COWS DURING THE STUDY

Ingredient	Ration A[1]	Ration B[2]
	(%)	(%)
Chopped alfalfa hay	63.3	43.7
Cottonseed hulls		43.7
Ground milo	31.7	7.6
Cane molasses	5.0	5.0

[1] 1500 IU Vitamin A per lb.

[2] 1050 IU Vitamin A per lb.

TABLE II

PROXIMATE ANALYSIS AND GROSS ENERGY VALUES OF FEEDS ON DRY MATTER BASIS

Feed Ingredient	Crude Protein	Ether Extract	Crude Fiber	NFE[1]	Ash	Gross Energy
	(%)	(%)	(%)	(%)	(%)	(cal./gm.)
Prairie hay	5.50	3.94	33.74	42.92	7.56	4285.267
Milo	10.72	4.92	1.44	70.96	1.79	4274.014
Cottonseed meal (44%)	40.40	5.26	13.09	27.76	6.07	4729.061
Alfalfa hay	19.88	4.34	27.18	26.84	9.94	4355.551
Ration A	15.10	4.27	16.55	50.43	7.06	4283.197
Ration B	12.30	3.69	33.53	38.85	5.70	4254.779
Calf ration	17.95	4.34	19.83	42.68	9.50	4339.093

[1]Nitrogen-free-extract

TABLE III

DIGESTIBLE ENERGY AND TOTAL DIGESTIBLE NUTRIENT CONTENT OF RATIONS

Ration	Digestible Energy	Total Digestible Nutrients
	Mcal./lb.	Lb./100
A	1.216	58.79
B	1.067	48.8

non-lactating phase. The five large producing cows from the lactating phase and the four additional large producing cows comprise the nine large producing cows during the non-lactating phase. Two small producing cows did not conceive so they were removed from the non-lactating phase reducing the number of small producing cows to six. There were five large producing cows and six small producing cows that remained on test during both phases and were used for the analysis of energy requirements for the complete production year. There were two maintenance cows in each size group during both the lactating and non-lactating phases and they were also used for the analysis of maintenance requirements based on the complete year.

All calves were individually fed a ration composed of 93 percent chopped alfalfa hay and 7 percent cane molasses from 112 days of age until they were weaned at 215 days of age. The calves were fed all that they would consume of this ration each morning, and records of feed intake were maintained. Calves were allowed to remain with their dams at all times except during the feeding period each day.

Skeletal size was estimated for each cow at the beginning of the experiment and at monthly intervals throughout the test. Each cow was confined in a squeeze chute to obtain the following physical measurements; width of pin bones, width of hook bones, width of loin and circumference of heart. Photographs of each cow were taken through a 6 in. by 12 in. grid, and the following measurements were obtained from these photographs; length of body, height at withers, depth of chest and distance from chest floor to ground level. Thickness of fat cover over the 13th rib was estimated by use of a thermister thermometer (Brackelsburg *et al*., 1967). Values presented in Table IV verify that

TABLE IV

MEASURES OF SIZE AND PREVIOUS PRODUCTIVITY OF COWS INVOLVED IN THE STUDY

Measurement	Small Cows	Large Cows	Standard Error
Initial weight (lb.)	956	1318	27.6
Average weaning weight of previous calves (lb.)[1]	448 [c]	485 [c]	11.1
Physical measurements:[2]			
Width at pins (in.)	8.88[b]	10.42[b]	0.404
Width at hooks (in.)	19.45[a]	22.02[a]	0.269
Loin width (in.)	13.62[a]	15.15[a]	0.287
Heart girth (in.)	71.30[a]	80.30[a]	0.748
Fat thickness (mm)[3]	10.77[a]	15.22[a]	0.898
Fat thickness/100 lb. (mm)	1.13[d]	1.19[d]	0.005
Photograph measurements;[4]			
Length of body (in.)	50.35[a]	54.45[a]	0.561
Wither height (in.)	43.55[a]	47.30[a]	0.256
Depth of chest (in.)	23.80[a]	26.55[a]	0.282
Chest floor to ground (in.)	20.50[b]	21.50[b]	0.274

[a, b, c, d]Indicate statistical significance between means where: a = ($P<.005$), b = ($P<.025$), c = ($P<.05$) and d = ($P>.10$).

[1]Weaning weights were adjusted to a standard age of 205 days.

[2]These measurements were taken while the cow was restrained in a squeeze chute.

[3]A thermister probe was employed to estimate the fat thickness over the 13th rib.

[4]These measurements were taken from photographs made of the cow through a 6 in. by 12 in. grid.

the large cows were significantly ($P<.05$) larger than the small cows in all measures of skeletal size as well as body weight. However, no significant ($P>.10$) difference was noted in fat cover over the 13th rib when expressed as millimeters of fat cover per 100 lb. of body weight.

Milk production was estimated at 14 day intervals by measuring weight increase of the calf after nursing. Calves were allowed to nurse the afternoon before a test and were separated from the cows at 5 p.m. and remained separated until 7 a.m. the next morning. They were then weighed, allowed to nurse and again weighed. The increase in weight was taken as an estimate of milk production of the dam. The calves were then held away from their dams until 5 p.m. at which time the test was repeated. The sum of the morning and afternoon yields represent daily milk yield of the dam. Also, milk samples were obtained at monthly intervals for milk fat and gross energy analyses. All cows were injected with approximately 1.5 ml. of oxytocin (Armour Pharmaceutical P.O.P. - 20 USP units/ml.) three to five minutes prior to milking. Milk samples were obtained by hand milking the right fore quarter until all milk was removed. The milk was mixed thoroughly and two samples of approximately 200 ml. each were collected. One sample was used for milk fat analysis, and the other sample was frozen until analyzed for gross energy using a Parr Bomb Calorimeter.

Two digestion trials were conducted by use of the chromium oxide reference technique. The first trial was conducted in August of 1965 to determine the TDN and DE content of ration A which was fed during the lactating phase. The second trial was conducted during February of 1966 to determine the same parameters for ration B which was fed during the non-lactating phase. Each trial was conducted by the following procedure; all cows were given 20 gm. of chromium oxide in their feed each day for a 14 day preliminary period and a five day collection period. Rectal "grab" samples of feces were collected between 7:30 and 8:30 a.m., and the afternoon samples were collected between 4:30 and 5:30 p.m. Each sample was placed in an individual plastic bag to which a small amount of thymol was added to prevent putrefaction. The morning and afternoon samples for each cow were pooled separately and mixed thoroughly with a food mixer. Two samples of approximately 200 gm. were taken from each composite. One was dried at 55° C. in a forced air oven while the other sample was frozen and kept in reserve. After the samples were dry, they were ground through a 1 mm. screen in a Willy mill. The morning and afternoon samples for each cow were composited on an equal dry matter basis and analyzed.

Proximate analyses of feed and fecal samples were determined by the procedures of the A.O.A.C. (1960). Gross energy values of feed, fecal and milk samples were determined by use of a Parr Adiabatic Bomb Calorimeter. The milk samples were first dried onto cellulose pellets in order to determine energy content. This procedure involved drying approximately 4 ml. of milk onto a cellulose pellet which weighed approximately 1 gm. The gross energy of the cellulose (4055.619 $\pm$ 10.423 cal./gm.) was then subtracted from the total gross energy to determine gross energy of the milk. Chromium oxide content of fecal samples was determined with the aid of a Perkin-Elmer Model 300 Atomic Absorption Spectrophotometer by the procedure outlined by Williams _et al_. (1962).

Coefficients for apparent digestibility and apparent digestible energy values were calculated by the equation presented by Kane et al. (1953):

$$\text{Digestibility} = 100 - \left[100\left(\frac{\%\text{ indicator in feed}}{\%\text{ indicator in feces}} \times \frac{\%\text{ nutrient in feces}}{\%\text{ nutrient in feed}}\right)\right].$$

Values obtained from the digestion trials were used to calculate TDN and DE obtained from ration A and ration B. However, TDN and DE consumption during Period I, from calving to 56 days post-partum, were estimated from values presented by Morrison (1957).

TDN requirements were corrected by the following relationship (Knott et al., 1934) to adjust all cow weights to the designated weight change pattern:

Pounds gained X 3.53 = TDN required for gain,

Pounds lost X 2.73 = TDN equivalent of loss.

Factors for DE were derived by multiplying the factors for TDN by 2127.199 kcal. This value was used instead of the average value of 2000 kcal. reported in the literature (Blaxter, 1962) because in this study 1 lb. TDN = 2127.199 kcal. of DE.

Daily DE and TDN requirements of producing cows were corrected for the energy required for milk production by the procedure described below. Daily milk production was converted to a 4 percent fat corrected basis by the following equation (Gaines and Davidson, 1923):

$$4\%\ \text{FCM} = 0.4\ (\text{lb. of milk}) + 15\ (\text{lb. of fat}).$$

The daily energy required for milk production was obtained by multiplying the 4 percent FCM by 0.32 lb. for TDN and 0.65 Mcal. for DE (N.R.C., 1966). The daily energy required for milk production was then subtracted from the daily energy requirement to obtain the corrected daily energy requirement.

Simple regression analyses and analyses of variance were conducted by the procedures outlined by Steel and Torrie (1960). Multiple regression equations were calculated by the "pivotal method" from "normal equations" of the following form:

$$b_1 \Sigma x_1^2 + b_2 \Sigma x_1x_2 + ---- + b_k \Sigma x_1x_k = \Sigma x_1y$$

$$b_1 \Sigma x_2x_1 + b_2 \Sigma x_2^2 + ---- + b_k \Sigma x_2x_k = \Sigma x_2y$$

$$b_1 \Sigma x_kx_1 + b_2 \Sigma x_kx_2 + ---- + b_k \Sigma x_k^2 = \Sigma x_ky$$

where, the sums of squares and sums of cross products are calculated in terms of deviations from the means.

Even though most research indicates that energy requirements vary with weight$^{0.75}$, the relationships between energy requirements and body weight were expressed in linear form in this study. This was necessary because one group of large and one group of small cows were used for the estimation of energy requirements; and since there were no cows in the intermediate weights, the data dictated the use of linear analyses.

RESULTS

The results of this study are presented in the following order: (1) performance of cows and calves expressed as calf weight and milk production of dams, (2) energy requirements of cows during (a) the lactating phase, (b) the non-lactating phase and (c) the complete year, which includes data from both the lactating and non-lactating phases. Estimates of energy requirements are presented as digestible energy (DE) and total digestible nutrients (TDN).

Cow and Calf Performance

Means and standard errors for calf weights and milk production are presented in Table V for both the large and small cows. Large cows produced calves that were 10.8 lb. ($P<.01$) heavier at birth and 41 lb. heavier at 215 days of age than calves produced by small cows. Also, calves of the large cows consumed 67.5 lb. more feed than those of small cows. However, differences between the two size groups for weaning weight and feed consumption were not significant ($P>.10$).

Differences in milk production between the two size groups were not significant ($P>.10$); however, the small cows produced a significantly ($P<.01$) greater percentage of milk fat than did large cows. As a result they produced 1.80 lb. more 4 percent fat corrected milk (FCM) daily than did large cows. The small cows produced more milk fat; therefore, they also had a higher daily production of gross energy in milk. These data are in contrast to those of Mason _et al_. (1957), who

TABLE V

MEANS AND STANDARD ERRORS FOR CALF WEIGHTS AND MILK PRODUCTION DATA

Trait Measured	Small Cows	Large Cows
Calving date (days)[1]	72.7 ± 5.85 [a]	50.4 ± 5.85 [a]
Birth weight (lb.)	70.0 ± 2.04 [a]	80.8 ± 2.04 [a]
Weaning weight (lb.)	353.0 ± 16.04	394.0 ± 24.45
Feed consumed by calves (lb.)	303.6 ± 30.73	371.2 ± 16.36
Daily milk production (lb.)	12.80 ± 0.63	12.46 ± 1.92
Daily milk fat (%)	2.30 ± 0.16 [a]	1.58 ± 0.55 [a]
Daily milk fat production (lb.)	0.305 ± 0.031	0.203 ± 0.039
Daily 4% fat corrected milk (lb.)	9.82 ± 0.67	8.02 ± 1.30
Daily gross energy of milk (Kcal)	7.274 ± 0.473	6.343 ± 1.011

[a]Indicates that the means differ significantly ($P < .01$).

[1]Day number of the year and the approximate date would be 72.7 = 3/13 and 80.8 = 3/21.

reported a slight positive relationship between milk fat percentage and cow weight for dairy cows.

The difference of 41.0 ± 29.2 lb. between the weaning weights of calves (Table V) produced by the two groups when fed in dry lot was not significant (P>.10). This difference is quite similar to the significant (P<.05) difference of 37.0 ± 15.74 lb. between the average weaning weights of calves produced by the two groups prior to the test (Table IV).

Lactating Phase

Calculated regression lines for daily DE required for maintenance, daily DE required for maintenance and cow gain plus fetal growth and daily DE required for total production are shown in Figure 2 and Table VI. The regression coefficient of 0.00787 for maintenance cows indicates that the DE required for maintenance increased by 0.787 Mcal. for each 100 lb. increase in body weight. Cow weight accounted for 67.3 percent of the total variation in DE required for maintenance. The DE requirements for total production (maintenance, body weight gain plus fetal growth and milk production) increased by 0.628 Mcal. for each 100 lb. increase in cow weight. When the amount of energy required to support milk production (N.R.C., 1966) is deducted from the total daily DE requirement during the lactating phase, an estimate of the energy required for maintenance and cow gain plus fetal growth or DE requirement independent of milk production is obtained. The highly significant (P<.01) regression coefficient for daily DE requirement independent of milk production indicates that the DE required for maintenance and cow gain plus fetal growth increased by 0.980 Mcal. for each 100 lb. increase in cow weight. Cow weight accounted for 45.4 percent of the

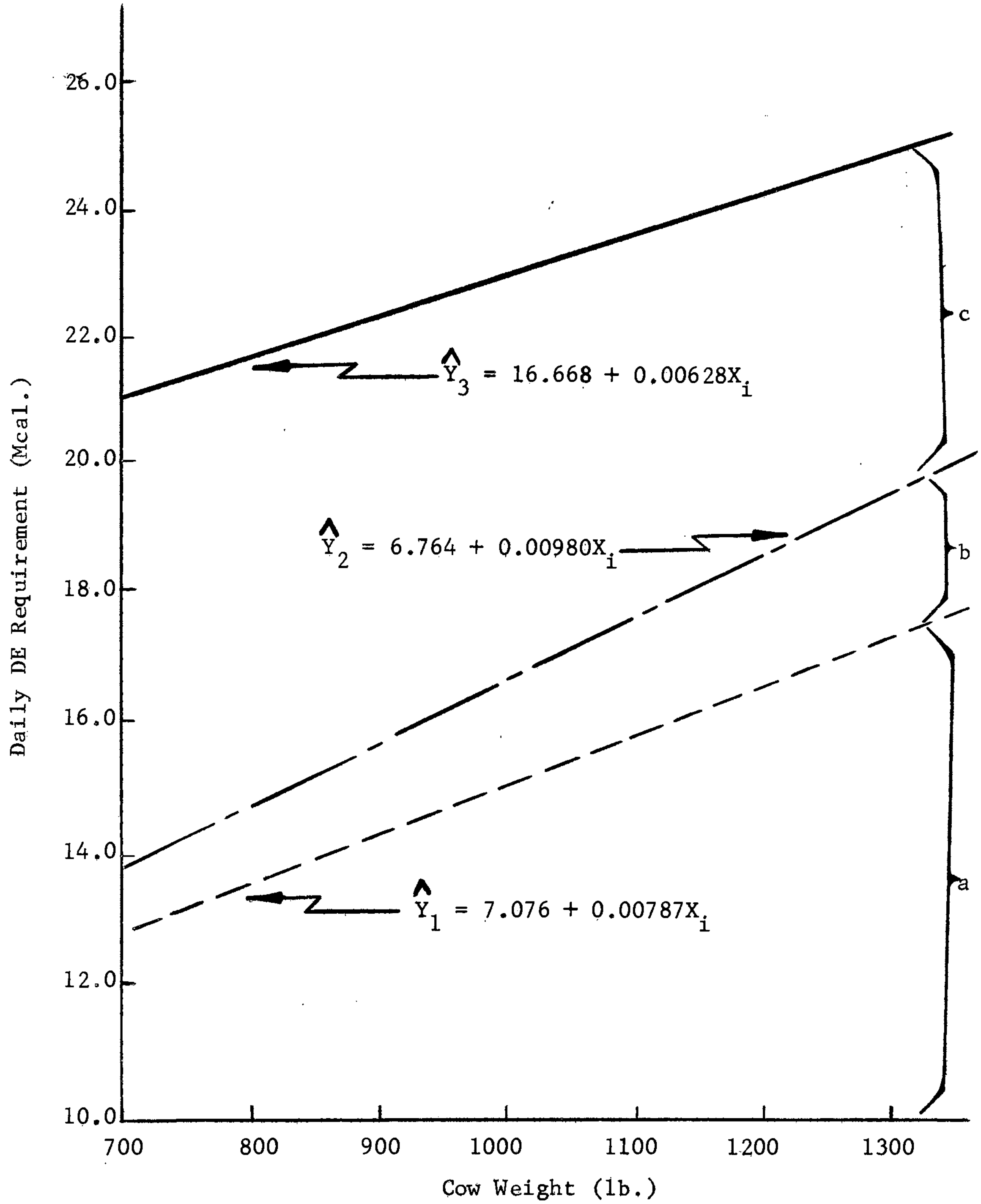

Figure 2. Daily Digestible Energy Required for Maintenance (Y_1), Maintenance and Cow Gain Plus Fetal Growth (Y_2) and Total Production (Y_3) During the Lactating Phase. (See text for explanation of a, b and c.)

TABLE VI

REGRESSION EQUATIONS FOR DAILY DIGESTIBLE ENERGY REQUIREMENTS REGRESSED ON COW WEIGHT

Equation	DE Intercept	Regression Coefficient[1]	S_b[2]	$S_{x.y}$[3]	Variation Accounted for by Regression
<u>LACTATING PHASE</u>					
Producing cows:					
DE/day (Mcal.)	16.668	0.00628[e]	0.00491	2.8055	13.0
Corr. DE/day (Mcal.)[4]	6.764	0.00980[a]	0.00322	1.8490	45.4
Maintenance cows:					
DE/day (Mcal.)	7.076	0.00787[d]	0.00387	1.8074	67.3
<u>NON-LACTATING PHASE</u>					
Producing cows:					
DE/day (Mcal.)	5.664	0.00831[b]	0.00366	2.1517	28.3
Maintenance cows:					
DE/day (Mcal.)	6.861	0.00606[c]	0.00168	0.7842	86.6
<u>COMPLETE YEAR</u>					
Producing cows:					
DE/day (Mcal.)	11.231	0.00819[c]	0.00440	2.4139	27.7
Corr. DE/day (Mcal.)[4]	6.783	0.00886[b]	0.00329	1.8019	44.6
Maintenance cows:					
DE/day (Mcal.)	6.637	0.00742[c]	0.00175	0.8152	90.0

[1]Superscript indicates probability of a larger value of "t" due to chance where: a = ($P<.01$), b = ($P<.025$), c = ($P<.05$), d = ($P<.10$) and e = ($P<.15$).

[2]Standard error of the regression coefficient

[3]Standard error of the estimate

[4]Values were corrected for the estimated DE required for milk production (N.R.C., 1966).

variation in the daily DE requirement for maintenance and cow gain plus fetal growth; however, weight accounted for only 13.0 percent of the variation in total daily DE required.

The energy required for various functions may be estimated from Figure 2 if the assumptions are made that area "a" represents the DE required for "active maintenance," area "b" represents the DE required for cow gain plus fetal growth and area "c" represents the energy required for milk production. On the basis of these assumptions Mcal. of DE required for maintenance, body gain plus fetal growth and milk production for a 900 lb. cow was 14.160, 1.421 and 6.736 Mcal. per day, respectively; whereas, a 1300 lb. cow required 17.308, 2.192 and 5.328 Mcal. per day for these respective functions. These observations indicate that the 900 lb. cow utilized 69.8 percent of the daily DE requirement for maintenance and body gain plus fetal growth whereas a 1300 lb. cow utilized 78.5 percent of the daily DE requirement for these functions. Also, the 900 lb. cow utilized 30.2 percent of the daily DE requirement for lactation while the 1300 lb. cow utilized only 21.5 percent of the daily DE requirement for lactation. This difference in the percentage of DE utilized for milk production may be explained in part by the fact that the small cows produced 0.931 kcal. more gross energy in milk than did the large cows (Table V).

The predicted DE required for maintenance shown in Figure 2 compares favorably with the N.R.C. (1966) recommended allowances for dairy cows. For example, the N.R.C. (1966) requirement for maintenance of a 1000 lb. dairy cow is 14.18 Mcal. DE per day whereas the predicted requirement from this study is 14.95 Mcal. per day. If the DE requirement for milk production (N.R.C., 1966) is added to the maintenance requirement, this value is comparable to the predicted daily DE requirement for total production. The average daily milk yield of all cows in this study was 9.13 lb. of 4 percent FCM, and the DE required to produce this amount of milk would be 5.55 Mcal. (N.R.C., 1966). The requirement of a 1000 lb. cow for milk production and maintenance may be calculated by adding the value 5.55 Mcal. to the daily maintenance requirement which is 14.18 Mcal. The value obtained is 19.73 Mcal. which is less than the predicted requirement of 22.95 Mcal. per day shown in Figure 2. However, the value of 19.73 Mcal. based on N.R.C. (1966) does not include the energy required for body weight gain plus fetal growth during this period. The N.R.C. (1963) suggests that a 900 to 1100 lb. beef cow in the first 3 to 4 mo. post-partum should receive 33.6 Mcal. DE per day which is much higher than the daily requirement of 22.95 Mcal. per day for a 1000 lb. cow predicted from the equation based on this study. It may also be noted that the recommended allowances for beef cattle (N.R.C., 1963) and the recommended allowances for dairy cattle (N.R.C., 1966) are also different.

Differences between the daily DE requirements of large and small maintenance cows (Table VII) were not statistically significant ($P>.10$); even though the large maintenance cows required 3.127 Mcal. DE per day more than did the small maintenance cows; however, there were only four animals involved in this analysis. Likewise, differences between the total daily DE required by the large and small producing cows were not significant ($P>.10$); even though the large cows required 1.781 Mcal. more DE daily than did the small cows. When the daily DE requirements for producing cows were corrected for milk production, the difference

TABLE VII

MEANS AND STANDARD ERRORS FOR DAILY DIGESTIBLE ENERGY REQUIREMENTS OF LARGE AND SMALL COWS IN VARIOUS STAGES OF PRODUCTION

Period	Small Cows		Large Cows	
<u>LACTATING</u> <u>PHASE</u>				
Producing cows:				
DE/day (Mcal.)	22.952 -	0.738	24.733 -	1.719
Corr. DE/day (Mcal.)[1]	16.468	0.629[b]	19.520	0.952[b]
Maintenance cows:				
DE/day (Mcal.)	13.875	0.950	17.002	2.047
<u>NON-LACTATING</u> <u>PHASE</u>				
Producing cows:				
DE/day (Mcal.)	14.156	0.705	15.939	0.894
Maintenance cows:				
DE/day (Mcal.)	11.797	0.007[b]	14.792	0.317[b]
<u>COMPLETE</u> <u>YEAR</u>				
Producing cows:				
DE/day (Mcal.)	19.380	0.922	21.808	1.245
Corr. DE/day (Mcal.)[1]	15.547	0.788[c]	18.274	1.261[c]
Maintenance cows:				
DE/day (Mcal.)	12.899	0.504	16.142	1.057

[1]Daily energy requirements were corrected for energy required for milk production as explained in Materials and Methods.

[a, b, c, d]Indicate level of statistical significance where: a = (P<.01), b = (P<.025), c = (P<.05) and d = (P<.10).

of 3.052 Mcal. between the requirements of large and small cows was significant ($P<.025$).

Daily TDN requirements followed the same general pattern as the daily DE requirements. The daily TDN requirements regressed on cow weight are shown in Figure 3 and Table VIII for maintenance cows, producing cows independent of milk production and producing cows for total production. Regression coefficients indicate that for each 100 lb. increase in body weight daily TDN requirements increased by 0.381 and 0.360 for producing cows and maintenance cows, respectively. The highly significant ($P<.01$) regression coefficient for daily TDN requirements for production independent of milk production regressed on body weight indicates that TDN requirements for maintenance and cow gain plus fetal growth increased by 0.538 lb. per day for each 100 lb. increase in cow weight. The weight of the cow accounted for 64.1, 51.6 and 18.0 percent of the variation associated daily TDN required for maintenance, maintenance and cow gain plus fetal growth and total production, respectively.

The TDN allowances recommended by N.R.C. (1966) for maintenance of a 1000 lb. dairy cow is 7.10 lb. daily and is only 0.14 lb. lower than the predicted value of 7.24 lb. per day (Figure 3). If the TDN required to produce 9.13 lb. of 4 percent FCM, 3.01 lb., is added to the maintenance requirement, a value of 10.11 lb. is obtained for daily TDN required for maintenance and milk production of a 1000 lb. cow and is lower than the 11.00 lb. TDN per day shown in Figure 3. However, the predicted value of 11.00 lb. TDN per day is much lower than the N.R.C. (1963) recommended allowance for a 900 to 1100 lb. beef in the first 3 to 4 mo. of lactation which is 16.8 lb. daily.

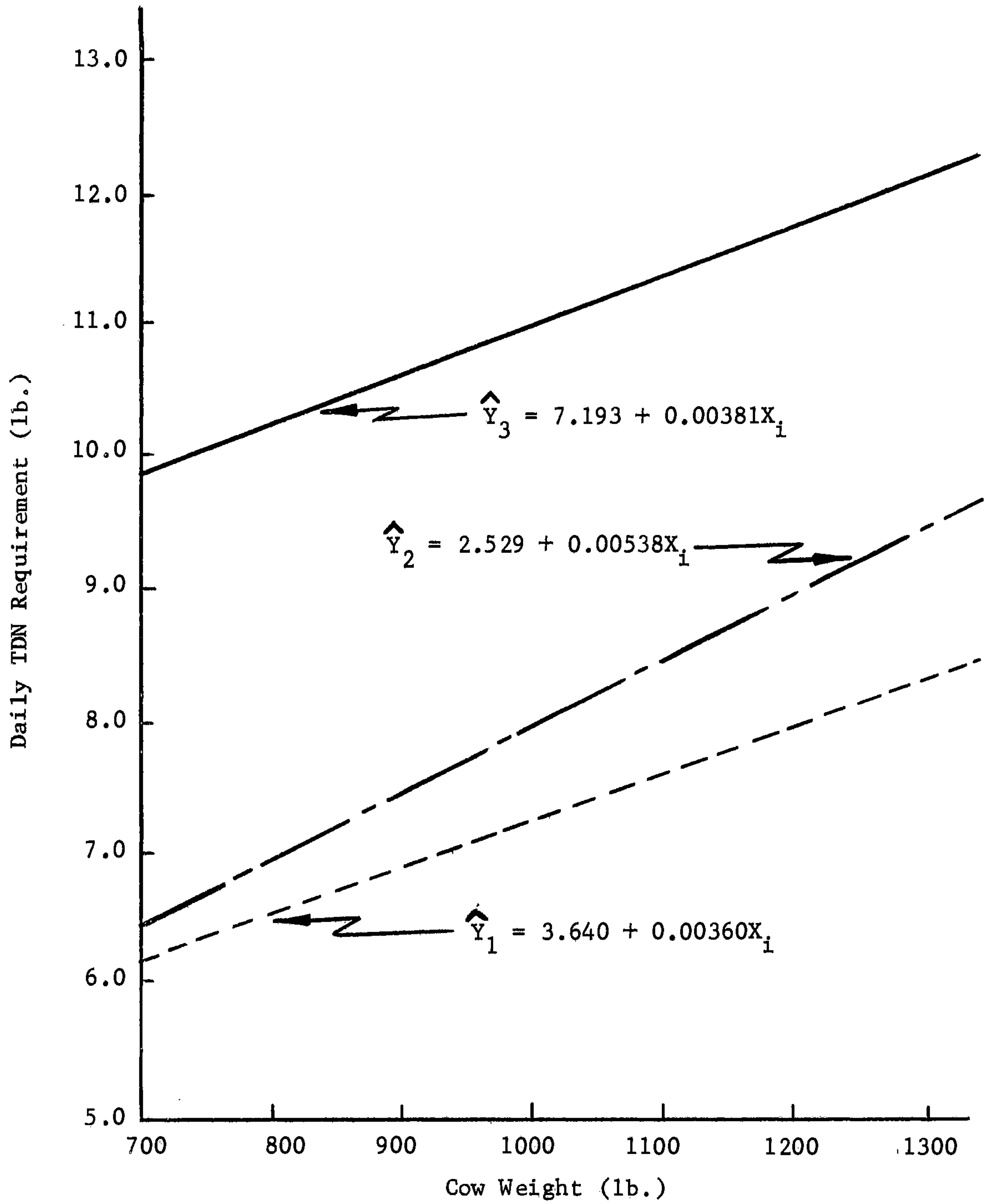

Figure 3. Daily Total Digestible Nutrients Required for Maintenance (Y_1), Maintenance and Cow Gain Plus Fetal Growth (Y_2) and Total Production (Y_3) During the Lactating Phase

TABLE VIII

REGRESSION EQUATIONS FOR DAILY TOTAL DIGESTIBLE NUTRIENT REQUIREMENTS REGRESSED ON COW WEIGHT

Equation	TDN Intercept	Regression Coefficient[1]	S_b[2]	$S_{x.y}$[3]	Variation Accounted for by Regression
<u>LACTATING PHASE</u>					
Producing cows:					
TDN/day (lb.)	7.193	0.00381[d]	0.00245	1.3975	18.0
Corr. TDN/day (lb.)[4]	2.529	0.00538[a]	0.00157	0.8978	51.6
Maintenance cows:					
TDN/day (lb.)	3.640	0.00360[e]	0.00190	0.8866	64.1
<u>NON-LACTATING PHASE</u>					
Producing cows:					
TDN/day (lb.)	2.771	0.00379[b]	0.00157	0.9204	30.9
Maintenance cows:					
TDN/day (lb.)	3.138	0.00277[d]	0.00132	0.6294	86.2
<u>COMPLETE YEAR</u>					
Producing cows:					
TDN/day (lb.)	4.908	0.00432[c]	0.00203	1.1122	33.4
Corr. TDN/day (lb.)[4]	2.081	0.00532[a]	0.00148	0.8091	58.9
Maintenance cows:					
TDN/day (lb.)	3.183	0.00346	0.00266	0.3912	89.3

[1]Superscript indicates probability of a larger value of "t" due to chance where: a = (P<.01), b = (P<.025), c = (P<.05), d = (P<.10) and e = (P<.15).

[2]Standard error of the regression coefficient

[3]Standard error of the estimate

[4]Values were corrected for the estimated TDN required for milk production (N.R.C., 1966).

Data presented in Table IX indicate that the large producing cows required 1.093 lb. ($P<.10$) more TDN per day than did the small cows. However, when the daily TDN requirements were corrected for milk production (N.R.C., 1966), the difference in daily TDN requirements of 1.670 lb. between the large and small cows was highly significant ($P<.01$). Even though the large maintenance cows required 1.391 lb. more TDN daily than the small maintenance cows, this difference was not statistically significant ($P>.10$).

Non-lactating Phase

Data for the non-lactating phase are presented as calculated regressions of daily DE requirements regressed on body weight in Figure 4 and Table VI. The significant ($P<.025$) regression coefficient of 0.00831 for producing cows indicates that daily DE requirements increased by 0.831 Mcal. for each 100 lb. increase in body weight. The significant ($P<.05$) regression coefficient for maintenance cows indicates that for each 100 lb. increase in body weight the DE requirement for maintenance increased by 0.606 Mcal. per day. Cow weight accounted for 86.6 percent of the variation in daily DE requirements for maintenance; however, it accounted for only 28.3 percent of the variation in DE requirements of producing cows.

If the assumptions are made as before, that area "a" represents the DE required for "active maintenance" and area "b" represents the DE required for cow gain plus fetal growth (Figure 4), the energy requirement may be partitioned into the amounts utilized for various functions by cows of different sizes (Figure 4). Cows weighing 900 lb. required 12.310 and 0.830 Mcal. DE per day for maintenance and cow gain plus

TABLE IX

MEANS AND STANDARD ERRORS FOR DAILY TOTAL DIGESTIBLE NUTRIENT REQUIREMENTS OF LARGE AND SMALL COWS IN VARIOUS STAGES OF PRODUCTION

Period	Small Cows	Large Cows
LACTATING PHASE		
Producing cows:		
TDN/day (lb.)	11.004 ± 0.360[d]	12.097 ± 0.872[d]
Corr. TDN/day (lb.)[1]	7.861 ± 0.307[a]	9.531 ± 0.472[a]
Maintenance cows:		
TDN/day (lb.)	6.770 ± 0.508	8.161 ± 0.980
NON-LACTATING PHASE		
Producing cows:		
TDN/day (lb.)	6.595 ± 0.329	7.488 ± 0.370
Maintenance cows:		
TDN/day (lb.)	5.397 ± 0.005[b]	6.772 ± 0.145[b]
COMPLETE YEAR		
Producing cows:		
TDN/day (lb.)	9.195 ± 0.423[d]	10.495 ± 0.581[d]
Corr. TDN/day (lb.)[1]	7.310 ± 0.115[a]	9.010 ± 0.112[a]
Maintenance cows:		
TDN/day (lb.)	6.114 ± 0.276	7.606 ± 0.509

[1]Daily energy requirements were corrected for energy required for milk production as explained in Materials and Methods.

[a, b, c, d] Indicate level of statistical significance where: a = ($P<.01$), b = ($P<.025$), c = ($P<.05$) and d = ($P<.10$).

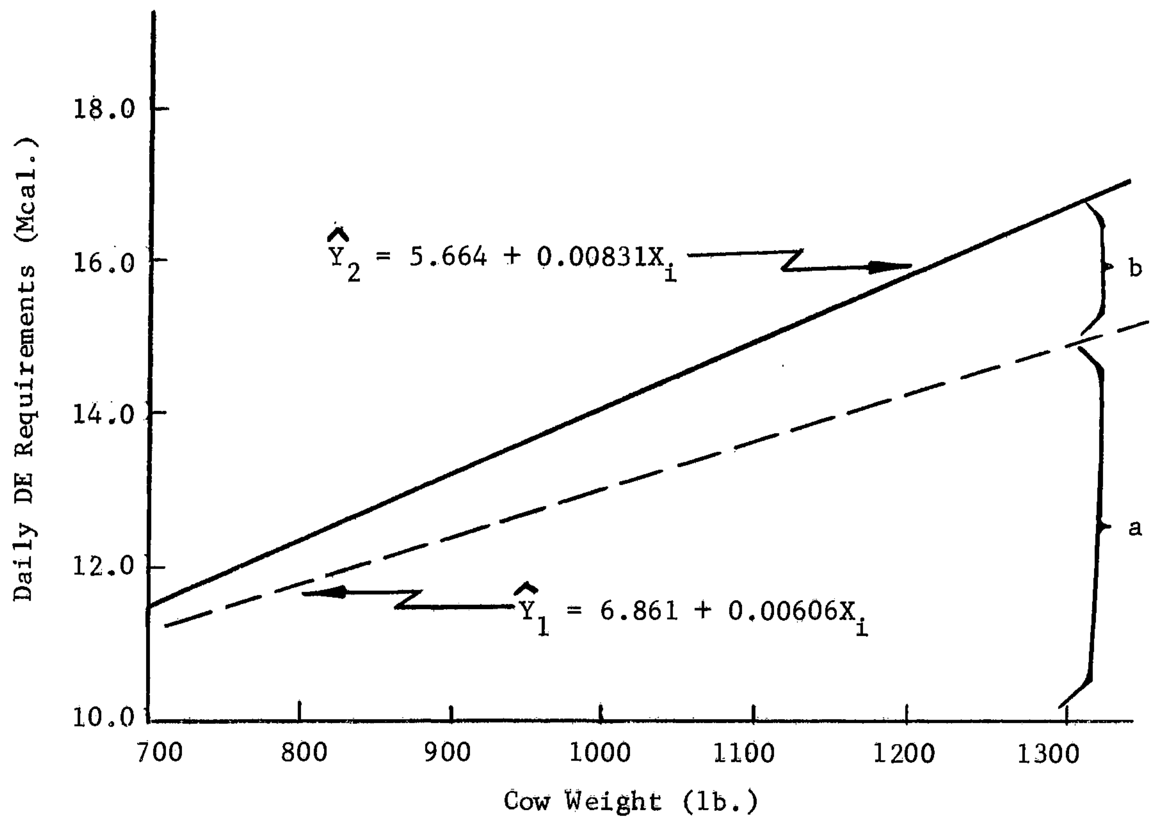

Figure 4. Daily Digestible Energy Required for Maintenance (Y_1) and Maintenance and Cow Gain Plus Fetal Growth (Y_2) During the Non-lactating Phase. (See text for explanation of a and b.)

fetal growth, respectively; while those weighing 1300 lb. required 14.732 and 1.734 Mcal. DE for the respective functions of maintenance and cow gain plus fetal growth. These results indicate that the 900 lb. cow utilized 93.7 and 6.3 percent of the daily DE requirement for maintenance and for body gain plus fetal growth, respectively; whereas the 1300 lb. cow utilized only 89.5 percent of the daily DE requirement for maintenance and 10.5 percent for body gain plus fetal growth. A possible explanation for the observation that small cows utilized a smaller percentage of the daily DE requirement for body weight gain plus fetal growth is the fact that the small cows gained less total weight during this phase even though the percentage weight gains were similar.

The predicted daily DE requirement of 13.97 Mcal. (Figure 4) for producing cows is somewhat lower than the recommended allowance for wintering a 1000 lb. pregnant beef cow which is 18.0 Mcal. daily (N.R.C., 1963). The recommended allowance for maintenance of a 1000 lb. dairy cow (N.R.C., 1966) is 14.18 Mcal. per day which is only 1.26 Mcal. greater than the predicted daily requirement for maintenance of a 1000 lb. cow during the non-lactating phase of 12.92 Mcal. (Figure 4).

The DE requirements of large and small producing cows did not differ significantly ($P>.10$) during the non-lactating phase (Table VII). However, the large cows did require 1.783 Mcal. more DE daily than did the small cows. On the other hand, the difference of 2.995 Mcal. DE per day between the large and small maintenance cows was significant ($P<.025$).

The TDN requirements during the non-lactating phase followed the same general patterns as DE requirements. When the data for TDN requirements are illustrated by use of regression analysis (Figure 5),

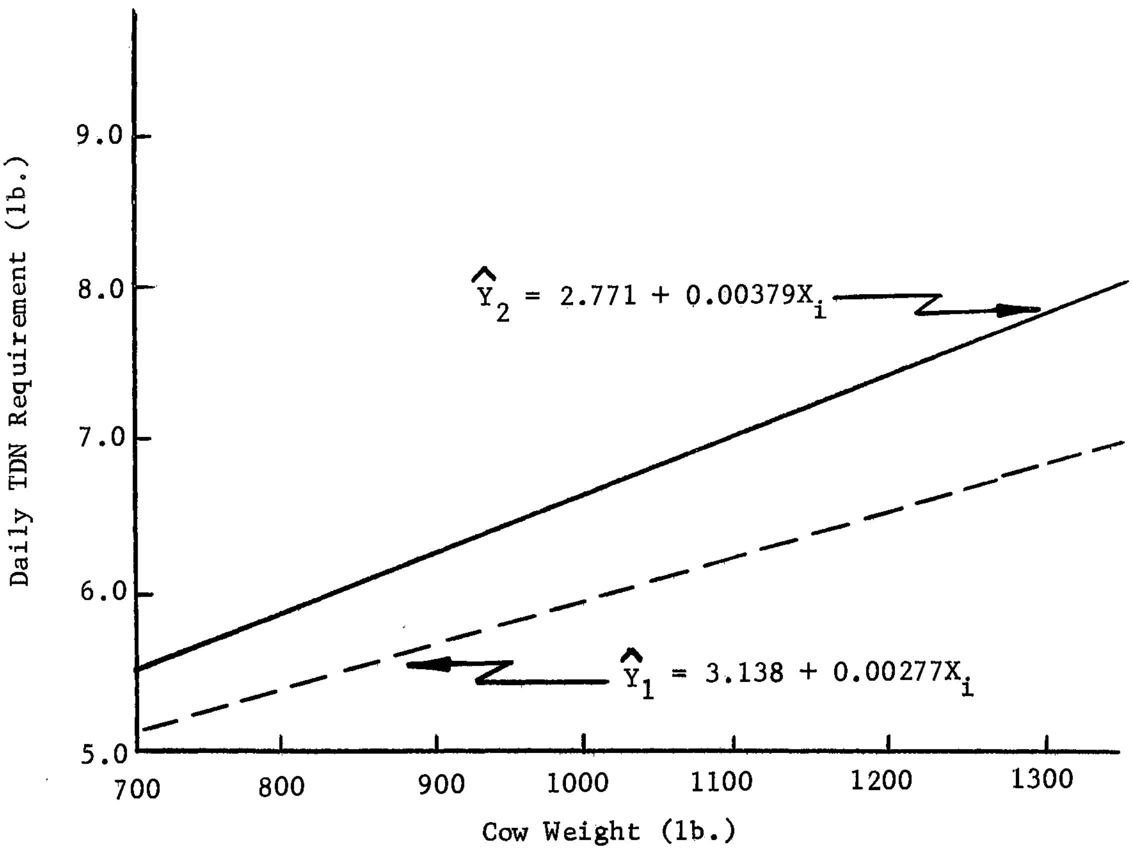

Figure 5. Daily Total Digestible Nutrients Required for Maintenance (Y_1) and Maintenance and Cow Gain Plus Fetal Growth (Y_2) During the Non-lactating Phase

daily TDN requirements of producing cows increased by 0.379 lb. for each 100 lb. increase in cow weight. The regression coefficient was significant (P<.025), and cow weight accounted for 30.9 percent of the variation in daily TDN requirements (Table VIII). Daily TDN requirements for maintenance increased by 0.277 lb. per day for each 100 lb. increase in cow weight. In this case, cow weight accounted for 86.2 percent of the total variation in daily TDN requirements.

The predicted daily TDN requirement of 6.56 lb. is lower than the recommended daily allowance of 9.0 lb. TDN daily (N.R.C., 1963) for wintering a 1000 lb. beef cow. The predicted daily TDN requirement for maintaining a 1000 lb. cow during the non-lactating phase is 5.91 lb., which is 1.20 lb. per day less than the recommended daily allowance for maintaining a 1000 lb. dairy cow (N.R.C., 1966).

The daily TDN requirements during the non-lactating phase are presented in Table IX and are similar to data for DE requirements. The difference of 0.893 lb. (Table VII) between the daily TDN requirements of large and small producing cows was not significant (P>.10). However, the difference of 1.375 between the maintenance requirements of large and small cows was significant (P<.025).

Examination of Figures 2 and 4 and Figures 3 and 5 indicates that maintenance requirements were greater during the lactating phase than during the non-lactating phase. This difference might be explained by a consideration of the rations used during the two phases. First, ration A, which was used in the lactating phase, contained 63.3 percent roughage whereas ration B, which was used in the non-lactating phase, contained 87.4 percent roughage. As ration B contained more roughage, which has greater retention time in the rumen than concentrates, the cows could have had more fill during the non-lactating phase. Since cows were given feed allowances on the basis of body weight changes, those having greater fill would have been fed less in an attempt to compensate for the increased weight. Also, due to the large amount of alfalfa hay in both rations (Table I), the crude protein content of both rations (Table II) was higher than that recommended by N.R.C. (1963). The amino acids of the excess protein would be deaminated and the nitrogen converted to urea, and the carbon chains could be utilized as an energy source. This process of protein utilization for energy produces a large amount of excess heat (Blaxter, 1962). During the summer this excess heat would require an expenditure of energy to rid the body of the added heat. However, during the non-lactating phase, which was in the winter season, some of the heat would be used to warm the body and would not be a total loss to the animal.

Complete Year

Data presented in this section were collected during both the lactating and non-lactating phases and involves five large and six small producing cows and two maintenance cows in each size group.

Data on DE requirements for the total production period are presented in Table VI and Figure 6 by means of calculated regressions. The significant ($P<.05$) regression coefficient of 0.00819 for the producing cows indicates that the DE requirements increased by 0.819 Mcal. per day for each 100 lb. increase in body weight. Therefore, each 1300 lb. cow required 3.276 Mcal. daily and 1195.74 Mcal. DE annually more than did 900 lb. cows.

After the data were corrected for the DE required for milk production (N.R.C., 1966), a significant ($P<.025$) regression coefficient

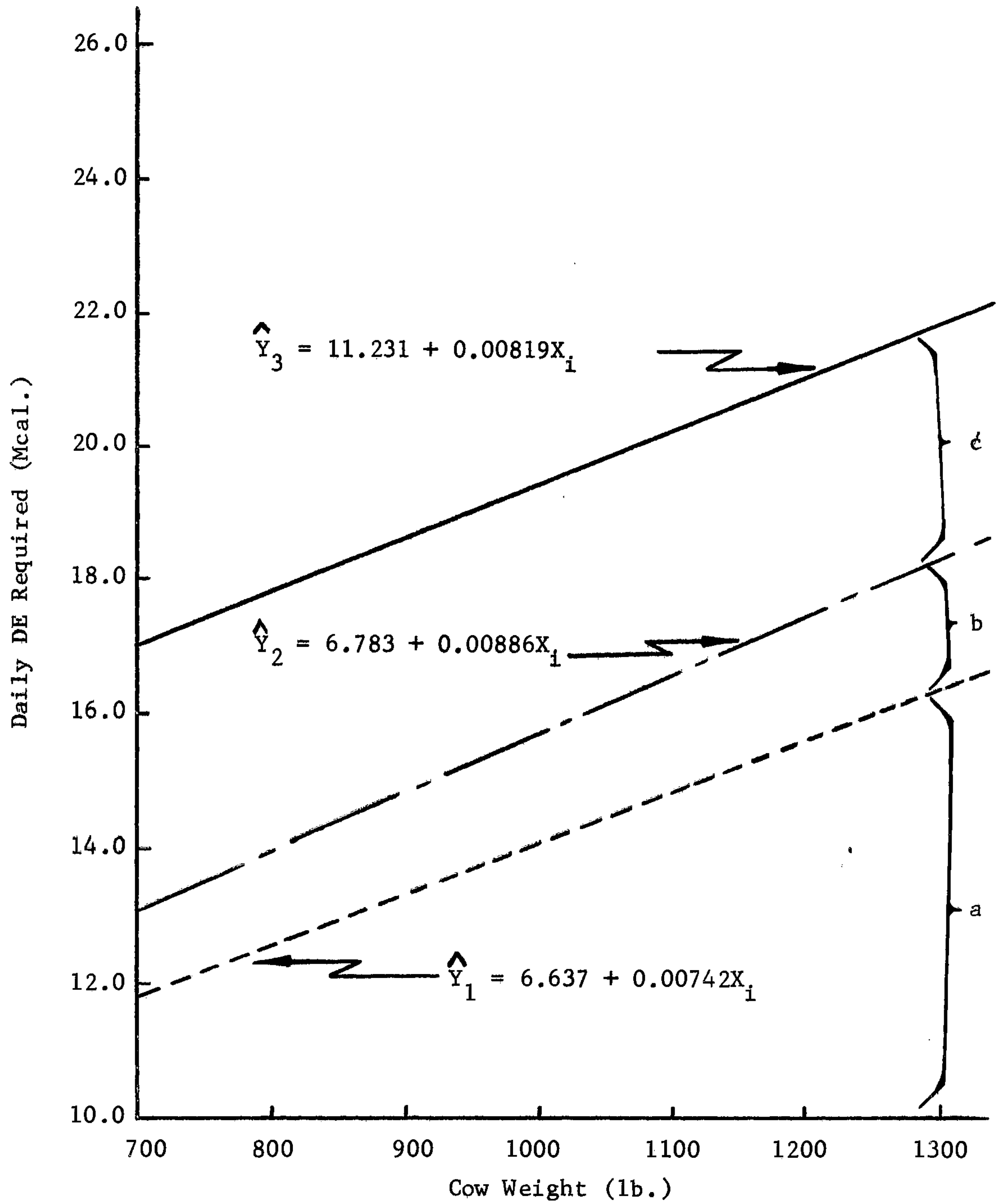

Figure 6. Daily Digestible Energy Required for Maintenance (Y_1), Maintenance and Cow Gain Plus Fetal Growth (Y_2) and Total Production (Y_3) During the Complete Year. (See text for explanation of a, b and c.)

was obtained when energy required for maintenance and body gain plus fetal growth was regressed on body weight. The coefficient of 0.00886 indicates that the requirement for maintenance and body gain plus fetal growth increased 0.886 Mcal. for each 100 lb. increase in body weight. In this case, body weight accounted for 44.6 percent of the total variation in DE requirements whereas it accounted for only 27.7 percent of the variation in DE requirements for total production (Table VI).

The daily DE requirements of the maintenance cows calculated on an annual basis were regressed on body weight, and a significant ($P<.05$) coefficient of 0.00742 was obtained indicating that each 100 lb. increase in cow weight required an increase of 0.742 Mcal. in daily DE requirements for maintenance. Weight accounted for 90.0 percent of the variation in maintenance requirements. When expressed on an annual basis, an increase of 100 lb. in body weight was associated with a 270.3 Mcal. increase in the DE requirement for maintenance.

If the assumptions are again made that area "a" represents DE required for "active maintenance," area "b" represents the DE required for body gain plus fetal growth and area "c" represents the DE required for milk production, the energy required for the various functions may be partitioned (Figure 6). The 900 lb. cows required 13.315 Mcal. for maintenance, 1.442 Mcal. for body gain plus fetal growth and 3.849 Mcal. for milk production whereas the 1300 lb. cows required 16.583, 2.018 and 3.583 Mcal. for maintenance, body gain plus fetal growth and milk production, respectively. If these estimations are expressed as percentage of total requirements, a 900 lb. cow utilized 71.6 percent of the DE requirement for maintenance while a 1300 lb. cow utilized 74.4 percent of the total DE requirement for maintenance. A 900 lb. cow utilized

7.8 percent of the total DE requirement for body gain plus fetal growth whereas a 1300 lb. cow utilized 9.2 percent for the same function. These differences may be explained partially on the basis of body weight. First, maintenance requirements are known to be greater for larger cows (Brody, 1945 and Kleiber, 1961). Secondly, even though all cows followed similar weight change patterns, the large cows had to gain more total body weight than the small cows as the pattern was based on percentage weight change. The proportion of the total daily DE requirement utilized for lactation was 20.7 percent for a 900 lb. cow and 16.4 percent for a 1300 lb. cow. This difference may be due in part to the greater gross energy yield in milk from small cows (Table V). The daily average gross energy on milk from small cows was 7.274 kcal. while the daily gross energy yield in milk from large cows was only 6.343 kcal.

For comparative purposes the N.R.C. (1966) requirements for dairy cows were used to calculate an annual daily requirement. This was done by weighting a recommended allowance derived for the lactating phase by 215/365 and weighting a recommended allowance derived for the non-lactating phase by 150/365. This yields a value of 20.29 Mcal. DE per day for the daily recommended allowance for a 1000 lb. producing cow which agrees rather closely with the predicted value of 19.43 Mcal. DE daily (Figure 6) for a 1000 lb. producing cow. However, the predicted value is less than the value derived from the N.R.C. (1963) beef cattle requirements for a 1000 lb. producing cow which is 27.18 Mcal. daily calculated on an annual basis.

The predicted value for the maintenance requirement of a 1000 lb. cow shown in Figure 6 is 14.06 Mcal. per day. This value is in close agreement with the N.R.C. (1966) recommended daily allowance for maintenance of a 1000 lb. dairy cow which is 14.18 Mcal.

Data presented in Table VII indicates that over the complete year the DE requirements of the large producing cows exceeded the DE requirements of small producing cows by 2.428 Mcal. per day. However, this difference was not significant (P>.10). When extended over the complete production year (365 days), the large cows required 886.22 Mcal. more DE than small cows. When the daily requirements were corrected for estimated daily DE required to support milk production (N.R.C., 1966), the large cows required 2.627 Mcal. DE per day more (P<.05) than the small cows.

The large maintenance cows required 16.142 Mcal. DE per day whereas the small maintenance cows required only 12.899 Mcal. daily, but this difference was not significant (P>.10); however, there were only four animals involved in the analysis.

Energy requirements for the total production period are also expressed as TDN. The regressions of TDN requirements for producing cows, producing cows independent of milk production and maintenance cows regressed on body weight are presented in Figure 7. In the case of producing cows, the significant (P<.05) regression coefficient indicates that an increase of 100 lb. in body weight required an increase of 0.432 lb. in the daily TDN requirement. When these data were corrected for the TDN required for milk production (N.R.C., 1966), a highly significant (P<.01) regression coefficient of 0.00532 was obtained indicating that for each 100 lb. increase in body weight the daily requirement for maintenance and body gain plus fetal growth increased by 0.532 lb. The regression coefficient for TDN requirements for

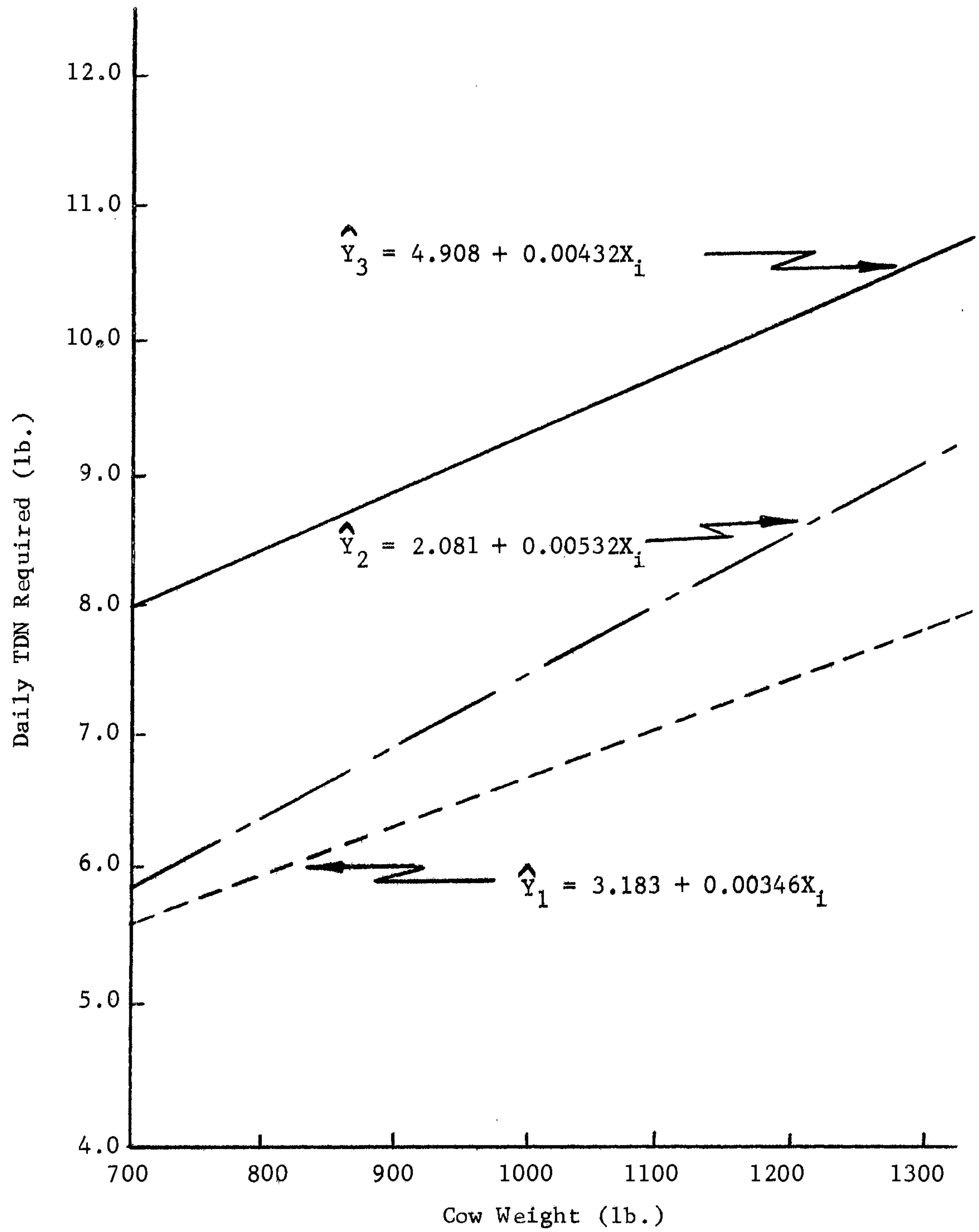

Figure 7. Daily Total Digestible Nutrients Required for Maintenance (Y_1), Maintenance and Cow Gain Plus Fetal Growth (Y_2) and Total Production (Y_3) During the Complete Year

maintenance regressed on body weight indicates that a 0.346 lb. increase in daily TDN requirement results when body weight is increased by 100 lb. For maintenance cows 89.3 percent of the variation in DE requirement is attributable to weight. Weight accounted for 33.4 percent of the variation in requirements for total production whereas it accounted for 58.9 percent of the variation in requirements for maintenance and cow gain plus fetal growth.

When the daily TDN requirement is derived from the N.R.C. (1966) recommended allowances for dairy cattle as described for DE comparison, a value of 11.03 lb. per day is obtained for the requirements of a 1000 lb. producing cow. This value is 1.80 lb. per day greater than the predicted daily TDN requirement of a 1000 lb. producing cow which is 9.23 lb. (Figure 7). The recommended allowance for a 1000 lb. beef cow (N.R.C., 1963) of 13.57 lb. daily is even higher than the requirement derived from the dairy requirements (N.R.C., 1966).

The predicted daily requirements of a 1000 lb. maintenance cow calculated on an annual basis was 6.64 lb. TDN. This value is only 0.46 lb. per day lower than the recommended daily allowance of 7.10 lb. for maintenance of a 1000 lb. dairy cow (N.R.C., 1966).

Means and standard errors for daily TDN requirements of large and small cows for the complete year are presented in Table IX. The large producing cows required an average of 10.495 lb. TDN daily whereas the average daily TDN requirement of small producing cows was 9.195 lb. This difference of 1.300 lb. daily approached statistical significance ($P>.10$). When these data were corrected for TDN required to support milk production, a highly significant ($P<.01$) difference of 1.700 lb. in daily TDN requirement for maintenance and cow gain plus fetal growth was noted indicating that the large cows required more energy for these functions than did small cows. Large maintenance cows required an average of 7.606 lb. of TDN daily whereas the daily requirement was only 6.114 lb. for small cows. This difference was not statistically significant ($P>.10$); however there were only four animals involved in the analysis.

DISCUSSION

This section will be devoted to discussions of four individual subjects. First, the value of variables other than weight for predicting DE requirements of producing beef cows. Second, prediction of requirements based on this study and a comparison of these requirements to published requirements. Third, a comparison of the relative total energy requirements of cows of various sizes. Fourth, a comparison of the increase in energy requirements expected for each 100 lb. increase in body weight versus the expected increase in weaning weight for each 100 lb. increase in cow weight.

Body measurements were used in an attempt to account for more of the total variation in daily DE requirements. Multiple regression equations of daily DE requirements regressed on body weights, various body measurements and milk production are presented in Table X. Equation 1 indicated that weight alone accounted for only 27.7 percent of the total variation in daily DE requirements. The amount of variation in DE requirements that can be accounted for is increased when any measure shown in Table X is used in conjunction with weight. However, length of body (equation 3) and heart girth (equation 4), when considered separately with weight, account for more variation in daily DE requirements than any of the other variables. When considered separately with weight, length of body (equation 3) and heart girth (equation 4) accounted for 44.8 and 42.9 percent, respectively; however, when

TABLE X

MULTIPLE REGRESSION EQUATIONS FOR DIGESTIBLE ENERGY REQUIREMENTS REGRESSED ON COW WEIGHT, VARIOUS BODY MEASUREMENTS AND MILK PRODUCTION

Equation No.	DE Intercept	Body Weight	Wither Height	Length of Body	Heart Girth	Fat Thickness	Annual Milk Yield	Variation Accounted for by Regression
	(Mcal.)	(lb.)	(in.)	(in.)	(in.)	(mm)	(lb.)	(%)
1	11.231	0.00819						27.7
2	30.408	0.01421	-.572					30.8
3	35.614	0.01522		-.625				44.8
4	1.073	0.02053			-.503			42.9
5	8.568	0.01478				-.517		34.9
6[1]	4715.522	0.13007					0.934	39.4
7[2]	4.463	0.00753					0.841	81.0
8	52.142	0.02458		-.538	-.422			55.2
9[1]	7522.395	5.16246		-162.390			0.902	80.4
10[1]	-122.072	2.81824			22.424		0.978	71.7
11[1]	1176.428	1.46743				154.824	1.149	74.6
12[1]	5002.485	3.99362		-170.701	53.176		1.004	81.8

[1]Calculated on the basis of total annual DE requirements and total annual milk production

[2]Calculated for lactating phase on basis of daily DE requirements and daily milk production

weight, length of body and heart girth were considered together (equation 8), 55.2 percent of the variation in DE requirements was attributable to these three variables.

Daily milk production during the lactating phase considered with body weight accounted for 81.0 percent of the variation in daily DE requirements during that phase. These two variables account for more of the variation in DE requirements than any two of the other variables. However, when body weight and annual milk production (equation 7) were used to predict annual DE requirements, only 39.4 percent of the variation was accounted for by these variables. The addition of length of body (equation 9), heart girth (equation 10) or fat thickness (equation 11) to the equation above increased the amount of variation accounted for to 80.4, 71.2 and 74.6 percent, respectively. Weight, length of body, heart girth and milk production considered together (equation 12) accounted for 81.8 percent of the total variation in annual DE requirements.

These data indicate that the power of prediction for DE requirements may be increased by consideration of variables other than body weight.

Daily DE requirements during the lactation phase may be determined by two different methods from this study. First, the energy equivalent for each lb. of 4 percent FCM 0.662 Mcal., (N.R.C., 1966) may be added to the requirements for maintenance and cow gain plus fetal growth, which may be predicted from the equation (Figure 2):

$$\text{Daily DE (Mcal.)} = 6.764 + 0.00980\text{Weight (lb.)}.$$

Secondly, a multiple regression equation may be developed using cow weight and daily yield of 4 percent FCM as independent variables to predict the dependent variable, daily DE requirement. This equation, which accounts for 67.2 percent of the total variation in daily DE requirements, developed from this study is:

$$\text{Daily DE (Mcal.)} = 2.934 + 0.01091\text{Weight (lb.)} + 0.941 \text{ daily } 4\% \text{ FCM (lb.)}.$$

Daily DE requirements calculated by both methods from this study compare favorably (Table XI). However, both are higher than the recommended allowances for dairy cows (N.R.C., 1966). This difference may be explained by the fact that the N.R.C., (1966) requirements are calculated on the basis of maintenance and milk production whereas the predicted requirements also include cow gain plus fetal growth. The recommended nutrient allowances for beef cattle (N.R.C., 1963) indicates that the daily DE requirement of a cow weighing from 900 to 1100 lb. is 33.6 Mcal. This value is greater than any value shown in Table XI. Therefore, indicating that the recommended DE requirements for a lactating beef cow (N.R.C., 1963) may be too high.

Daily TDN requirements for lactation may be predicted by the same procedures as described for predicting daily DE requirements. Daily TDN requirements during lactation may be predicted by adding the TDN required for milk production, 0.330 lb. per lb. of 4 percent FCM, (N.R.C., 1966) to the TDN required for maintenance and cow gain plus fetal growth which may be predicted from the equation (Figure 3):

$$\text{Daily TDN (lb.)} = 2.529 + 0.00538\text{Weight (lb.)}.$$

TABLE XI

DAILY DIGESTIBLE ENERGY AND TOTAL DIGESTIBLE NUTRIENT REQUIREMENTS OF BEEF COWS FOR LACTATION BASED ON WEIGHT AND YIELD OF 4 PERCENT FAT CORRECTED MILK

Body Weight	Lb.	Daily DE (Mcal.)			Daily TDN (Lb.)		
		Predicted		N.R.C.	Predicted		N.R.C.
(Lb.)	4% FCM[1]	I[2]	II[3]	(1966)[4]	I[5]	II[6]	(1966)[4]
800	6	17.31	18.58	16.45	7.99	8.81	8.24
	8	19.19	19.90	17.77	8.95	9.47	8.90
	10	21.07	21.21	19.10	9.92	10.13	9.56
	12	22.95	22.55	20.42	10.89	10.79	10.22
	14	24.84	23.87	21.75	11.86	11.45	10.88
900	6	18.40	19.56	17.15	8.61	9.35	8.58
	8	20.28	20.89	18.48	9.57	10.01	9.24
	10	22.16	22.20	19.80	10.54	10.67	9.90
	12	24.04	23.53	21.12	11.51	11.33	10.56
	14	25.93	24.85	22.45	12.48	11.99	11.22
1000	6	19.49	20.54	18.15	9.23	9.89	9.08
	8	21.37	21.86	19.48	10.19	10.55	9.74
	10	23.25	23.18	20.80	11.16	11.21	10.40
	12	25.14	24.51	22.12	12.13	11.87	11.06
	14	27.18	25.83	23.45	13.10	12.53	11.72
1100	6	20.58	21.52	19.15	9.85	10.43	9.58
	8	22.46	22.83	20.48	10.81	11.09	10.24
	10	24.34	25.14	21.80	11.78	11.75	10.90
	12	26.23	26.47	23.12	12.75	12.41	11.56
	14	28.11	27.79	24.45	13.77	13.07	12.22
1200	6	21.67	22.50	20.50	10.47	10.96	10.27
	8	23.55	23.82	21.82	11.43	11.62	10.93
	10	25.44	25.14	23.14	12.40	12.28	11.59
	12	27.32	26.47	24.47	13.37	12.94	12.25
	14	29.20	27.79	25.79	14.34	13.60	12.91
1300	6	22.76	23.48	21.23	11.09	11.50	10.62
	8	24.64	24.80	21.23	12.05	12.16	11.28
	10	26.53	26.42	23.87	13.02	12.82	11.94
	12	28.41	27.45	25.20	13.99	13.48	12.60
	14	30.29	28.77	26.52	14.86	14.14	13.26

[1]Calculated as 4% FCM (lb.) = 0.4 (weight of milk) + 15 (weight of fat).

[2]Calculated by the formula: Daily DE (Mcal.) = 2.934 + 0.01091weight (lb.) + 0.941 4% FCM (lb.).

[3]Determined by adding the DE required to produce each lb. of 4% FCM (N.R.C., 1966) to the requirement for maintenance, body gain and fetal growth calculated by the formula: Daily DE (Mcal.) = 6.764 + 0.00980weight (lb.).

[4]N.R.C. (1966) requirements for maintenance and lactation of dairy cows.

[5]Calculated by the formula: Daily TDN (lb.) = 0.122 + 0.0062weight (lb.) + 0.484 4% FCM (lb.).

[6]Determined by adding the TDN required to produce each lb. of 4% FCM (N.R.C., 1966) to the requirement for maintenance, body gain and fetal growth calculated by the formula: Daily TDN (lb.) = 2.529 + 0.0053weight (lb.).

The multiple regression equation developed from this study for predicting TDN requirements is:

$$\text{Daily TDN (lb.)} = 0.122 + 0.00620\text{Weight (lb.)} + 0.484\ 4\%\ \text{FCM (lb.)}.$$

This equation accounted for 72.5 percent of the variation in daily TDN requirements during the lactating phase. A comparison of the two predicted values and the requirements recommended for dairy cows (N.R.C., 1966) is presented in Table XI. As with DE requirements, the values predicted by the two methods developed from this study agree closely while both are generally higher than the requirement derived from recommended TDN allowances for dairy cows (N.R.C., 1966). The recommended TDN allowance for lactating beef cows (N.R.C., 1963) indicate that beef cows weighing 900 to 1100 lb. should receive 16.8 lb. TDN daily which is greater than any value presented in Table XI.

Predicted energy requirements for wintering beef cows, which corresponds to the non-lactating phase of this study, are shown in Table XII. The DE requirements were calculated by the following regression equation (Figure 4):

$$\text{Daily DE (Mcal.)} = 5.664 + 0.00831\text{Weight (lb.)}.$$

Values for TDN requirements were calculated by the following equation (Figure 5):

$$\text{Daily TDN (lb.)} = 2.771 + 0.00379\text{Weight (lb.)}.$$

Predicted DE and TDN requirements for maintenance calculated on the basis of the complete year are also presented in Table XII. Daily

TABLE XII

DAILY DIGESTIBLE ENERGY AND TOTAL DIGESTIBLE NUTRIENT REQUIREMENTS FOR MAINTENANCE OF MATURE BEEF COWS AND WINTERING MATURE, PREGNANT BEEF COWS

Body Weight	Predicted Values DE[1]	Predicted Values TDN[2]	N.R.C. (1966) DE	N.R.C. (1966) TDN
(lb.)	(Mcal.)	(lb.)	(Mcal.)	(lb.)
	Maintenance of Mature Cows			
800	12.67	5.75	12.48	6.26
900	13.32	6.30	13.18	6.60
1000	14.06	6.64	14.18	7.10
1100	14.80	6.99	15.18	7.60
1200	15.54	7.34	16.52	8.29
1300	16.28	7.68	17.25	8.64
	Wintering Mature, Pregnant Beef Cows			
800	12.31	5.80		
900	13.14	6.28		
1000	13.97	6.56		
1100	14.80	6.94		
1200	15.64	7.32		
1300	16.47	7.70		

[1]Daily DE (Mcal.) = 6.637 + 0.00742weight (lb.) for maintenance and daily DE (Mcal.) = 5.669 + 0.00831weight (lb.) for wintering.

[2]Daily TDN (lb.) = 3.183 + 0.00346weight (lb.) for maintenance and daily TDN (lb.) = 2.771 + 0.00379weight (lb.) for wintering.

DE requirements were calculated by the equation (Figure 6):

$$\text{Daily DE (Mcal.} = 6.637 + 0.00742\text{Weight (lb.)},$$

and the daily TDN requirements for maintenance were calculated by the following equation (Figure 7):

$$\text{Daily TDN (lb.)} = 3.183 + 0.00346\text{Weight (lb.)}.$$

These values are shown in comparison with the N.R.C. (1966) requirements for maintaining mature dairy cows. The close agreement between the predicted values and the N.R.C. (1966) recommended energy allowances for dairy cows suggests that the daily energy allowances proposed for dairy cows by N.R.C. (1966) may be used to predict maintenance requirements of beef cows.

The percentage by which the energy required by large cows exceeds the energy requirements of small cows is of interest when considering the economics of cow size. A 900 lb. cow required 13.317 Mcal. DE for maintenance whereas a 1300 lb. cow required 16.285 Mcal. DE for maintenance. Therefore, the 1300 lb. cow required 22.3 percent more DE daily for maintenance than a 900 lb. cow. In a similar manner, a 1300 lb. cow required 22.0 percent more TDN for maintenance than a 900 lb. cow. In the case of DE required for maintenance and cow gain plus fetal growth, a 900 lb. cow required 14.757 Mcal. DE per day while a 1300 lb. cow required 18.301 Mcal. DE daily. This is an increase of 24.0 percent in the DE requirements of a 1300 lb. cow over a 900 lb. cow. Likewise, a 1300 lb. cow required 31.0 percent more TDN for maintenance and cow gain plus fetal growth than did a 900 lb. cow. When the requirement for total production which includes energy utilized for maintenance, body gain plus fetal growth and lactation, is considered a 1300 lb. cow required 21.878 Mcal. DE per day while a 900 lb. cow required only 18.602 Mcal. DE daily. Therefore, the 1300 lb. cow required 17.6 percent more DE daily for total production than did the 900 lb. cow. In a like manner, 19.6 percent more TDN was required by a 1300 lb. cow than by a 900 lb. cow for total production.

A comparison of the amount of energy required annually to support each additional 100 lb. of cow weight and the expected increase in calf weaning weight for each 100 lb. increase in cow weight is necessary for economic evaluation of the data. In this study, each additional 100 lb. increase in cow weight was associated with a 299.30 Mcal. increase in the annual DE requirement or a 157.68 lb. increase in the annual TDN requirement. Expected increases in weaning weight associated with each 100 lb. increase in cow weight have been reported from 4.9 lb. (Tanner *et al*., 1965) to 18.0 lb. (Marchello *et al*., 1960). Economic evaluation of the data would be dependent on certain assumptions relative to expected increase in weaning weight associated with increments of cow weight and the value per unit of weaned weight.

SUMMARY

This experiment was conducted at the Fort Reno Livestock Research Station at El Reno, Oklahoma, to study the influence of mature cow size on energy requirements of beef cows for maintenance and production. All cows were maintained in a dry lot and individually fed weighed amounts of feed daily. There was a group of large cows that averaged 1318 lb. in weight and a group of small cows with an average weight of 956 lb. Cows in each size group were divided into two categories: (1) producing cows that were fed to follow a set weight change pattern and (2) maintenance cows that were fed to maintain a constant weight throughout the entire study. The study was divided into two phases: (1) a lactating phase during which the producing cows were fed to follow a set weight change pattern while producing a calf and (2) a non-lactating phase during which producing cows were fed to gain 5 percent of their body weight while producing a fetus. Proper weight change was attained by weekly adjustment of feed allowances on the basis of weekly weights taken after a 12 hr. period without feed and water. Two digestion trials were conducted by use of the chromium oxide reference technique to determine the digestible energy (DE) and total digestible nutrient (TDN) values for the rations used in the study. Regression analyses were used to predict the increase in daily energy requirements for each 100 lb. increase in body weight.

There were only small differences between the productivity in terms

of calf performance and milk production between the two groups of cows while in dry lot.

During the lactating phase DE requirements for total production (maintenance, cow gain plus fetal growth, and milk production) increased by 0.628 Mcal. per day for each 100 lb. increase in body weight. The DE required for total production independent of milk production, which includes energy required for maintenance and cow gain plus fetal growth, increased by 0.980 Mcal. per day for each 100 lb. increase in cow weight. Maintenance requirements during this phase increased by 0.787 Mcal. per day for each 100 lb. increase in cow weight. During this phase the amount of variation in daily DE requirements accounted for by cow weight was 67.3 percent for maintenance, 45.4 percent for production independent of milk production and 13.0 percent for total production.

Total energy requirements during the non-lactating phase were partitioned into that required for maintenance and that required for cow gain plus fetal growth. During this phase daily DE requirements for maintenance and cow gain plus fetal growth increased by 0.831 Mcal. for each 100 lb. increase in cow weight whereas maintenance requirements increased by 0.606 Mcal. daily for each 100 lb. increase in weight. The amount of total variation in daily DE requirements accounted for by cow weight were 28.3 percent for producing cows and 86.6 percent for maintenance cows.

The total energy requirements for the complete year, which includes both the lactating phase and the non-lactating phase, were partititioned into the energy required for maintenance, for cow gain plus fetal growth, and for lactation. The daily DE required for total production increased by 0.819 Mcal. for each 100 lb. increase in cow weight, and the daily DE required for maintenance and cow gain plus fetal growth increased by 0.886 Mcal. for each 100 lb. increase in cow weight. The daily DE required for maintenance increased by 0.742 Mcal. for each 100 lb. increase in cow weight. For the complete year, cow weight accounted for 90.0, 44.6 and 27.7 percent of the total variation in DE requirements for maintenance, production independent of milk production and total production, respectively.

Data for TDN requirements followed the same general patterns as those for DE requirements.

Milk yield and the following body measurements; wither height, length of body, heart girth and estimated fat thickness at the 13th rib were used in conjunction with cow weight in multiple regression analyses to predict DE requirements of producing cows. Weight alone accounted for only 27.7 percent of the total variation in daily DE requirements whereas the addition of either body length or heart girth to the equation increased the amount of accountable variation to 44.8 percent or 42.9 percent, respectively. When weight, length of body and heart girth were considered together, 55.2 percent of the variation in daily DE requirements could be attributed to these three variables. Daily milk production and cow weight were used to predict the daily DE requirements during the lactating phase and accounted for 81.0 percent of the variation in daily DE requirements during that phase. However, annual milk production and cow weight accounted for only 39.4 percent of the variation in annual DE requirements. When length of body was added to this equation, the amount of variation in annual DE requirements accounted for was increased to 80.4 percent. This equation accounted for almost as much of the variation in annual DE requirements as an equation which contained weight, length of body, heart girth and annual milk production, which accounted for 81.8 percent of the total variation in annual DE requirements.

Equations are presented for calculation of daily DE and TDN requirements for beef cows during lactation, the wintering period and for maintenance. The predicted requirements based on data from this study are compared to published energy requirements.

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APPENDIX

TABLE XIII

INDIVIDUAL WEIGHTS AND DIGESTIBLE ENERGY REQUIREMENTS OF PRODUCING COWS USED IN VARIOUS PHASES OF THE STUDY

Cow No.[1]	Body Weight	Lactating Phase		Non-lactating Phase	Entire Year	
		DE/day	Corr. DE/day[2]	DE/day	DE/day	Corr. DE/day[2]
	(lb.)	(Mcal.)	(Mcal.)	(Mcal.)	(Mcal.)	(Mcal.)
Large cows:						
2	1315			12.696		
4	1140			13.086		
5	1280	27.105	21.634	19.262	24.190	19.158
6	1285	26.890	20.780	18.654	23.450	19.926
8	1315	25.546	19.346	14.259	20.479	16.038
9	1370	26.177	19.780	19.547	23.396	19.748
10	1285	17.946	16.061	16.792	17.528	16.502
21	1130			14.236		
22	1260			14.916		
Small cows:						
11	1005	23.206	16.809	15.114	19.639	16.130
12	1040	22.367	17.038			
13	970	22.074	13.545	11.884	17.498	12.858
14	1005	22.864	16.999	15.824	20.318	16.616
15	975	23.901	16.116			
16	980	26.479	19.136	15.067	22.335	17.658
17	935	19.024	14.423	12.038	16.044	13.450
19	990	23.706	17.676	15.012	20.443	16.570

[1]Some cows were not used in all phases of the study as some cows lost calves during the lactating phase or did not conceive for the next calf.

[2]Daily DE requirements were corrected for DE required for milk production as explained in Materials and Methods.

TABLE XIV

INDIVIDUAL WEIGHTS AND DIGESTIBLE ENERGY REQUIREMENTS OF MAINTENANCE COWS USED IN VARIOUS PHASES OF THE STUDY

Cow No.	Body Weight	Lactating Phase DE/Day	Non-lactating Phase DE/Day	Entire Year DE/Day
	(lb.)	(Mcal.)	(Mcal.)	(Mcal.)
Large cows:				
3	1320	19.049	14.475	17.199
7	1250	14.955	15.109	15.085
Small cows:				
18	930	14.825	11.803	13.403
20	750	12.925	11.790	12.396

TABLE XV

INDIVIDUAL WEIGHTS AND TOTAL DIGESTIBLE NUTRIENT REQUIREMENTS OF PRODUCING COWS USED IN VARIOUS PHASES OF THE STUDY

Cow No.[1]	Body Weight	Lactating Phase		Non-lactating Phase	Entire Year	
		TDN/day	Corr. TDN/day[2]	TDN/day	TDN/day	Corr. TDN/day[2]
	(lb.)	(lb.)	(lb.)	(lb.)	(lb.)	(lb.)
Large cows:						
2	1315			8.790		
4	1140			6.004		
5	1280	13.020	10.327	8.956	11.500	9.874
6	1285	12.938	9.930	8.540	11.099	9.365
8	1315	13.085	10.033	7.513	10.581	8.928
9	1370	12.832	9.682	8.607	11.048	9.142
10	1285	8.614	7.686	7.697	8.247	7.742
21	1130			7.153		
22	1260			7.131		
Small cows:						
11	1005	11.148	7.998	6.902	9.272	7.544
12	1040	10.740	8.117			
13	970	10.694	6.395	5.436	8.275	5.990
14	1005	10.961	8.074	7.735	9.610	7.788
15	975	11.460	8.026			
16	980	12.707	9.092	6.890	10.594	8.292
17	935	9.049	6.784	5.950	7.729	6.451
19	990	11.373	8.405	6.655	9.692	7.796

[1]Some cows were not used in all phases of the study as some cows lost calves during the lactating phase or did not conceive for the next calf.

[2]Daily TDN requirements were corrected for TDN required for milk production as explained in Materials and Methods.

TABLE XVI

INDIVIDUAL WEIGHTS AND TOTAL DIGESTIBLE NUTRIENT REQUIREMENTS OF MAINTENANCE COWS USED IN VARIOUS PHASES OF THE STUDY

Cow No.	Body Weight	Lactating Phase TDN/Day	Non-lactating Phase TDN/Day	Entire Year TDN/Day
	(lb.)	(lb.)	(lb.)	(lb.)
Large cows:				
3	1320	9.141	6.627	8.115
7	1250	7.181	6.917	7.096
Small cows:				
18	930	7.278	5.392	6.390
20	750	6,261	5.402	5.838

TABLE XVII

DATA FROM PRODUCING COWS USED FOR CALCULATION OF MULTIPLE REGRESSION EQUATIONS

Cow No.	Annual DE Required[1]	Daily DE Required	Body Weight	Wither Height	Length of Body	Heart Girth	Fat Thickness[2]	Annual Milk Yield	Daily Milk Yield
	(Mcal.)	(Mcal.)	(lb.)	(in.)	(in.)	(in.)	(mm.)	(lb.)	(lb.)
Large cows:									
5	8716.862	24.189	1280	47.0	53.0	79.5	11.67	2930.45	13.63
6	8579.435	23.450	1285	48.0	52.0	75.5	8.67	3362.60	15.64
8	7631.174	20.479	1315	47.0	54.0	77.5	11.67	2820.80	13.12
9	8560.178	23.396	1370	46.5	56.0	82.0	12.00	3201.35	14.89
10	6377.168	17.528	1285	47.0	54.0	82.0	13.67	1075.00	5.00
Small cows:									
11	7256.493	19.639	1005	44.5	50.0	70.5	6.83	2881.00	13.40
13	6528.671	17.498	970	44.0	51.0	72.5	5.67	3261.55	15.17
14	7289.431	20.318	1005	44.0	48.5	74.5	8.33	2625.15	12.21
16	7952.990	22.335	980	44.5	50.5	69.0	8.67	3455.05	16.07
17	5895.804	16.044	935	44.0	53.0	70.5	7.67	2423.05	11.27
19	7348.422	20.443	990	43.0	47.0	71.0	6.67	2629.45	12.23

[1]Annual DE requirement was calculated by multiplying the daily DE requirement during lactating phase by 215 days and adding this to the daily DE requirement during the non-lactating phase times 150 days.

[2]A thermister probe was employed to estimate the fat thickness over the 13th rib.

TABLE XVIII

SUMS, SUMS OF SQUARES AND SUMS OF CROSS-PRODUCTS FOR COW WEIGHT AND DIGESTIBLE ENERGY REQUIREMENTS CALCULATED ON ACTUAL DATA AND DATA CORRECTED FOR WEIGHT CHANGE

	Producing Cows			Maintenance Cows	
	Weight	DE/day	Corr. DE/day[1]	Weight	DE/day
ACTUAL DATA					
Large cows:					
Lactating phase					
n[2]	5	5	5	2	2
s[3]	6,535	124.8198	96.7571	2,570	35.3481
ss[4]	8,546,975	3,164.5334	1,884.2564	3,304,900	638.2548
scp[5]		163,327.4080	126,504.4200		45,697.0090
Non-lactating phase					
n	9	9		2	2
s	11,380	138.5710		2,570	28.3803
ss	14,440,300	2,181.5916		3,304,900	402.8585
scp		176,058.7010			36,450.3140
Entire year					
n	5	5	5	2	2
s	6,535	108.5311	90.8595	2,570	32.3915
ss	8,546,975	2,390.1797	1,666.2047	3,304,900	527.4005
scp		141,918.9180	118,792.7435		41,705.8420
Small cows:					
Lactating phase					
n	8	8	8	2	2
s	7,900	185.8057	134.7380	1,680	28.4838

TABLE XVIII (Continued)

	Producing Cows			Maintenance Cows	
	Weight	DE/day	Corr. DE/day[1]	Weight	DE/day
ss	7,807,900	4,342.6401	2,287.5830	1,427,400	406.3481
scp		183,618.5355	133,212.6170		24,031.7100
Non-lactating phase					
n	6	6		2	2
s	5,885	84.1247		1,680	54.6146
ss	5,775,675	1,197.3344		1,427,400	769.8237
scp		82,724.1490			49,517.1080
Entire year					
n	6	6	6	2	2
s	5,885	116.8987	93.9043	1.680	25.8217
ss	5,775,675	2,301.7495	1,487.2484	1,427,400	334.3344
scp		116,869.8685	92,279.5015		21,814.5630
DATA CORRECTED FOR WEIGHT CHANGE					
Large cows:					
Lactating phase					
n	5	5	5	2	2
s	6,535	123.6638	97.6011	2,570	34.0036
ss	8,546,975	3,117.6364	1,923.3165	3,304,900	586.5012
scp		161,763.8980	127,570.9100		43,837.9020
Non-lactating phase					
n	9	9		2	2
s	11,380	143.4489		2,570	29.5841

TABLE XVIII (Continued)

	Producing Cows			Maintenance Cows	
	Weight	DE/day	Corr. DE/day[1]	Weight	DE/day
ss	14,440,300	2,343.9836		3,304,900	437.8102
scp		182,228.4515			37,993.3960
Entire year					
n	5	5	5	2	2
s	6,535	109.0426	91.3707	2,570	32.2842
ss	8,546,975	2,409.0385	1,683.5449	3,304,900	523.3701
scp		142,601.8100	119,475.2390		41,559.2010
Small cows:					
Lactating phase					
n	8	8	8	2	2
s	7,900	183.6207	131.7428	1,680	27.7506
ss	7,807,900	4,245.0958	2,191.6711	1,427,400	386.8525
scp		181,482.7910	130,287.1225		23,481.4860
Non-lactating phase					
n	6	6		2	2
s	5,885	84.9393		1,680	23.5932
ss	5,775,675	1,217.3541		1,427,400	278.3196
scp		83,503.5235			19,819.4220

TABLE XVIII (Continued)

	Producing Cows			Maintenance Cows	
	Weight	DE/day	Corr. DE/day[1]	Weight	DE/day
Entire year					
n	6	6	6	2	2
s	5,885	116.2779	93.2829	1,680	25.7985
ss	5,775,675	2,278.9025	1,468.9011	1,427,400	333.2888
scp		114,258,6440	91,667.7890		21,761.4150

[1]Daily energy requirements were corrected for energy required for milk production by procedure explained in Materials and Methods.

[2]n = number of observations in each cell.

[3]s = sum of all observations in each cell.

[4]ss = sum of squares of the cell.

[5]scp = sum of cross-products between weight and the item represented by the cell.

TABLE XIX

SUMS, SUMS OF SQUARES AND SUMS OF CROSS-PRODUCTS FOR COW WEIGHT AND TOTAL DIGESTIBLE NUTRIENT REQUIREMENTS CALCULATED ON ACTUAL DATA AND DATA CORRECTED FOR WEIGHT CHANGE

	Producing Cows			Maintenance Cows	
	Weight	TDN/day	Corr. TDN/day[1]	Weight	TDN/day
ACTUAL DATA					
Large cows:					
Lactating phase					
n[2]	5	5	5	2	2
s[3]	6,535	62.376	49.548	2,570	16.996
ss[4]	8,546,975	793.304	495.765	3,304,900	146.791
scp[5]		81,601.170	64,771.345		21,915.880
Non-lactating phase					
n	9	9		2	2
s	11,380	64.080		2,570	12.978
ss	14,440,300	464.772		3,304,900	84.243
scp		81,433.650			16,668.330
Entire year					
n	5	5	5	2	2
s	6,535	52.237	44.918	2,570	15.261
ss	8,546,975	553.235	406.647	3,304,900	117.095
scp		68,311.730	58,712.355		19,650.180
Small cows:					
Lactating phase					
n	8	8	8	2	2
s	7,900	89.070	63.929	1,680	13.892

TABLE XIX (Continued)

	Producing Cows			Maintenance Cows	
	Weight	TDN/day	Corr. TDN/day[1]	Weight	TDN/day
ss	7,807,900	998.249	515.271	1,427,400	96.726
scp		88,026.405	63,211.325		11,630.660
Non-lactating phase					
n	6	6		2	2
s	5,885	38.906		1,680	10.606
ss	5,775,675	255.263		1,427,400	56.408
scp		38,237.830			8,960.700
Entire year					
n	6	6	6	2	2
s	5,885	55.465	46.043	1,680	12.238
ss	5,775,675	517.806	361.515	1,427,400	75.149
scp		54,495.425	45,253.335		10,345.440
DATA CORRECTED FOR WEIGHT CHANGE					
Large cows:					
Lactating phase					
n	5	5	5	2	2
s	6,535	60.489	47.658	2,570	16.322
ss	8,546,975	746.991	458.729	3,304,900	135.125
scp		79,146.535	62,312.855		21,042.370

TABLE XIX (Continued)

	Producing Cows			Maintenance Cows	
	Weight	TDN/day	Corr. TDN/day[1]	Weight	TDN/day
Non-lactating phase					
n	9	9		2	2
s	11,380	67.391		2,570	13.544
ss	14,440,300	514.450		3,304,900	91.762
scp		85,525.770			17,393.890
Entire year					
n	5	5	5	2	2
s	6,535	52.475	45.051	2,570	15.211
ss	8,546,975	557.467	408.423	3,304,900	116.206
scp		68,629.385	58,886.075		19,581.800
Small cows:					
Lactating phase					
n	8	8	8	2	2
s	7,900	88.032	62.891	1,680	13.539
ss	7,807,900	976.031	499.687	1,427,400	92.169
scp		87,001.770	62,196.690		11,464.290
Non-lactating phase					
n	6	6		2	2
s	5,885	39.568		1,680	10.974
ss	5,775,675	264.182		1,427,400	58.255
scp		38,887.005		1,427,400	9,066,060

TABLE XIX (Continued)

	Producing Cows			Maintenance Cows	
	Weight	TDN/day	Corr. TDN/day[1]	Weight	TDN/day
Entire year					
n	6	6	6	2	
s	5,885	55.172	43.861	1,680	
ss	5,775,675	512.703	324.595	1,427,400	
scp		54,206.975	43,094.845		10,321.200

[1]Daily energy requirements were corrected for energy required for milk production by procedure explained in Materials and Methods.

[2]n = number of observations in each cell.

[3]s = sum of all observations in each cell.

[4]ss = sum of squares of the cell.

[5]scp = sum of cross-products between weight and the item represented by the cell.

VITA

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