ENERGY REQUIREMENTS OF MATURE BEEF COWS

AS INFLUENCED BY BODY SIZE

By

CRAIG GARY LUDWIG

Bachelor of Science
Iowa State University
Ames, Iowa
1963

Master of Science
Iowa State University
Ames, Iowa
1968

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
DOCTOR OF PHILOSOPHY
May, 1971

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Thesis Approved:

Robert Totusek
Thesis Adviser

Richard R Frahm

Jack E. McCroskey

W. S. Newcomer

Eldon Nelson

D. D. Durham
Dean of the Graduate College

ACKNOWLEDGEMENTS

The author wishes to express his sincere appreciation to Dr. Robert Totusek, Professor of Animal Science, for his counsel and guidance during the preparation of this thesis.

Acknowledgement is also due Dr. J. V. Whiteman, Professor of Animal Science, Dr. J. E. McCroskey, Associate Professor of Animal Science, E. C. Nelson, Associate Professor of Biochemistry and Dr. W. S. Newcomer, Professor of Physiology for their assistance in improving the manuscript and serving on the author's graduate committee.

The author would also like to thank Mr. D. F. Stephons, Superintendent of the Fort Reno Livestock Research Station, and his staff for their part in caring for the experimental animals.

The author is also indebted to colleagues in the Graduate College and especially Dr. Joe Hughes at Oklahoma State University for their encouragement and assistance.

Special recognition is extended to the author's parents, and to his wife, Nancy, for their aid and encouragement during the preparation of this manuscript.

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CHAPTER I

INTRODUCTION

As energy sources available to man and beast become more limiting, only the more efficient animals in converting feed to a salable product will remain in production. Because of her relatively low reproductive rate, in terms of output of calf weight relative to energy input, the beef female does not excel as an efficient energy converter. As selection pressure for more efficient cows increases, the relationship of cow size to the efficiency of energy utilization will become increasingly important.

The largest single expenditure in producing a feeder calf is the energy required by the beef cow to support maintenance, milk production, body weight gain and fetal development. Other factors such as productive efficiency, composition and rate of gain for both pre- and post-weaning periods of the offspring are related to cow size, but have little to do with efficiency of energy utilization in feeder calf production to eight months of age. However, in relation to total production efficiency from birth of a feeder calf to slaughter of the same animal, these factors do enter into the energy utilization picture and can affect overall production efficiency. How production efficiency is altered during the post-weaning period by these factors was not investigated in this trial.

Most previous research has been conducted with non-producing cows under laboratory conditions and, to date, little research has been done pertaining to the full energy requirements of the producing beef cow. This trial followed a one-year preliminary study to determine energy requirements of mature beef cows of various sizes for maintenance and production and to establish energy requirement levels during lactation and non-lactation periods for producing cows.

Since feed resources represent 60 to 80 percent of the cost of producing a feeder calf, any improvement in the efficiency by which energy is utilized by the cow-calf unit would greatly benefit the beef industry.

CHAPTER II

LITERATURE REVIEW

A review of the literature on the influence of cow size on efficiency of energy utilization suggests a consideration of two broad areas: 1) factors which influence the total energy requirements of the beef cow, and 2) cow size and its effect on productivity. Total energy requirements are influenced largely by the productive function of the dietary energy. These functions include: fasting metabolism, maintenance requirements, environmental influences, growth, lipogenesis, gestation and lactation. Actual energy requirements represent a complex interaction of all the above factors, however, for clarity and convenience, each factor will be discussed individually.

Factors Which Influence Total Energy Requirements of the Beef Female

Fasting Metabolism

Fasting metabolism has been described by Brody (1964) as the resting energy metabolism in a thermoneutral environment uncomplicated by the heat of feeding.

A linear correlation between the logarithm of fasting metabolic rate and logarithm of body weight has shown that the metabolic rate of mammals, ranging from mice to cattle, is proportional to the three-fourth power of body weight (Kleiber, 1961). Kleiber (1947, 1961) reported an interspecies mean of 70 kcal/kg $^{0.75}$/24 hr for fasting metabolism. In a review of basal metabolism in relation to body size, Brody (1964) suggested basal metabolism varied with body weight raised to 0.73 power for all animals. It has generally been accepted by researchers in the area of energy metabolism that basal metabolism is a function of body weight to the 0.70 - 0.75 power. However, the amount of heat produced per kilogram $^{0.75}$/24 hr for ruminants has remained open to some controversy.

With 8-day old calves, Ritzman and Colovos (1943) found fasting metabolism to be 172 kcal/kg $^{0.75}$/24 hr. This declined to 100 kcal/kg $^{0.75}$/24 hr when these animals were one year of age, and, at 27 months of age, basal metabolism dropped to 83 kcal/kg $^{0.75}$/24 hr.

Non-pregnant dry Holstein cows were reported to have a fasting metabolism rate of 73 kcal/kg $^{0.75}$/24 hr by Flatt and Coppock (1965). In a summary of several fasting metabolism trials with Holstein and Jersey cows, Flatt and Coppock (1965) noted heat production varied from 63.5 to 80.9 kcal/kg $^{0.75}$/24 hr.

Basal heat production for mature steers was 90.0 kcal/kg $^{0.75}$/24 hr as reported by Forbes et al. (1941). Mitchell et al. (1940), Blaxter and Wainman (1961a), Forbes et al. (1928), Rogerson (1960), Blaxter (1962), Forbes et al. (1927) and Mitchell and Hamilton (1941) found fasting metabolism of mature steers to be 71.8, 74.0, 78.5, 78.4, 76.4, 78.5 and 78.5 kcal/kg $^{0.75}$/24 hr, respectively. These values are all lower than the heat production reported by Forbes et al. (1931). Higher values were also reported by Blaxter and Wainman (1964), who obtained fasting heat production values for mature cattle ranging from 78.1 to 95.2 kcal/kg $^{0.73}$/24 hr, and an average of 85.6 kcal/kg $^{0.73}$/24 hr on six animals.

Fasting metabolism in the bovine appears to be high in young animals with a gradual decrease with age until the animal reaches maturity, as noted by Ritzman and Colovos (1943) and Brody (1964). Further evidence that this takes place in ruminants comes from Blaxter (1964), who with sheep found basal metabolism declined during the interval between one year and six years of age by 20 percent.

Basal heat production has been the starting point in determining the energy requirement of ruminants and this heat production has been generally accepted as being between 70.0 and 80.0 kcal/kg $^{0.75}$/24 hr by most researchers.

Maintenance Requirements

Brody (1964) described maintenance requirement as the net dietary energy required to keep an organism in a "steady" energetic state. Basal metabolism differs from maintenance in the respect that heat produced in basal metabolism comes from the breakdown of body tissue, whereas in maintenance enough dietary energy is fed to compensate for the heat produced from animal tissue catabolism. Maintenance requirements include dietary calories for maintaining the animal in a steady energetic state and an additional allowance for the specific dynamic effect food intake has on metabolic rate.

Maintenance requirements for the most part have been determined in a thermoneutral environment, however, under normal conditions, a variety of factors influence this requirement of beef cattle. This so-called "working maintenance" varies with body size, activity, level of nutrition, body condition and climatic factors including temperature variations, air movement and rain.

Good reviews on maintenance requirements and how environmental influences can alter these requirements are presented by Flatt and Coppock (1965) and Blaxter (1962).

Maintenance Requirements and Body Size

Body size and its effect on maintenance requirements of ruminants has been explored by several researchers, with most relating the energy for maintenance to body weight raised to some exponent. Exponents have ranged from 0.43 to a maximum of 1.0. Green *et al.* (1959) used 0.43; Green *et al.* (1959), 0.60; Winchester and Hendricks (1953), 0.66; Thomas and Moore (1960), 0.70; Brody (1964), 0.73; Green *et al.* (1959), 0.73; Kleiber *et al.* (1945), 0.75; Luitingh (1961), 0.78; Morrison (1956), 0.87; Thomas and Moore (1960), 0.90; Haecker (1903), 1.0 and Gaines (1943), 1.0.

As in basal metabolism, it has been generally accepted that under normal conditions maintenance requirements vary with body weight raised to the 0.70 - 0.75 power (Brody, 1964, Kleiber, 1932, 1947, 1961). For ease of computations and Kleiber's (1961) logical discussion body weight raised to the 0.75 power has been accepted as the standard for calculating and expressing maintenance requirements. Likewise, the National Research Council Committee on Animal Nutrition (N.R.C.) (1963) used body weight to the three-forths power as a reference for estimating maintenance energy requirements for beef cattle.

Actual Maintenance Requirements

Blaxter (1962) proposed an efficiency of utilization of 74 percent for metabolizable energy (ME), and, consequently, ME for maintenance was calculated by multiplying basal metabolism by a factor of 1.35. Using the interspecies mean of 70 kcal/kg $^{0.75}$/24 hr (basal metabolism, Kleiber 1961) and the multiplicative factor of 1.35, the estimated maintenance requirement for ruminants becomes 94.5 kcal ME/kg $^{0.75}$/24 hr.

Klosterman et al. (1968) felt some measure in addition to body weight should be incorporated to describe cow size and suggested a weight to height ratio. Using beef cows of various sizes and weights in average condition, Klosterman et al. (1968) found this ratio to be about 4.0 and described beef cow maintenance requirements per day in terms of digestible energy (DE) with the formula:

$$DE_m = 130\ W^{0.75} - (W/H - 4.0)\ 1,716$$

where

DE_m = digestible energy for maintenance in kcal,

W = body weight in kilograms,

H = body height at the hooks in centimeters.

Van Es (1961), in a summary of published data, calculated the average energy requirement for maintenance of cattle to be 109 kcal ME/kg $^{0.75}$/24 hr. Hashizume et al. (1964a) and Hashizume et al. (1964) found average maintenance requirements for dry non-pregnant dairy cows to be 116 and 116.3 kcal ME/kg $^{0.75}$/24 hr, respectively. Varying results with dry non-pregnant dairy cows were reported by Bouwer et al. (1961). Values of 107 and 120 kcal ME/kg $^{0.75}$/24 hr were obtained in two trials. Flatt and Coppock (1965), in a summary of 54 reported trials, calculated the maintenance requirement of dry non-pregnant dairy cows to be 104.5 kcal ME/kg $^{0.75}$/24 hr. This was in close agreement with van Es (1961), Hashizume et al. (1964a, 1964), and the first trial of Bouwers et al. (1961).

Thomas and Moore (1960) found considerable difference between Holstein and Jersey dairy cows in alfalfa dry matter (DM) required to maintain body weight. Holstein cows required 11.8 lb DM/1000 lb of live weight, while Jersey cows required 13.5 lb of DM/1000 lb for maintenance. Converted to a total digestible nutrient (TDN) basis, the requirements were 6.02 and 6.89 lb TDN/1000 lb of body weight, respectively, In two separate trials, Rebhan and Donker (1960) reported average maintenance requirements of dairy bulls to be 8.50 and 6.60 lb of TDN/1000 lb live weight.

Cochrane et al. (1925) found the average maintenance requirement for dry dairy cows to be 5.49 therms of net energy (NE) per 1000 lb of body weight. A similar value of 6.11 therms of NE per 1000 lb of live weight for growing dairy heifers was reported by Eckles et al. (1927).

Most work concerning maintenance requirements for the bovine female has been done with dairy animals, and its validity and application to the beef breeds may be questionable. Blaxter (1967) reported a 20 percent higher metabolic rate in Ayrshire cattle than in Angus. If this concept is true, then results from dairy cattle work would not be applicable to the beef female without some correction factor.

While little research has been done on the maintenance requirement of beef cows, there has been considerable research to determine the maintenance requirement of beef steers. Garrett et al. (1959) conducted extensive research with slaughter cattle and sheep and calculated maintenance requirements for cattle in terms of TDN, DE, ME, and NE.

The following formulas were obtained:

$$TDN = 0.036\ W^{0.75}$$

$$DE = 76\ W^{0.75}$$

$$ME = 62\ W^{0.75}$$

$$NE = 35\ W^{0.75}$$

where

TDN is expressed in lb,

W = body weight in lb,

DE, ME and NE are expressed in kcal.

With steers weighing 461, 569 and 816 lb, Luitingh (1961) found maintenance requirements could be calculated by the following formula:

$$Y = 0.716 - 0.0065X$$

where

Y = maintenance requirement in lb of TDN/day,

X = body weight in lb.

Using the above formula, the calculated daily TDN requirements are 3.7, 4.5 and 6.0 lb for the three weights, respectively, and converted to pounds of TDN required per day per 1000 lb body weight, 7.89, 7.91 and 7.35 lb, respectively.

Trowbridge et al. (1915) calculated the daily maintenance requirement for beef steers to be 12.92 therms ME, or 8.75 lb TDN, per 1000 lb of live weight, which is high compared to values reported by Luitingh (1961) and Garrett et al. (1959).

Using growing cattle, Winchester and Hendricks (1953) obtained the following formula for calculating maintenance requirements:

$$f = 0.0553\ W^{2/3}$$

where

f = lb of TDN/day,

W = body weight in lb.

N.R.C. (1963) has used the formula 74.5 $W^{0.75}$ to estimate kcal of DE required to maintain body weight in beef cattle. This formula was derived from an average of the work done on energy requirements, with a safety factor added to assure a reasonable response.

The maintenance requirements obtained by various researchers are summarized in Table I. The considerable amount of variation is obvious. The environment in which these determinations were made could account for some of the variation and the overlapping between DE and ME.

Environmental Influences on Maintenance Requirements

Because maintenance requirements have been determined in a thermo-neutral environment and under non-working conditions, attempts have been made to determine effects of environmental influence on maintenance requirements.

Weather Conditions

Temperature, air movement and rain play a primary role in affecting the energy maintenance requirement of the ruminant. Attempts have been made to measure energy expenditure in relation to weather conditions; a good review has been provided by Blaxter (1963). Although research has been limited, the results have verified that climatic factors do alter maintenance requirements.

TABLE I

SUMMARY OF MAINTENANCE REQUIREMENT OF CATTLE (1000 LB BASIS)

Reference	Type of Requirement Expressed	Requirement/24 hr[1]
Thomas and Moore (1960)	TDN	6.02
Garrett *et al.* (1959)		6.29
Rebhan *et al.* (1960)		6.60
Thomas and Moore (1960)		6.89
Winchester and Hendricks (1953)		6.95
Luitingh (1961)		7.35
Luitingh (1961)		7.89
Luitingh (1961)		7.91
Rebhan and Donker (1960)		8.50
N.R.C. (1963)		9.00
Trowbridge *et al.* (1915)	DE	12,920.00
N.R.C. (1963)		13,023.00
Garrett *et al.* (1959)		13,285.00
Klosterman *et al.* (1968)		16,341.00
Garrett *et al.* (1959)	ME	10,838.00
Blaxter (1962)		11,879.00
Flatt and Coppock (1965)		13,135.00
Bouwer *et al.* (1961)		13,450.00
van Es (1961)		13,701.00
Hashizume *et al.* (1964)		14,581.00
Cochrane *et al.* (1925)	NE	5,493.00
Eckles *et al.* (1927)		6,110.00
Garrett *et al.* (1959)		6,118.00

[1]TDN is expressed in lb; DE, ME and NE in kcal.

Forbes et al. (1926), working with sheared and unsheared cattle, reported that sheared animals lost on the average 553 cal/100 kg of live weight/24 hr more than unsheared animals at the same temperature. As temperature decreased, heat production by both sheared and unsheared cattle increased.

The critical temperature of steers was determined at maintenance, sub-maintenance and fasting by Blaxter and Wainman (1961). The average critical temperature for the three feeding levels was 6.3, 11.6 and 18.1°C, respectively. More important than the critical temperature determinations in this study was a conclusion reached in the analysis of data where it was found that for insulation purposes, the skin and hair coat of cattle is of similar value to skin and fleece of comparable length in sheep. Because little research has been done with the bovine in relation to maintenance requirements as influenced by weather conditions, results obtained with sheep under various climatic conditions could possibly be applied to cattle. Lambourne and Reardon (1963), in work with pen-fed sheep inside and outside during the winter, noted a considerable difference in grams of digestible organic matter (DOM) required for maintenance between the two groups, (Table II).

Similar results were reported by Joyce and Blaxter (1964) who found heat production increased maintenance requirements by a factor of 3.3 at -3°C in a 4.2 mph wind compared to a thermoneutral environment. At 5°C with a wind of 4.2 mph, maintenance requirements increased 27 percent with a fleece length of 10 mm, but only 11 percent at a fleece length of 50 mm.

Joyce and Blaxter (1964), in work with sheep, used a wind of 10 mph at an air temperature of -5°C, and found maintenance energy requirements

TABLE II

GRAMS OF DOM REQUIRED TO MAINTAIN VARIOUS WEIGHTS FOR SHEEP FED INSIDE AND OUTSIDE DURING THE WINTER

Feeding Area	Sheep Weight (kg)	Grams of DOM
Inside	26	200
	32	300
	46	420
Outside	26	420
	33	480
	46	490

increased 50 percent. However, Blaxter (1963) states that the increase in maintenance requirements is reduced by 50 percent under such conditions if the hind quarters, or posterior, of the animals are exposed directly to the wind as compared to side exposure. Joyce _et al_. (1966) also found that as air temperature decreased and as wind velocity increased, energy requirements for sheep increased markedly.

With a 0.4 mph wind, steers with normal hair coats increased heat production 300 kcal/24 hr as air temperature decreased from $20^{o}C$ to $0^{o}C$, (Blaxter _et al_., 1963). When air movement was increased to 1.6 mph at $0^{o}C$, heat production increased by 617 kcal/24 hr over that measured at $20^{o}C$ and 1.6 mph wind. Shearing of the steers and exposure to $0^{o}C$ resulted in a heat production of 13,183 kcal/24 hr at a wind speed of 0.4 mph and 13,595 kcal/24 hr at a wind speed of 1.6 mph, as compared to 8,673 kcal/24 hr under the same wind speeds at $20^{o}C$.

When wet and in wind, lambs with short fleeces produced an additional 1812 kcal/M^2/24 hr and sheep in long fleece 998 kcal/M^2/24 hr, as compared to dry lambs in still air (Joyce _et al_., 1966). Conclusions were that rain significantly reduced the insulation value of the wool for sheep directly exposed. In this same work, it was also shown that 53 percent of the heat required to dry wet animals must be produced by the animals themselves. Blaxter (1963, 1964) concluded that even when air temperatures are above $0^{o}C$, a combination of high wind with rain can increase maintenance needs threefold in both cattle and sheep. Rain (Blaxter, 1967) hinders the animal in two ways; firstly, the rain causes a deformation of the coat causing the fibers and hair to flatten and lie closer to the skin, thus reducing its thickness and insulation and, secondly, wetting and then drying of the coat can cause very complex heat changes within the fleece and hair.

It appears that air temperature and wind, individually and in combination, affect dietary energy requirements for maintenance to some extent, depending on the severity of either or both. Rain, included along with air movement and temperature, results in additional stress and increased energy requirements for the animal.

Body Movement and Its Effect on Maintenance Requirements

The conclusions reached in studies in respiration chambers on maintenance energy requirements have been criticized for not accounting for energy expenditures during animal activity experienced out-of-doors. Where livestock must travel for food and water, the activity factor, like the climatic factor, would exert some effect on maintenance requirements. The quantity and quality of forage grazed, the distance animals need to walk harvesting forage, in addition to climatic conditions, determine the additional energy required to support these normal activities. Good reviews on body movement and energy expenditure are presented by both Blaxter (1967) and Brody (1964).

Reid et al. (1958) reported grazing 1000 lb dairy cows required 40 to 50 percent more energy to support maintenance and the physical activity of grazing than barn-fed animals. Blaxter (1967) reported that grazing cattle required 15 percent more energy for maintenance than cattle fed indoors. This is in close agreement with the 15.7 percent increase that Brody and Proctor (1935) reported in a similar study, however, both of these values are far short of the values Reid et al. (1958) reported.

Kroman et al. (1961) observed that grazing steers spent 50 percent more time eating than steers fed silage from the same pasture. Maintenance energy requirements for the grazing animals were higher, but not statistically different, from those fed in a pen. The fact that these trials were carried out on lush irrigated pasture may account for the small differences observed.

Langlands et al. (1963) found grazing required 18 percent more energy for maintenance and 11 percent more energy per lb of gain than barn-fed sheep. Similar results were also obtained by Langlands et al. (1963a).

In three trials, Coop and Hill (1962) found 1.48, 1.63 and 1.36 lb of DOM/day/100 lb of live weight for maintenance of sheep grazing pasture compared to 0.92 lb for pen-fed sheep reported by Coop (1962). Coop and Hill (1962) suggested the large excess in DOM requirements observed in grazing animals could be attributed to climatic factors, as well as to the energy for walking and harvesting forage.

Hall and Brody (1933) found an additional 2.1 kcal/kg body weight/24 hr is required by adult cattle for standing compared to lying down. Forbes et al. (1927a) obtained a value of 2.8 kcal/kg body weight/24 hr increase in the energy required for standing cattle over cattle in a lying position. Maynard and Loosli (1962) stated that active cattle and sheep require 10 percent more energy than animals at rest.

The energy cost of sheep eating pasture has been calculated to be 0.6 - 0.8 kcal/hr/kg of live weight (Graham, 1962). This would be equivalent to the sheep walking 1000 m (Blaxter, 1964). Using the shearing requirement reported by Graham (1962) and a 6 hr grazing period daily, 190 kcal of energy is required by a 100 lb sheep to cover forage gathering expenditures. If the sheep walked one mile per day, an additional 43 kcal would be required. Together, these two activities account for only 18 percent of the daily maintenance requirement of a 100 lb sheep.

Clapperton (1961, 1964) measured the energy cost of horizontal and vertical locomotion in sheep. Horizontal locomotion took place at 0.59 cal/horizontal kg m, whereas walking on an inclined plane required 6.36 cal/vertical kg m.

It was suggested by Gaines (1937) that the working maintenance requirements of dairy cows varied directly with body weight rather than weight to 0.75 power as is the case for basal metabolism. However, Brody (1964) disagreed and reasoned that because larger animals move slower, take longer steps and have lower metabolic rates, working maintenance requirements would vary with body weight to a fractional power thereof.

A summary of the working maintenance requirements and indoor maintenance requirements has been compiled by Blaxter (1964) and is reproduced in Table III.

Body Condition and Its Effect on Maintenance Requirements

Armsby and Fries (1917) recognized that the inter-relationships between body condition and maintenance requirements of ruminants existed as they observed that maintenance requirements increased at a faster rate than did body weight. With an increase of 300 lb of weight in mature steers, a 36 percent increase in maintenance energy requirements was noted. Results of Eckles <u>et al</u>. (1927) verified Armsby and Fries' (1917) belief that as body condition increases, maintenance requirements per unit of body weight increases. Eckles <u>et al</u>. (1927) demonstrated that calves in very fat condition required 25 percent more energy to

TABLE III

ESTIMATES OF THE MAINTENANCE REQUIREMENTS OF SHEEP AND CATTLE MADE UNDER NATURAL GRAZING CONDITIONS COMPARED WITH THE MAINTENANCE REQUIREMENTS TO BE EXPECTED FROM CALORIMATRIC EXPERIMENTS

Animal	Country	Estimated in Terms of Digested Organic Matter (lb)	Estimate Expressed as Metabolizable Energy* (kcal/day)	Calculated From In-door Experiments+ (kcal/day)	Reference†
Sheep	New Zealand	1·47	2 500		1
	New Zealand	1·63	2 771		1
	New Zealand	1·36	2 312	~ 1 500	1
	Scotland	1·02	1 734		2
	Australia	1·23	2 091		3
Cow	USA	11·5	18 600		4
	New Zealand	12·4	21 100		5
	New Zealand	14·7	25 000	~ 11 500	6
	Scotland§	7·2	12 200		7
Calf	England	10·5	17 800	~ 13 500	8

*1 lb digested organic matter has been taken to supply an average of 1700 kcal metabolizable energy.

+With an allowance for additional walking and standing.

†1, Coop and Hill (1962); 2, Langlands, Corbett, McDonald and Reid (1963a); 3, Lambourne and Reardon (1963); 4, Reid, Smith and Anderson (1958); 5, Wallace (1956); 6, Hutton (1962); 7, Corbett, Langlands and Boyne (1961); 8, Holmes, Jones and Drake-Brockman (1961).

§Close-folded cows.

maintain 1000 lb of body weight than calves in normal condition. Very fat calves required 6.79 therms NE per 1000 lb live weight while calves in normal condition required only 5.43 therms. Similar results were observed by McCandlish and Gaessler (1920) who reported that dairy cows in a high state of condition required 7.39 lb of TDN and cows in thin condition required 5.42 lb of TDN to maintain 1000 lb of cow weight, a 36 percent increase in maintenance requirements due to body condition.

Using mature dairy bulls considered to be in low, medium and high body condition, Rebhan and Donker (1960) found the TDN required to maintain 1000 lb of live weight to be 6.50, 8.70 and 10.30 lb for the three conditions, respectively. This represents a 33.8, 58.5 and 18.4 percent increase in maintenance requirements of the medium over the low, high over the low, and high over the medium, respectively. The 58.5 percent increase of the high over low is in excess of the value other researchers reported for the bovine. However, the description of body condition was very arbitrary in all experiments, and could account for some of the differences.

Klosterman et al. (1968) observed that when the amount of energy fed was based on body weight without regard for degree of fatness, cows in high condition tended to gain in body weight while cows in thin condition tended to lose weight, indicating that body weight increased in proportion more than maintenance requirements. This is contrary to results of other researchers.

Previous Plane of Nutrition

If energy is restricted during the growing phase of the bovine, and then followed by a high level of energy intake, compensatory growth or gain appears to occur (Steensberg, 1947; Winchester and Howe, 1955; Hughes *et al*., 1955 and Winchester and Ellis, 1956).

The above researchers observed an increase in the daily rate of gain for animals placed on a high energy level following a period of low energy intake as compared to animals maintained on a high energy level throughout the experimental period. In addition, limited energy intake did not significantly affect the total energy required to reach a given weight even though these animals required from two to five months additional feeding time.

The theory for such results is that limited fed animals adjust their maintenance requirement downward while on a limited energy intake. Upon resumption of a higher level of energy intake, maintenance requirements remain lower than for animals of comparable weights which have been maintained on a higher energy level. An increased rate of growth is then observed from the energy conserved from maintenance (Tillman, 1967).

Figure 1, which Reid (1967) used to demonstrate the effect of previous plane of nutrition on fasting heat production of sheep, helps verify this theory.

Present Plane of Nutrition

Brody (1964) presented a good review of the principle of diminishing efficiency in energy utilization with respect to plane of nutrition.

In data obtained by Hogan *et al*. (1922), it is evident that plane of nutrition exerts a marked effect on the maintenance requirement of cattle. Results of their work were similar for both winter and summer trials and are presented in Table IV.

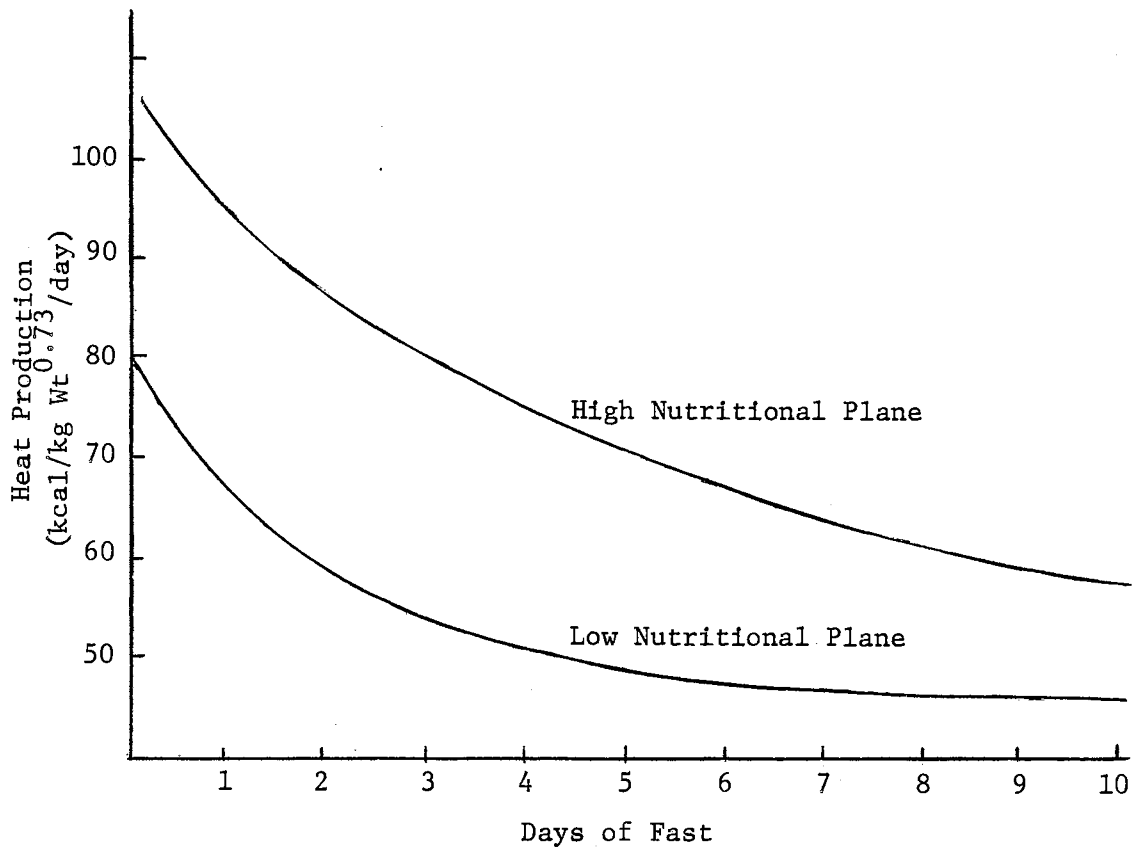

Figure 1. Effect of Previous Plane of Nutrition on Heat Production of Fasting Sheep

TABLE IV

EFFECT OF PLANE OF NUTRITION ON DAILY MAINTENANCE ENERGY REQUIREMENTS

Time of Year	Level of Nutrition	Daily Therms NE /1000 lb wt	% Increase Over the Next Lower Level
Summer	High	5.650	20.8
	Medium	4.676	12.3
	Low	4.165	
Winter	High	5.775	21.8
	Medium	4.741	5.0
	Low	4.517	

This work also indicates that raising the nutritional level from medium to high is much more detrimental to efficiency of energy utilization for maintenance than was raising the level from low to medium. Working with seven planes of nutrition ranging from fasting to 3 times maintenance, Forbes et al. (1930) noted that as feed intake increased, DE, ME and NE as a percent of gross energy decreased, indicating maintenance requirements were rising with increasing feeding levels.

Flatt and Coppock (1963) fed non-pregnant dry dairy cows one-half maintenance, maintenance and ad lib, and found that kcal/kg $^{0.75}$/24 hr varied directly with the feeding level. These results are in agreement with Trowbridge et al. (1915), who noted a proportional increase in maintenance requirements as feeding level increased.

From the above discussion and past research, it appears that the bovine is capable of partially adjusting its maintenance energy requirement to the availability of its feed supply.

Productive Function of Dietary Energy

Growth, lipogenesis, gestation and lactation are the four primary production functions of dietary energy in the beef female. In reality, during part of the beef cow's life cycle, these four functions take place simultaneously. Upon reaching a mature body size, only lipogenesis, gestation and lactation take place at any one time. All these factors must be considered in recommendations of total energy requirements of the beef female. However, for discussion purposes, the effect of growth, lipogenesis, gestation and lactations on the total energy required by the beef cow will be discussed individually.

Growth

In a comprehensive study with growing sheep and cattle, Garrett *et al*. (1959) calculated the energy requirements of cattle for maintenance plus gain with the following formulas:

$$TDN = 0.36W^{0.75} (1 + 0.57g)$$
$$DE = 76W^{0.75} (1 + 0.58g)$$
$$ME = 62W^{0.75} (1 + 0.60g)$$
$$NE = 35W^{0.75} (1 + 0.45g)$$

where

TDN = lb per day,

DE, ME, NE = kcal per day,

W = body weight in lb,

g = daily gain in lb.

Winchester and Hendricks (1953) proposed a formula much like that of Garrett and his colleagues for calculation of the combined energy requirement of maintenance and growth. Winchester and Hendricks' formula is:

$$TDN = 0.0553W^{0.666} (1 + 0.805g)$$

where

TDN = lb per day,

W = body weight in lb,

g = daily gain in lb.

N.R.C. (1963), in its energy recommendations for maintenance plus gain, uses the formula:

$$DE = 74.5W^{0.75} (1 + 0.59g)$$

where

DE = kcal per day,

W = body weight lb,

g = daily gain in lb.

Summarizing the preceding formulas described by Garrett *et al.* (1959), Winchester and Hendricks (1953) and N.R.C. (1963), one observes in Table V the close agreement of TDN and DE recommendations by these workers for maintenance and 0.40 lb gain/day for 1000 lb cows.

In summary of published data from cattle fed at or near maintenance, van Es (1961) found the energy gained should be multiplied by the factor 1.61 to correct to a no weight gain basis. Thus, the amount of energy required for weight gain can be estimated by multiplying the energy in body weight gain by 1.61. In similar work, Knott *et al.* (1934) calculated that 3.53 lb of TDN were required per pound of gain in dairy cattle.

Whether typical energy requirements for growth as described above are true for the beef female is open to question. The unusual growth pattern of relatively rapid weight gains to 12 months of age with decreased growth rate taking place from this point to four or five years of age would suggest varying requirements for the beef female as compared to slaughter cattle.

Lipogenesis

Excessive fattening is not desired in the breeding beef female at

TABLE V

ESTIMATED ENERGY REQUIREMENTS FOR MAINTENANCE

AND 0.40 LB GAIN DAILY FOR 1000 LB COW

Reference	Type of Requirement Expressed	Total Energy/Day[1]
Garrett *et al.* (1959)	TDN	7.75
Winchester and Hendricks (1953)		9.15
Garrett *et al.* (1959)	DE	16,423.00
N.R.C. (1963)		16,151.00

[1]TDN is expressed in lb, DE in kcal.

any time in her life cycle. However, many beef females will undergo some fattening simply because of circumstances. Access to an abundant feed supply, failure to produce a calf, poor milk production, and the post weaning period are situations which may cause fattening simply because productive energy demands are not as great as the energy available.

A review by Blaxter (1967) pointed out the importance of ration composition on the efficiency of ME utilization for lipogenesis. Armstrong and Blaxter (1961) explained the ration effect on lipogenesis by the crude fiber content of the ration and suggested that 3.3 times as much gross energy is required in the form of hay as compared to concentrate to produce the same amount of fat.

The net availability of ME for lipogenesis was calculated by Blaxter (1961) to be:

$$K = 0.94ME - 8.0$$

where

K = net ME available for fattening,

ME = ME for maintenance in kcal.

Blaxter (1961) concluded that the efficiency of lipogenesis can be expected to be 30 to 40 percent lower than that of maintenance.

In a summary of work conducted by the Pennsylvanian and Illinois workers with dairy and beef cattle, Reid (1961) concluded the mean efficiency of conversion of ME ingested above maintenance into body tissue was 58.4 percent. Blaxter (1964) found the average efficiency of grassland products in lipogenesis to be 47 percent, while Flatt and Coppock (1965) found an overall efficiency of ME for dry non-pregnant cows to be 50 percent. The efficiency by which cattle and sheep use ME for fat production was calculated by Blaxter and Wainman (1961a) to be 51.4 and 53.4 percent, respectively, which compares favorably with 52.1 percent found by Bateman and Blaxter (1964).

Disregarding age or size of animal, production of body fat is not very economical and indications are that 12,762 kcal of ME are required to produce 5,000 kcal in fat (Blaxter, 1961).

Gestation

Research concerning the energy required to maintain gestation in the bovine is rather limited. During the period of 41 to 73 days following conception, total heat production in pregnant cows was 123 kcal/ $kg^{0.75}$/24 hr. Van Es (1961) calculated a total heat production of pregnant cows 11 to 95 days before calving to be 133 kcal/$kg^{0.75}$/24 hr with a range of 103 to 175 kcal/$kg^{0.75}$/24 hr. He further found an average total heat production of 145 kcal/$kg^{0.75}$/24 hr for cows in the late states of pregnancy (11 to 39 days before calving).

Average total heat production during late pregnancy found by researchers is 157 kcal/$kg^{0.75}$/24 hr, an increase of 50 percent over maintenance heat production of dry non-pregnant cows.

Working with Holstein dairy cows, Hashizume <u>et al.</u> (1963) found resting metabolism increased 0.192 kcal/$kg^{0.75}$/24 hr of gestation (Flatt and Coppock, 1965). Jakobsen <u>et al.</u> (1957) calculated the energy retained by the pregnant cow from analysis of the uterus and its contents and reported that heat of combustion of products of conception to be:

$$\text{kcal} = 416.2_e^{0.0174t}$$

where

t = number of days after conception

In Figure 2 (Jackobsen, 1957), it is of interest to note that 86 percent of the total energy is deposited in the uterus during the last 10 weeks of pregnancy. It appears that during early pregnancy (first 20 - 30 weeks) the energy required to maintain pregnancy is very small while significantly more energy is required during later stages of pregnancy in the female bovine.

Lactation

An excellent review of the nutritional and physiological effects relative to the efficiency of milk production was presented by Braumgardt (1967). Brody (1964) presented a much broader review relating milk production to efficiency.

The energy requirement for lactation has been examined in the same manner as the energy requirement for lipogenesis. The efficiency of energy utilization for milk production, rather than energy required per unit of milk produced, has been the main subject of investigation. Gross energetic efficiency for 368 cows ranged from 28 to 34 percent (Brody, 1964). Gross efficiency was calculated by dividing the total calories produced in the milk by the total calories consumed by the cow.

Fries et al. (1924) found utilization of ME for milk production ranged from 60 to 76 percent and was 22 percent more efficient than energy utilization for body weight gain. Later, Forbes et al. (1926a) reported similar results when he found an average of 72.4 percent efficiency of conversion of ME to milk. Forbes et al. (1926a) found that ME

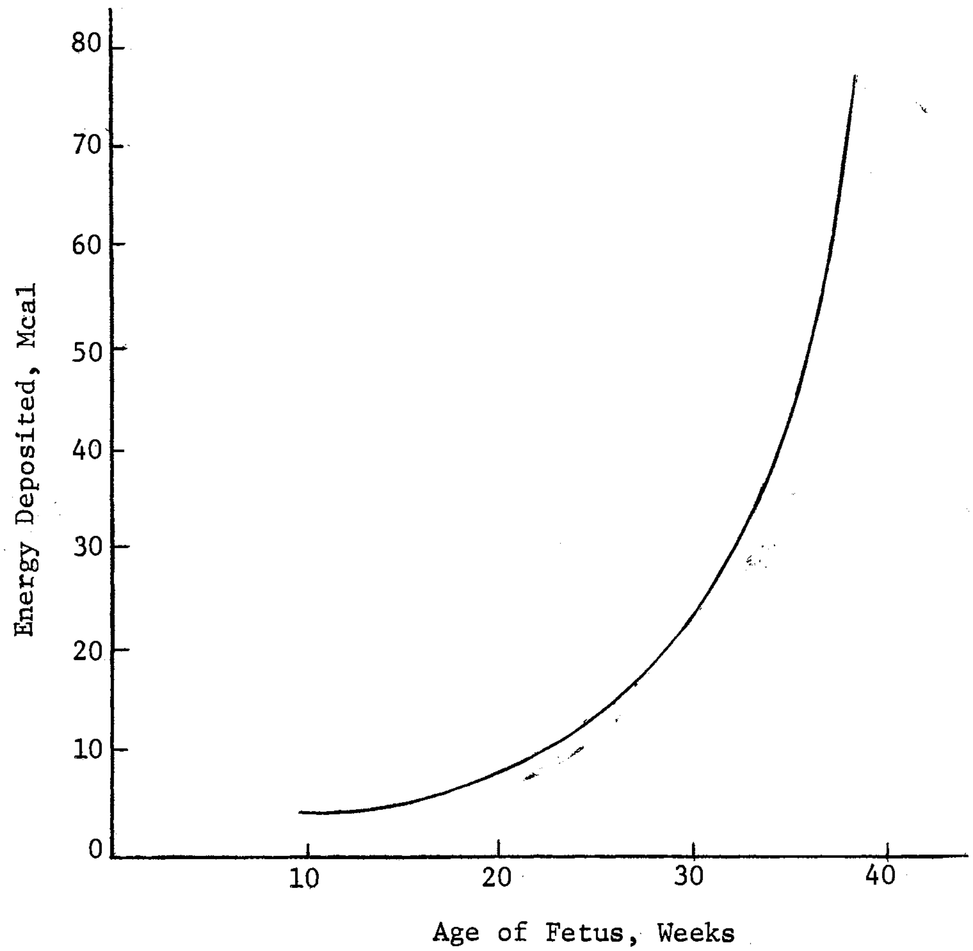

Figure 2. Heat of Combustion of the Uterine Contents of Cows at Different Stages of Pregnancy. The analyses are those made by Jakobsen *et al.* (1957).

for milk production is utilized 98.5 percent as efficiently as ME for maintenance. More recent results have been reported by Reid (1967). Working with diets containing 31.6, 33.2 and 56.4 percent concentrate and using 116.3 kcal ME/kg$^{0.75}$ as the energy required for maintenance, Reid (1967) calculated the net utilization of ME to be 71.3, 68.3 and 68.7 percent, respectively. In data summarized by Reid (1961, 1967), the efficiency with which ME was utilized for milk production was 70.2 percent.

Kleiber (1961) found 64 percent of the DE available for milk production is utilized. Similarity of results from past research indicates approximately 70 percent of available ME can be utilized for milk production.

Energy requirements recommended by N.R.C. (1966) per kilogram of 4 percent fat corrected milk (FCM) are 1.46, 1.63 and 1.85 megacalories for production levels of less than 20 kg, 20 to 35 kg and over 35 kg per day, respectively. Jones et al. (1965) considered it permissible to add 0.24 lb of digestible organic matter intake (DOMI) for each additional pound of FCM, with DOMI associated with body weight to 0.73 power up to a yield of 50 lb FCM/day.

Energy recommendations by N.R.C. (1966) demonstrate the principles of diminishing increments of energy utilization for milk production. Gross efficiency of milk production increases with increasing milk production (Bush, 1968) and (Blaxter, 1964), but efficiency of production per unit of milk decreases with increasing milk production. The net effect of these two opposing factors is an increase in the net efficiency until milk production reaches 80 to 100 lb per day (Kesler and Spahr, 1964).

Whether these same principles and concepts apply to the lactating beef cow is not known. In all probability, because milk production in the beef female falls far short of that in dairy bred animals, milk production in the beef cow does not take place as efficiently as in the dairy cow.

Cow Size and Its Effects on Productivity

A question often arising in connection with cow size is the influence of size on productivity. Productivity in the beef female is generally measured by weaning weight, which is directly influenced by milk production and cow size.

Various researchers have investigated the relationship of cow size and weaning weights. Gregory et al. (1950) reported correlations of 0.20 and -0.11 between cow weights and calf weaning weights for two separate groups of cows. In this same work, correlations of -0.12 and -0.34 were observed for calf gain from birth to weaning and cow gain from birth to weaning. A correlation of 0.25 between calf weaning weight and cow weight was reported by Lickley et al. (1960). A somewhat higher correlation of 0.51 was reported by O'Mary et al. (1959).

Contrary to what most researchers have observed, Vaccaro and Dillard (1966) observed no apparent relationship between cow size and preweaning gain in the beef calf.

Sawyer et al. (1963) found correlation coefficients of 18-month and 5 and one-half year dam weights with calf weaning weights to be 0.20 and 0.29, respectively. This is similar to the correlation coefficient of 0.239 between weaning weight and 18-month dam weight reported by Marchello et al. (1960).

Brinks _et al._ (1962) reported a higher correlation coefficient (0.21) between weaning weight and the dam's spring weight than between the dam's fall weight and weaning weight (0.09).

Correlation coefficients between cow weights and weaning weights appear to be small and even negative in some cases; however, the data does indicate heavier cows produce heavier calves at weaning with increases of 4.9 lb to 19.8 lb in weaning weight reported for each 100 lb increase in cow weight. Each additional 100 lb of cow weight has been reported to increase calf weaning weight by 4.9 lb, Tanner _et al._ (1965); 7.0 lb, Neville (1962); 8.5 lb, Tanner _et al._ (1965); 14.8 lb, Sawyer _et al._ (1963); 18.0 lb, Marchello _et al._ (1960) and 19.8 lb, Sawyer _et al._ (1963).

Other size factors in addition to cow weight have been examined in their relationship with calf weaning weight. Using wither height or back length of the cows, Tanner _et al._ (1965) accounted for 20 percent of the variation in weaning weight of the calves. The two factors together accounted for 23 percent of calf weaning weight variation. Correlation coefficients for foreshank length, forearm circumference, rump length and body length of the cow with weaning weight were calculated by O'Mary _et al._ (1959). Correlations obtained were 0.46, 0.48, 0.46 and 0.33, respectively. A multiple correlation coefficient of cow foreshank length, forearm circumference and rump length with weaning weight was reported to be 0.91 by these same workers.

Many researchers maintain that productivity of the beef cow, measured by weaning weight of the calf, is no more than a measure of milk production. Klett _et al._ (1965) showed an increase of 89 lb in weaning weight for every 5.0 lb increase in daily milk production by Angus cows.

Also, milk production accounted for over 40 percent of the variation in calf weaning weight. Drewry et al. (1959) accounted for 75, 77 and 60 percent of the variability associated with calf gain up to one, three and six months, respectively, with dam's milk production.

Correlation coefficients of calf weight with total butterfat, total solids-not-fat and total solids were 0.77, 0.85 and 0.79, respectively (Klett et al., 1965). Correlation coefficients of calf weaning weight and daily milk production calculated by Pope et al. (1963) ranged from 0.60 to 0.70. This is in close agreement with values (0.60 and 0.66) reported by Gifford (1953) and Klett et al. (1965), respectively. Calf gains up to five weeks of age, and milk production of the dam, were reported to have a correlation of 0.58 by Schwulst et al. (1966).

In a comprehensive study, Neville (1962) found correlation coefficients between milk production and the first, second, third and fourth 60 days of the nursing period to be 0.74, 0.63, 0.59 and 0.66, respectively.

Because milk is so important in influencing weaning weight, research on gain per unit of milk has been done with researchers reporting a range of 3.22 to 12.50 lb of milk required per pound of calf gain. Gifford (1953) reported that during the first, third and sixth months of lactation, 6.71, 5.15 and 3.22 lb of milk were required to produce a pound of calf gain. Drewry et al. (1959) found 12.5, 10.8 and 6.7 lb of additional milk were required per pound of calf gain for the same periods used by Gifford (1953). Averages indicate approximately 7.5 lb of milk are required per pound of calf gain.

Milk production level correlated with cow size appears to have a very low or possibly a negative value (Pope et al., 1963; Stone et al., 1960; and Mason *et al.*, 1957), indicating heavier calf weights affected by larger cows must be due to greater genetic potential of the larger animals.

Summary

Basically, maintenance requirements vary with body weight raised to the three-fourths power. However, numerous factors, including weather conditions, activity, body condition, previous and present plane of nutrition and productive function of the dietary energy can directly, or indirectly, affect the total energy required by the beef cow. A review of the literature reveals that a host of factors interact in affecting the "working maintenance" of the beef female.

CHAPTER III

MATERIALS AND METHODS

Twenty-four grade Hereford cows from six to seven years of age served as experimental animals in this trial started in February of 1967 and concluded in March of 1968. Twenty of the cows were selected from a herd in Oklahoma, and four from the Fort Reno Livestock Research Station, El Reno, Oklahoma, where the entire trial was conducted. Twenty-one of the 24 cows were designated as producing cows and ranged in initial weight from 770 to 1335 lb with an average of 1025 ± 32.9 lb. Animals designated as producing cows were pregnant when the trial began and an attempt was made to rebreed these animals during the study. Three non-producing cows, designated as maintenance cows, were used to estimate maintenance requirements and remained open throughout the entire experimental period. Initial weights for the maintenance cows were 815, 1225 and 1280 pounds.

Producing cows were selected on the basis of previous production performance and body condition. Larger cows were selected with an average advantage in weaning weight for their previous calves similar to that reported in the literature. Likewise, larger cows were selected to have more total fat cover over the 12th rib, but similar fat cover as the smaller cows when expressed per 100 lb of body weight.

All cows were placed in a drylot on March 8, 1967, where they were allowed to adapt one week before being placed on test. The experimental period for each producing cow started immediately prior to calving in 1967 and continued through to calving in 1968 approximately one year later.

Initial weights taken on producing cows just prior to calving in 1967 were used to develop individual weight change patterns. Maintenance cows were maintained at a constant weight throughout the entire experimental period. Weight changes were controlled by adjusting individual daily feed allowances based on weekly weights taken after a 12-hour shrink period during which the animals were without feed and water. Daily feed allowances were provided each morning in individual feed stalls in an open shed adjacent to the drylot.

Producing cows were allowed to follow a weight change pattern which appeared to be consistent with economy and good reproductive performance in studies reported by Smithson et al. (1966). This weight change pattern is described below and illustrated for a 1000 lb cow in Figure 3.

Period	Definition of Period	Weight Change
I (lactation)	From just prior to calving to 56 days post partum.	Loss of approximately 15 percent of pre-calving weight.
II (lactation)	From 56 days post partum to 215 days post partum.	Gain of approximately 8.5 percent of pre-calving weight.
III (non-lactation)	From 215 days post partum to immediately prior to the following parturition.	Gain of approximately 6.5 percent of pre-calving weight and theoretically reaching the weight observed at the time the cow was placed on experiment.

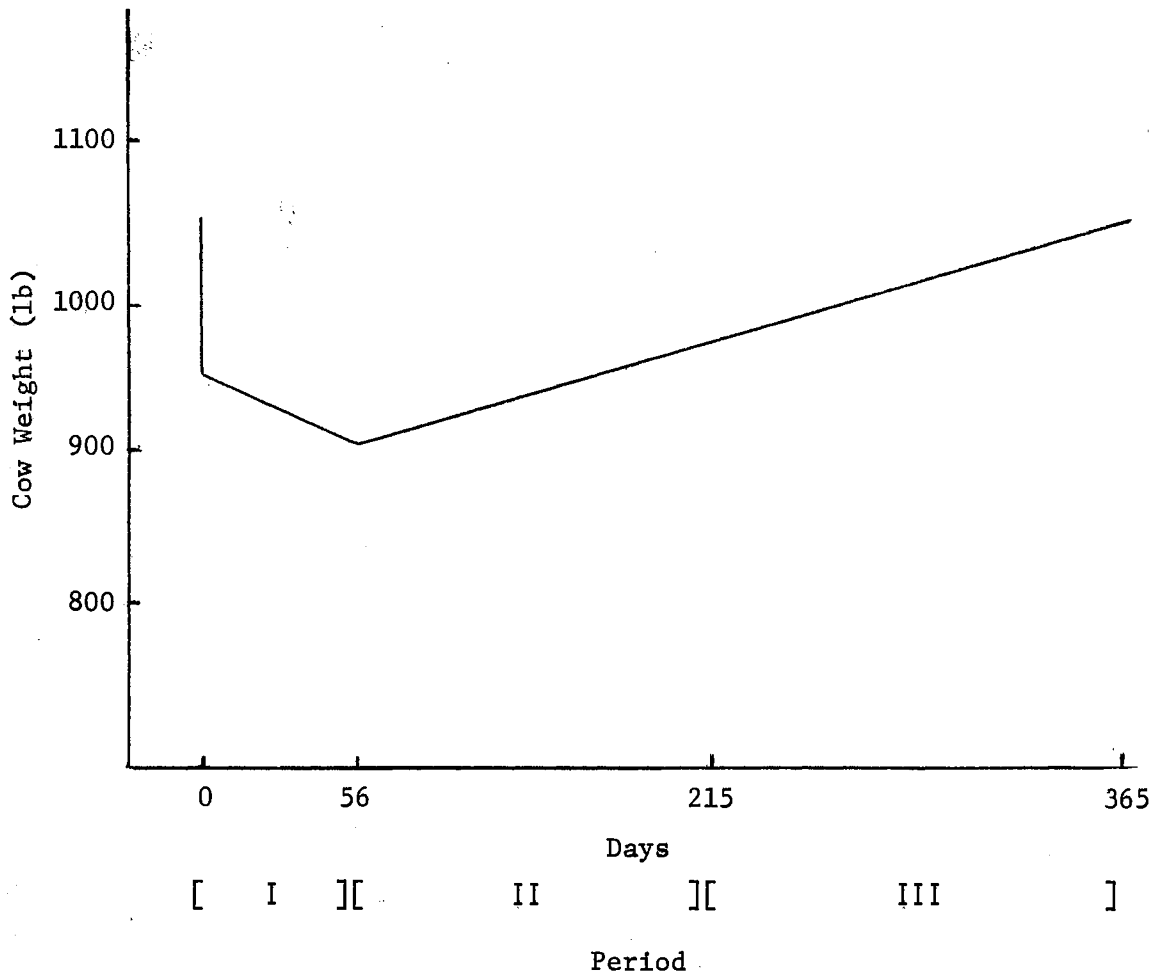

Figure 3. Weight Change Pattern for Producing Cows, Illustrated for a 1000 lb Cow

The experimental period for each producing cow was divided into a lactation phase and a non-lactation phase. The lactation phase consisted of time periods I and II and the non-lactation phase corresponded to period III in Figure 3. Cows which produced calves and raised them to 215 days of age were classified as producing cows during the lactation phase, periods I and II. Individuals which failed to rebreed during the lactation phase were excluded from the producing cow group during the non-lactation phase, period III. Table XI summarizes the classification of the cows during the two phases of the experiment. Four animals failed to rebreed, leaving 17 cows classified as producing during the non-lactation phase and the complete year.

Ration A (Table VI) was fed to all cows during the lactation phase of the experiment. At 215 days post-partum, when the calves were weaned, all cows were changed to ration B (Table VI). Feed samples were collected once each week for proximate analyses and gross energy determinations, with results reported for each ration in Table VII. Digestible energy and TDN values for rations A and B are shown in Table VIII. In addition, a free choice mixture of one part calcium carbonate was available to all the animals.

During the lactation phase of the experiment, calves of producing cows were allowed to run with their dams continuously with the exception of the period when the cows were fed each morning. For this period (approximately one hour), calves were allowed to individually eat, free choice, the calf creep ration shown in Table IX. The amount of creep ration consumed by each calf was recorded for the computation of total energy requirements per pound of calf weaned.

Direct physical measurements taken at the beginning of the experi-

TABLE VI

INGREDIENT MAKEUP OF RATIONS FED TO COWS

Ingredient	Ration A	Ration B
	(%)	(%)
Chopped Alfalfa Hay	63.30	43.70
Cottonseed Hulls	-----	43.70
Ground Milo	31.70	7.60
Cane Molasses	5.00	5.00
Vitamin A Premix	100 gm/T[1]	100 gm/T[2]

[1]30,000 IU Vitamin A per gram.

[2]21,000 IU Vitamin A per gram.

TABLE VII

PROXIMATE COMPOSITION AND GROSS ENERGY VALUES OF RATIONS FED TO COWS ON A 100% DRY MATTER BASIS

Feed	Crude Protein	Ether Extract	Crude Fiber	NFE	Ash	Gross Energy
	(%)	(%)	(%)	(%)	(%)	(cal/gm)
Ration A	16.26	2.66	15.59	58.45	7.04	4394
Ration B	12.00	2.15	29.94	49.75	6.16	4436
Calf Ration	14.53	3.28	8.95	68.00	5.10	4697

TABLE VIII

DIGESTABLE ENERGY AND TOTAL DIGESTIBLE NUTRIENT

CONTENT OF RATIONS FED TO COWS

Ration	Digestible Energy	Total Digestible Nutrients
	(Mcal/lb)	(%)
A	1.28	66.12
B	0.97	46.78

ment and at monthly intervals thereafter were:

1. Width at the pins
2. Width at the hooks
3. Width of the loin
4. Circumference of the heart girth
5. Fat thickness over the 12th rib

Fat thickness was an average of three measurements made 2, 3½ and 5 inches from the center of the back over the 12th rib with a thermister thermometer described by Brackelsburg _et al._ (1967).

Indirect physical measurements taken at the beginning of the experiment and at monthly intervals from photographs made through a 12 inch by 6 inch grid included:

1. Length of body
2. Height at withers
3. Depth of chest
4. Distance from chest floor to ground

Average values for the direct and indirect measurements are shown in Table X.

Milk production was estimated at monthly intervals by the calf nursing procedure. This procedure involved the weighing of calves individually before and after nursing following separation from their dams overnight and again in the evening of the same day after a separation period of eight hours. Raw milk samples were also taken at monthly intervals for fat and gross energy determinations. Collecting the raw milk samples involved injecting each producing cow with 2.0 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 four

TABLE IX

INGREDIENT MAKEUP OF CREEP RATION FED TO CALVES

Ingredient	% in Ration
Cracked Milo	46.20
Crimped Oats	20.00
Chopped Alfalfa	12.00
Wheat Bran	10.00
Soybean Meal (44%)	6.00
Molasses	5.00
Dicalcium Phosphate	0.74
Aureomycin (10 gm/lb)	0.06
Vitamin A premix	3.33 gm[1]/100 lb

[1]30,000 IU Vitamin A per gram.

TABLE X

AVERAGE MEASUREMENTS OF COW SIZE OVER THE ENTIRE EXPERIMENTAL PERIOD

Measurement	Average Value	Standard Deviation	Standard Error of Mean
Initial Weight (lb)	1025.19	150.86	32.92
End Weight (lb)	1017.43	154.28	33.67
Physical Measurements:			
Width at Pins (in)	11.52	1.072	0.062
Width at Hooks (in)	19.76	1.457	0.084
Loin Width (in)	13.02	0.920	0.053
Heart Girth (in)	69.14	4.530	0.261
Fat Thickness (mm)	7.93	2.277	0.131
Photograph Measurements:			
Length of Body (in)	53.73	3.198	0.197
Wither Height (in)	45.27	2.568	0.158
Depth of Chest (in)	24.50	2.037	0.125
Chest Floor to Ground (in)	20.79	1.152	0.071

quarters completely and from the total milk yield obtaining two 200 ml samples, one for fat determination and the other for gross energy analysis.

Individual digestion trials were done on each cow used in the experiment using the chromium oxide reference technique to determine both apparent TDN and DE values for rations A and B. The digestion trial for the lactation phase, during which ration A was fed, was conducted in October of 1967. For the non-lactation phase, when ration B was fed, the digestion trial was done in February of 1968. In both trials, each cow received 20 gm of chromium oxide mixed in the daily feed allowance for 19 days. The first 14 days served as a preliminary period and the last five days served as a collection period.

During the five-day collection period, rectal grab samples were obtained at 8:00 a.m. and 5:00 p.m. Each sample was placed in a plastic bag with a small amount of thymol added to prevent putrefaction. Individual samples were dried at 55°C in a forced air oven and ground through a 1 mm screen in a Wiley Mill prior to being stored for analysis. A composite sample was made for each cow by combining morning and afternoon samples from the five-day collection period on an equal dry matter basis for proximate analysis.

Proximate analysis of feed and fecal samples were determined by A.O.A.C. (1960) procedures. Gross energy values for feed, fecal and milk samples were determined by use of a Parr Adiabatic Bomb Colorimeter Series 1200. Gross energy determinations for milk samples involved drying approximately 4 ml of milk onto 0.80 to 0.90 gm of Sulka-Floc[1]

[1]Brown Company, Berlin, New Hampshire.

placed in a combustion capsule at 60°C. Following the combustion of the whole sample, the energy value for the Sulka-Floc was subtracted from the total energy and the remainder assumed to be the gross energy of the milk.

Apparent digestion coefficients and apparent digestible energy values were calculated by the equation presented by Kane et al. (1953).

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

Digestion coefficients were calculated on a dry matter basis for both rations A and B.

Chromium oxide in the feces was determined with an atomic absorption spectrophotometer by the procedure outlined by Williams et al. (1962). Recovery of chromium oxide in the feces was assumed to be 100 percent with ration A. However, a recovery of only 80 percent was assumed with ration B. The TDN and DE values for ration B were approximately 25 percent lower than standard book values if one assumed 100 percent chromium oxide recovery.

Streeter (1966) and Knapka et al. (1967) found that recovery of chromium oxide in high roughage rations ranged from 70 to 90 percent. Thus, an 80 percent recovery of chromium oxide was used to calculate digestion coefficients for the non-lactation phase of the experiment because of the large amount of roughage in ration B (87.4 percent, Table VI).

A problem encountered with both digestion trials was the unusually high ash content of the feces on a dry matter basis. This was particularly noticeable in the non-lactation phase where ash values as high as

50 percent were observed. Apparently the cows consumed a large amount of mineral and/or dirt to help satisfy their hunger since feed intake was restricted. If this were the case, just how it affected proximate analysis other than raising the ash content of the feces is not known.

Energy requirements for producing cows in lactation were individually corrected for milk production by the equations described by Gaines and Davidson (1923). This equation is:

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

Daily energy required for milk production was calculated by multiplying the 4 percent FCM by 0.32 lb for TDN and 0.65 Megcal for DE (N.R.C., 1966). Daily energy requirements for maintenance, weight gain and fetal growth were obtained by subtracting calculated daily energy required for milk production from total daily energy required by producing cows.

Other corrections in the data were made for weight changes in the predetermined weight change pattern. The formula (Knott _et al._, 1934) used for this correction was:

$$\text{Pounds gained or lost} \times 3.53 = \text{TDN required for weight change}$$

Digestible energy requirements for the same weight changes were calculated on actual DE contents of both rations A and B. If a cow exceeded her predetermined weight at 215 days post partum, then TDN and DE required for this amount of gain were calculated and subtracted from the total energy required during periods I and II and added to period III. If the cow was below the predetermined weight at either 215 days postpartum or at the termination of the experiment, then energy was added to the respective phase of the trial. Within the analysis of data, the corrected values will be identified.

The data obtained were analyzed by simple regression analysis and analysis of variance by the procedures outlined by Steel and Torrie (1960).

CHAPTER IV

RESULTS

Results of this study are divided into three phases: (1) energy requirement during the lactation phase, (2) energy requirement during the non-lactation phase, and (3) energy requirement for the complete year.

Cows which calved and nursed their calves to 215 days of age were classified as producing cows and used for analysis of data for the lactation and complete year portions of the trial. Cows failing to rebreed during the experiment were excluded from the non-lactation and complete year portions of the data analysis, but were used for data analysis during the lactation phase. Table XI summarizes the cows and their weights used for the analysis of date for the three phases of the experiment.

Means, standard deviations and standard errors of the mean for calf data and dam's milk production are presented in Table XII.

Lactation Phase

Table XIII summarizes the data of Figures 4 and 5 indicating the DE intercepts, regression coefficients, the standard error of the regression coefficients, the standard error of the estimates and the variation accounted for in daily DE requirements by body weight. Calculated regression lines for daily DE required for maintenance, cow

TABLE XI

AVERAGE STARTING WEIGHTS OF PRODUCING COWS DURING THE LACTATION AND NON-LACTATION PHASES OF THE TRIAL

Lactation Phase		Non-Lactation Phase	
Cow No.	Cow Wt	Cow No.	Cow Wt
57	922	57	922
58	1030	58	Failed to Rebreed
60	1180	60	1180
62	1082	62	1082
63	1050	63	1050
64	1200	64	1200
65	1160	65	1160
66	1280	66	Failed to Rebreed
67	1205	67	1205
68	1113	68	Failed to Rebreed
69	1335	69	Failed to Rebreed
71	945	71	945
72	887	72	887
73	823	73	823
74	928	74	928
75	860	75	860
76	910	76	910
77	1055	77	1055
78	950	78	950
79	770	79	770
82	912	82	912

TABLE XII

MEANS, STANDARD DEVIATIONS AND STANDARD ERRORS OF THE MEAN FOR CALF WEIGHTS AND MILK PRODUCTION DATA

Trait Measured	Value Observed	Standard Deviation	Standard Error of the Mean
Calving Date (days)	90.5	18.06	3.94
Birth Weight (lb)	70.3	9.77	2.13
Weaning Weight (lb)	445.0	49.35	10.77
Feed Consumed by Calves (lb)	774.9	122.48	26.73
Daily Milk Production (lb)	10.24	1.753	0.383
Milk Fat (%)	2.63	0.307	0.067
Daily Milk Fat Production (lb)	0.271	0.065	0.014
Daily 4% Fat Corrected Milk (lb)	8.16	1.623	0.354
Daily Gross Energy of Milk (Kcal)	2788.79	530.22	115.70

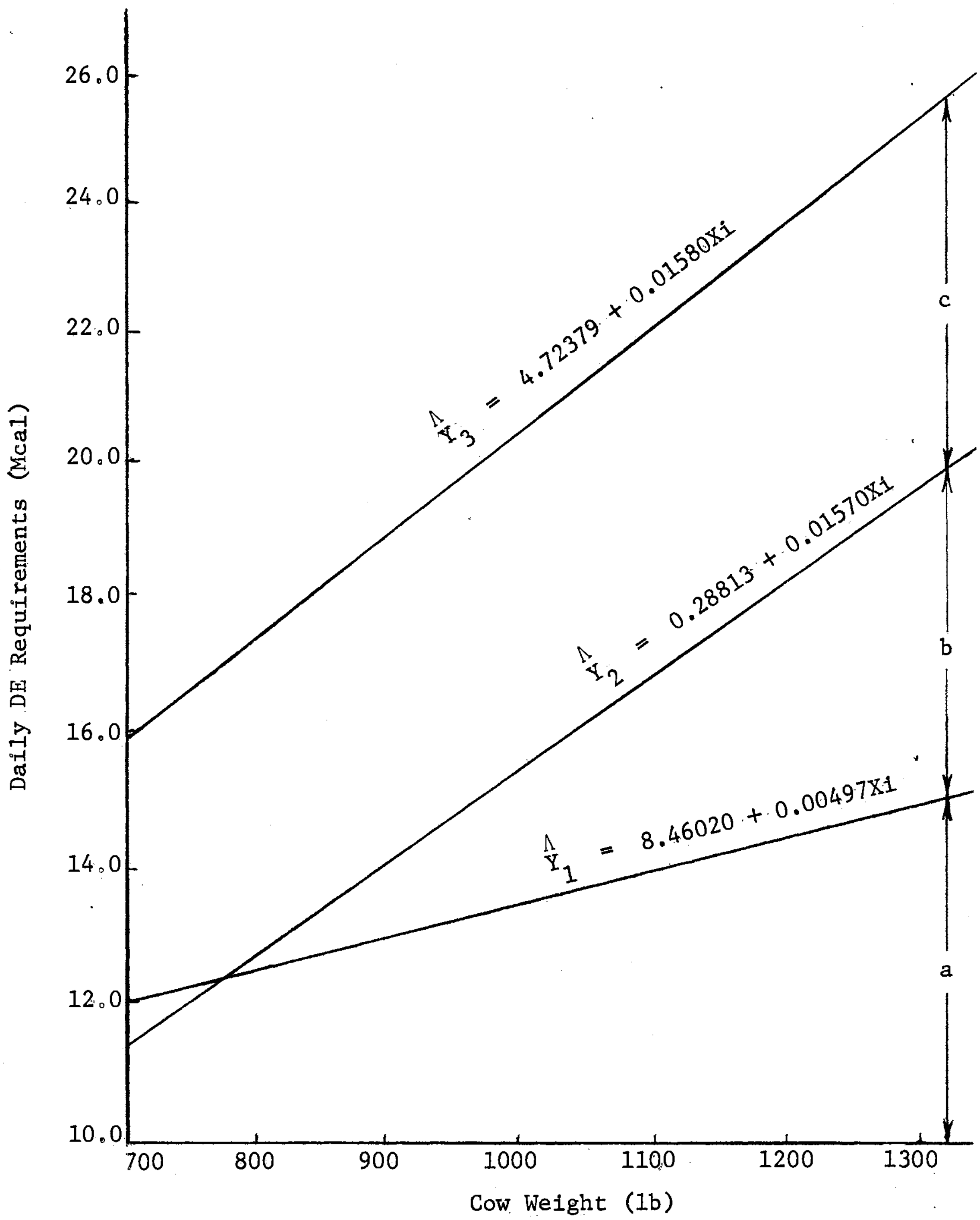

Figure 4. Daily Digestible Energy Required With Actual Amount of Feed Intake for Maintenance (Y_1), Maintenance and Cow Gain Plus Fetal Growth (Y_2), and Total Production (Y_3) During the Lactation Phase. (See text for explanation of a, b and c.)

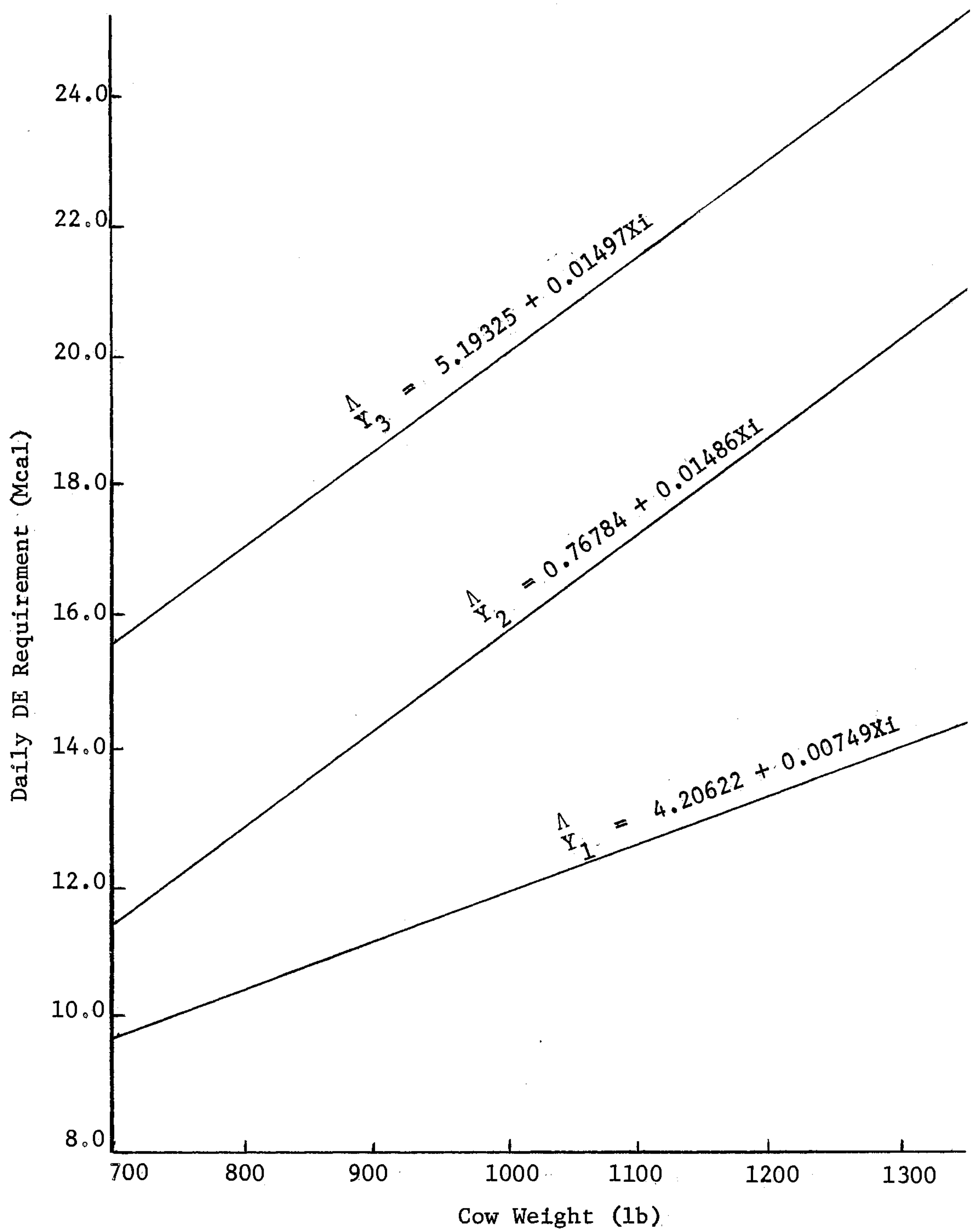

Figure 5. Daily Digestible Energy Required With Corrected Feed Intake for Maintenance (Y_1), Maintenance and Cow Gain Plus Fetal Growth (Y_2) and Total Production (Y_3) During the Lactation Phase

TABLE XIII

REGRESSION EQUATIONS FOR DAILY DIGESTIBLE ENERGY REQUIREMENTS REGRESSED ON COW WEIGHT

Equation	DE Intercept	Regression Coefficient	S_b	$S_{y \cdot x}$	Variation Accounted for by Regression
LACTATION PHASE					
Producing Cows:					
DE/day (Mcal)	4.7230	0.0158	0.00293	1.97924	60.53
Corr. DE/day (Mcal)	5.1933	0.0150	0.00310	1.09876	55.03
DE/day - milk production (Mcal)	0.2881	0.0157	0.00243	1.64414	68.68
Corr. DE/day - milk production (Mcal)	0.7678	0.0149	0.00265	1.79462	62.26
Maintenance Cows:					
DE/day (Mcal)	8.4602	0.0050	0.00075	0.27700	97.30
Corr. DE/day (Mcal)	4.2062	0.0074	0.00089	0.33083	98.60
NON-LACTATION PHASE					
Producing Cows:					
DE/day (Mcal)	3.8452	0.0076	0.00505	2.76769	13.06
Corr. DE/day (Mcal)	1.5560	0.0112	0.00577	3.16114	20.00
Maintenance Cows:					
DE/day (Mcal)	2.4993	0.0074	0.00127	0.47139	97.09
Corr. DE/day (Mcal)	8.6355	0.0033	0.00064	2.35693	96.44
COMPLETE YEAR					
Producing Cows:					
DE/day (Mcal)	5.3560	0.0115	0.00336	1.84038	44.02
Corr. DE/day (Mcal)	5.1197	0.0120	0.00312	1.71142	49.60
DE/day - milk production (Mcal)	3.2153	0.0109	0.00274	1.50005	51.29
Corr. DE/day - milk production (Mcal)	2.9696	0.0114	0.00259	1.41967	56.14
Maintenance Cows:					
DE/day (Mcal)	6.4807	0.0055	0.00012	0.04448	99.95
Corr. DE/day (Mcal)	6.1397	0.0057	0.00026	0.95210	97.77

gain plus fetal growth and total production are shown in Figures 4 and 5. Figure 4 illustrates the regression lines for actual feed intake data, while Figure 5 represents regression lines for feed intake corrected for variation in cow weight from the predetermined weight at 215 days post-partum. The abbreviation Corr. precedes the summarized data in Table XIII for those regression equations calculated on the basis of corrected feed intake relative to the predetermined cow weights at 215 day post-partum and at the termination of the study.

Regression coefficients of 0.0158 and 0.0150 calculated for actual and corrected feed intake, respectively, for total production indicate that per 100 lb increase in cow weight, DE requirements increased 1.58 and 1.50 Mcal. Cow weight accounted for 60.53 and 55.03 percent of the total variation in DE requirements during the lactation phase for total production calculated on actual feed and corrected feed, respectively.

Energy required for maintenance and cow gain plus fetal growth was calculated by subtracting the energy required for milk production from the total DE requirements. This regression line is represented by the line $\hat{Y}_2$ in Figures 4 and 5. Independent of milk production, the regression coefficients for total production were calculated to be 0.0157 and 0.0149 for actual and corrected feed, respectively. These coefficients indicate an additional 1.57 and 1.49 Mcal of DE are required for maintenance and cow gain plus fetal growth for each 100 lb increase in cow weight. With milk production subtracted from total production for actual and corrected feed intake, 68.68 and 62.26 percent of the variation in daily DE requirements were accounted for by cow weight, respectively. Cow weight accounted for about 7.5 percent more variation observed in daily DE requirements when energy for milk production was subtracted from total energy required regardless of whether calculated for actual or corrected feed intake. This would indicate that weight alone influences energy requirements for maintenance and cow gain plus fetal growth to a greater extent than cow weight influences the energy required for total production. Further evidence that this is true is the lower standard error of the estimate values (Table XIII) obtained when milk production energy requirements were not considered as compared to the standard error of the estimate when it was considered in the regression.

Cow weight alone accounted for over 50 percent of the variation in daily DE requirements during lactation with or without energy requirements for milk production considered in the regression.

Cow size or weight had little association with level of milk production and the data indicates regardless of cow size the amount of milk produced was about the same for all animals. Table XII shows average milk production of all producing cows to be 10.24 ± 0.38 lb. The regression coefficients of 0.0157 for $\hat{Y}_2$ and 0.0158 for $\hat{Y}_3$ in Figure 4 further indicate equal milk production for all cows regardless of size. With the small standard error of the mean as observed in Table XII, one can be even more confident that milk production was nearly the same for all cows.

Regression lines for daily DE requirements for maintenance are represented in Figures 4 and 5 by $\hat{Y}_1$. Regression coefficients of 0.0050 and 0.0075 were calculated for actual and corrected feed intake, respectively. To support working maintenance, an increase of 100 lb in cow weight requires an additional 0.50 and 0.75 Mcal of DE for actual and corrected feed intake, respectively. Lines $\hat{Y}_1$ and $\hat{Y}_2$ in Figure 4 intersect and in Figure 5, while the lines do not intersect, they do not appear to be parallel. Reasons for this are not evident, but the fact that only three animals were used to determine maintenance requirements would allow for chance to cause deviation from the normal. If this is true, an inaccurate estimate of true energy requirements for maintenance would have been obtained. Intersection of corresponding lines did not occur with results observed by Smithson (1968) in a study of the same nature.

Maintenance requirements for daily DE increased 0.50 and 0.75 Mcal for a 100 lb increase in cow weight calculated for actual and corrected feed intake, respectively. The data indicate DE requirements for maintenance increase at a slower rate with increasing cow weight than do the DE requirements for total production with or without milk production. Using the calculated regression equations for actual and corrected feed, the DE maintenance requirements for a 1000 lb cow are 13.43 and 11.69 Mcal, respectively. Each estimate is lower than the amount of DE (14.1 Mcal) recommended for maintenance of a 1000 lb dairy cow by N.R.C. (1966).

For daily DE maintenance requirements, cow weight accounted for 97.30 and 98.60 percent of the variation calculated for actual and corrected feed intake, respectively. The large amount of variation in daily DE requirements accounted for by body weight suggests that cow weight alone is a major factor in determining the energy requirements for maintenance. However, as previously mentioned, maintenance requirements were determined with only three cows and estimated requirements may not be accurate with such a small number of cows. The weights of the maintenance cows were such that one cow (815 lb) was near the lower limit of the weight range for all cows on test and the other two (1225 and 1280 lb) were near the upper limit of the weight range. With such a condition existing, the maintenance regression line was in essence calculated and drawn between two points. Statistically when a regression line is calculated between two points 100 percent of the variation in the independent variable is accounted for in the regression which in this case is daily DE requirements. Such a case almost existed with this data since only three maintenance cows were on test.

Assuming that the areas "a", "b", and "c" in Figure 4 represent maintenance, maintenance along with body weight gain plus fetal growth and total production, respectively, a 900 lb cow would require 12.93, 1.49 and 4.52 Mcal per day to support the three body functions, maintenance, body weight gain plus fetal growth and milk production, respectively. To support these same, respective, body functions, a 1300 lb cow would require 14.92, 5.78 and 4.56 Mcal/day. The data indicate a 900 lb cow utilized 76.4 percent of the daily DE requirement for maintenance and body weight gain plus fetal growth while a 1300 lb cow utilized 81.95 percent of the daily DE requirement for the same functions. To support lactation, the 900 lb cow used 23.86 percent of her daily DE requirements and the 1300 lb cow, 18.05 percent. These values and percentages are in close agreement with those observed by Smithson (1968).

Total digestible nutrient requirements for producing cows during the lactation portion of the trial followed the same pattern as the DE requirements through this phase of the experiment. Figures 6 and 7 show regression lines for maintenance, maintenance plus fetal growth and body weight gain and total production for non-corrected and corrected feed

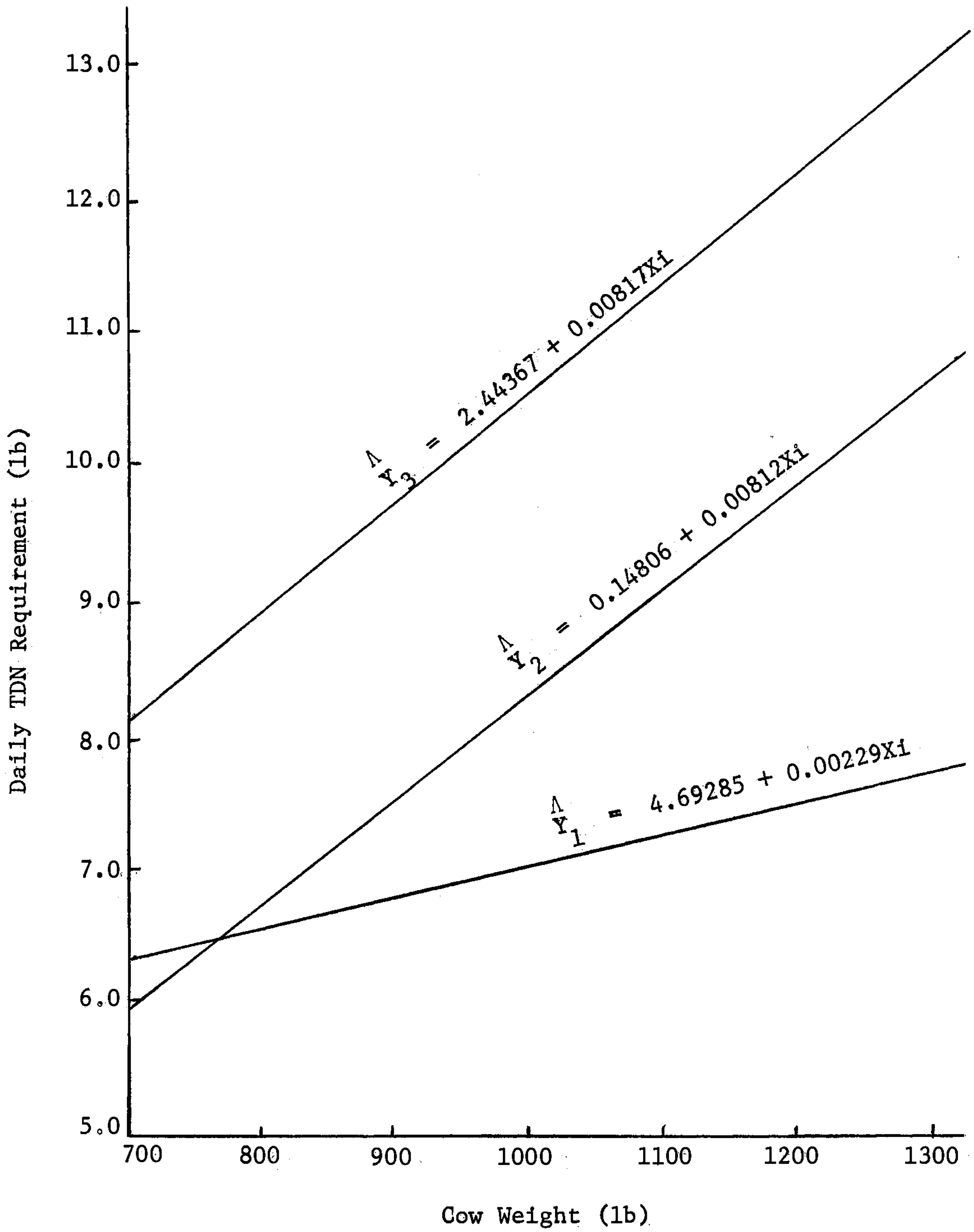

Figure 6. Daily Total Digestible Nutrients Required With Actual Feed Intake for Maintenance (Y_1), Maintenance and Cow Gain Plus Fetal Growth (Y_2), and Total Production (Y_3) During the Lactation Phase

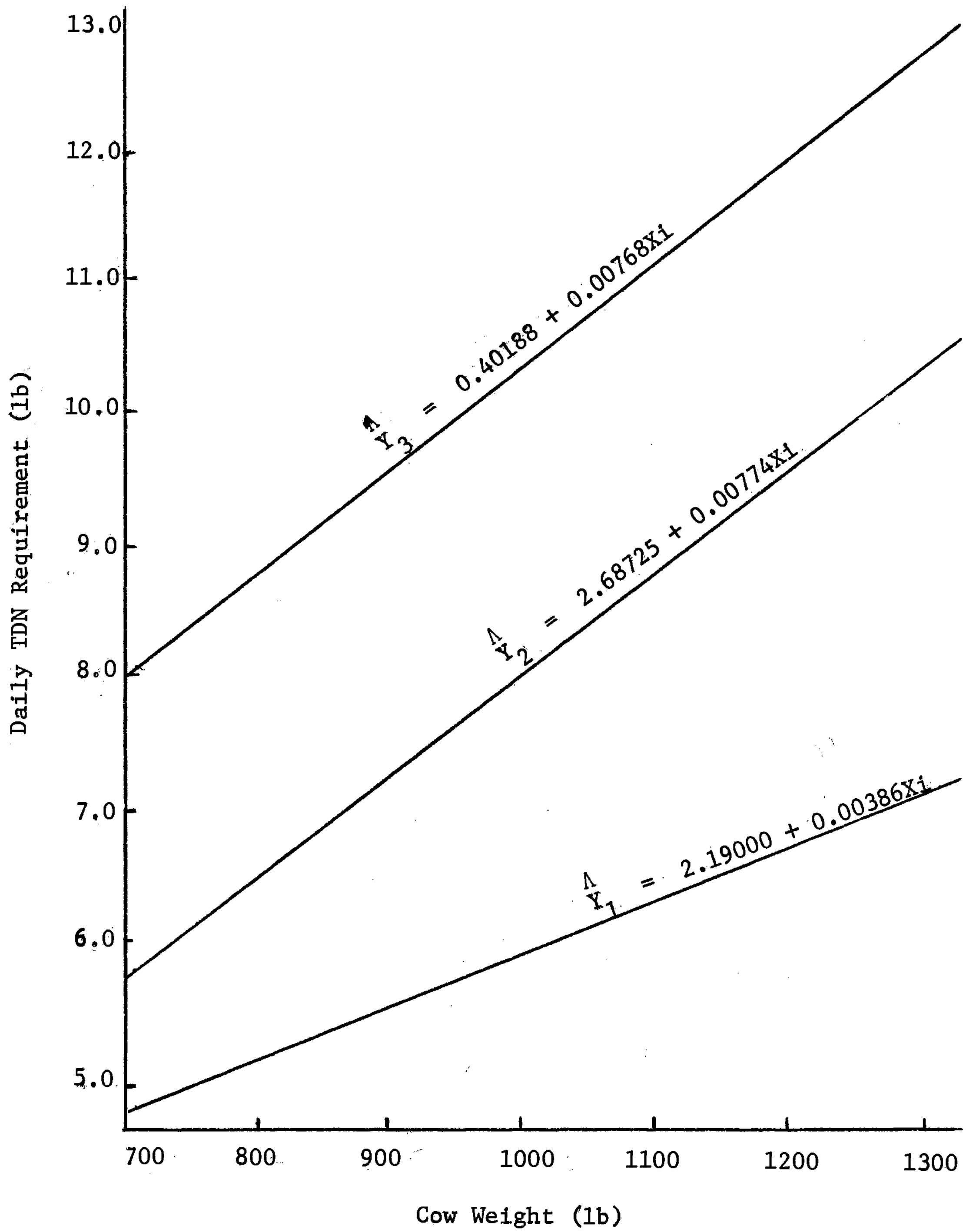

Figure 7. Daily Total Digestible Nutrients Required With Corrected Feed Intake for Maintenance (Y_1), Maintenance and Cow Gain Plus Fetal Growth (Y_2), and Total Production (Y_3) During the Lactation Phase

intake, respectively. Table XIV summarizes the data presented in Figures 6 and 7, indicating the TDN intercept, regression coefficients, the standard error of the regression coefficients, the standard error of the estimates and variation accounted for in daily TDN requirements by body weight.

Regression coefficients indicate that 0.82 and 0.77 lb of additional TDN were required to support total production for each 100 lb increase in cow weight for actual and corrected feed, respectively. Body weight accounted for essentially the same amount of variation (60.55%) in the daily TDN requirements for total production as observed in the DE data.

Requirements for maintenance plus cow gain and fetal growth represented by $\hat{Y}_2$ in Figures 6 and 7 increased 0.81 and 0.77 lb of TDN per 100 lb additional cow weight when calculated for actual and corrected feed, respectively.

Assumptions and observations relating to the TDN requirements are exactly as those for DE already discussed in this manuscript. One measure of energy is readily interchangeable to the other with the use of the appropriate conversion factor.

To support an additional 100 lb of cow weight daily, TDN requirements for maintenance increase 0.23 and 0.39 lb for actual and corrected feed intake, respectively. As in the DE data, over 97 percent of the variation in daily TDN requirement was accounted for by cow weight. However, the reason and explanation for this has been discussed earlier. The recommended TDN allowance for a 1000 lb dairy cow is 7.04 lb (N.R.C., 1966) while these data indicate 6.98 lb TDN is sufficient. The 6.98 lb TDN found in this study is in close agreement with the 1000 lb dairy cow requirements (N.R.C., 1966) and the 7.24 lb estimated by

TABLE XIV

REGRESSION EQUATIONS FOR TOTAL DIGESTIBLE NUTRIENT REQUIREMENTS REGRESSED ON COW WEIGHT

Equation	TDN Intercept	Regression Coefficient	S_b	$S_{y'x}$	Variation Accounted for by Regression
LACTATION PHASE					
Producing Cows:					
TDN/day (lb)	2.4437	0.0081	0.00151	1.02358	60.55
Corr. TDN/day (lb)	2.6873	0.0077	0.00161	1.08549	55.02
TDN/day-milk production (lb)	0.1481	0.0081	0.00126	0.85033	68.68
Corr. TDN/day-milk production (lb)	0.4019	0.0077	0.00137	0.92808	62.25
Maintenance Cows:					
TDN/day (lb)	4.6891	0.0023	0.00040	0.14672	97.10
Corr. TDN/day (lb)	2.1843	0.0039	0.00045	0.16756	98.60
NON-LACTATION PHASE					
Producing Cows:					
TDN/day (lb)	1.8502	0.0037	0.00244	1.33485	13.05
Corr. TDN/day (lb)	0.7525	0.0054	0.00278	1.52462	20.01
Maintenance Cows:					
TDN/day (lb)	2.0430	0.0029	0.00065	0.23905	95.25
Corr. TDN/day (lb)	4.1536	0.0016	0.00033	0.12050	96.06
COMPLETE YEAR					
Producing Cows:					
TDN/day (lb)	2.6993	0.0059	0.00169	0.92402	44.76
Corr. TDN/day (lb)	2.6138	0.0061	0.00157	0.85872	49.95
TDN/day-milk production (lb)	1.5915	0.0055	0.00136	0.74737	52.39
Corr. TDN/day-milk production (lb)	1.5062	0.0057	0.00129	0.70621	56.81
Maintenance Cows:					
TDN/day (lb)	3.3262	0.0027	0.00002	0.00890	99.99
Corr. TDN/day (lb)	3.0564	0.0029	0.00025	0.09155	99.21

Smithson (1968).

Again, assuming the areas between the three regression lines (Figure 6) represent TDN requirements for specific body functions, a 900 lb cow would require 6.75, 0.71 and 2.33 lb of TDN for maintenance, fetal growth plus body weight gain, and milk production, respectively. To support the respective body functions, a 1300 lb cow would require 7.67, 3.03 and 2.36 lb TDN per day. Percentages of TDN used for a particular body function are the same as those observed in the DE data.

Non-Lactation Phase

Figures 8, 9, 10 and 11 represent the calculated regression lines for the non-lactation portion of this study. Digestible energy and TDN, intercepts, regression coefficients, standard error of the regression coefficients, standard error of the estimates and variation accounted for by cow weight are summarized in Tables XIII and XIV.

Regression lines calculated for daily DE requirements are shown in Figures 8 and 9 for actual and corrected feed, respectively. With actual amount of feed intake, the regression coefficient 0.0076 indicates that for each additional 100 lb of cow weight, 0.76 Mcal of added DE was required to support maintenance plus body weight gain and fetal growth. When feed consumption was corrected for cow weight variation from the predetermined weights at 215 days post-partum and at the end of the trial, 1.12 Mcal of DE were required to support the same functions for each increase of 100 lb of cow weight. Correcting feed intake for cow weight variation from the predetermined weight increased the amount of variation in daily DE requirements accounted for by cow weight by 6.95 percent. Correcting feed intake during the lactation portion of the

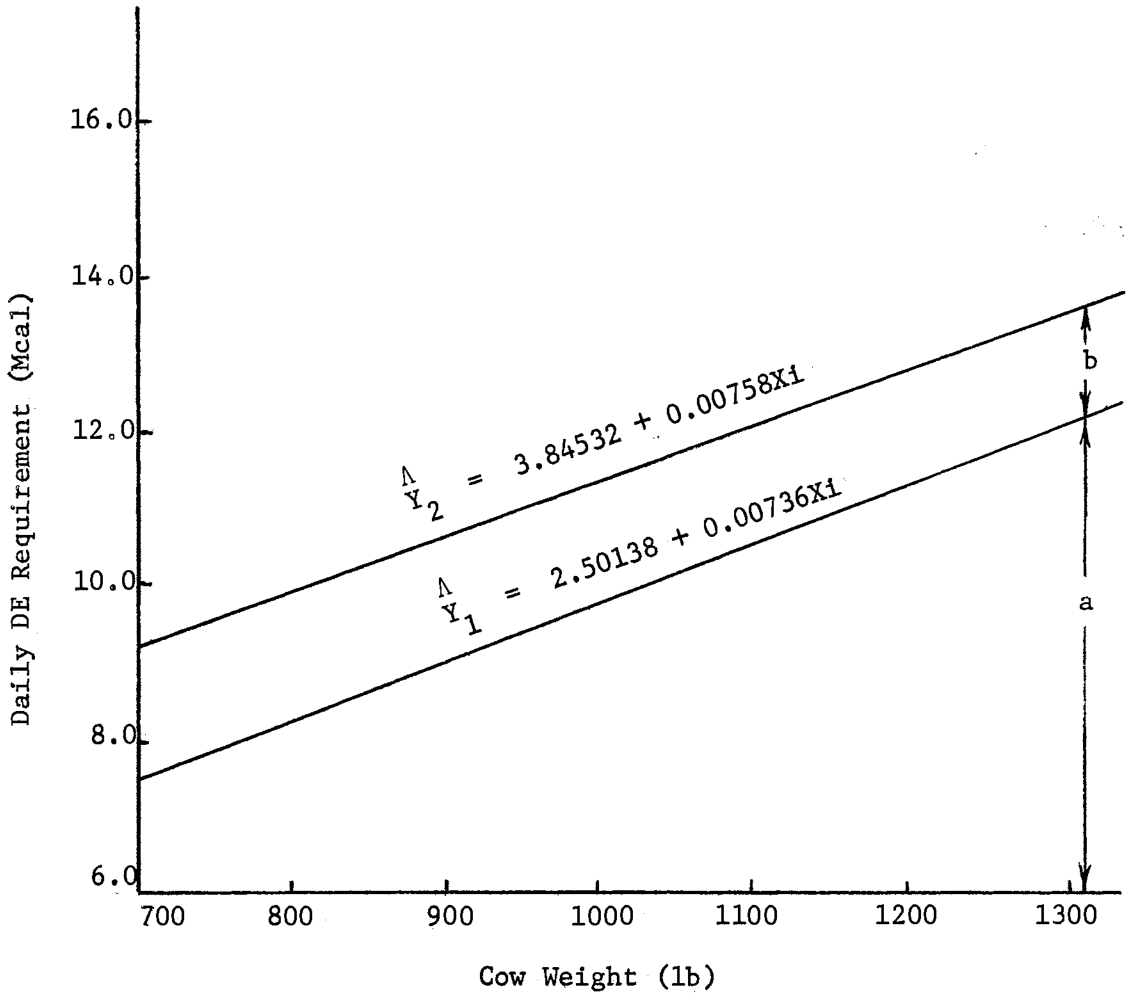

Figure 8. Daily Digestible Energy With Actual Feed Intake for Maintenance (Y_1) and Maintenance and Cow Gain Plus Fetal Growth (Y_2) During the Non-Lactation Phase

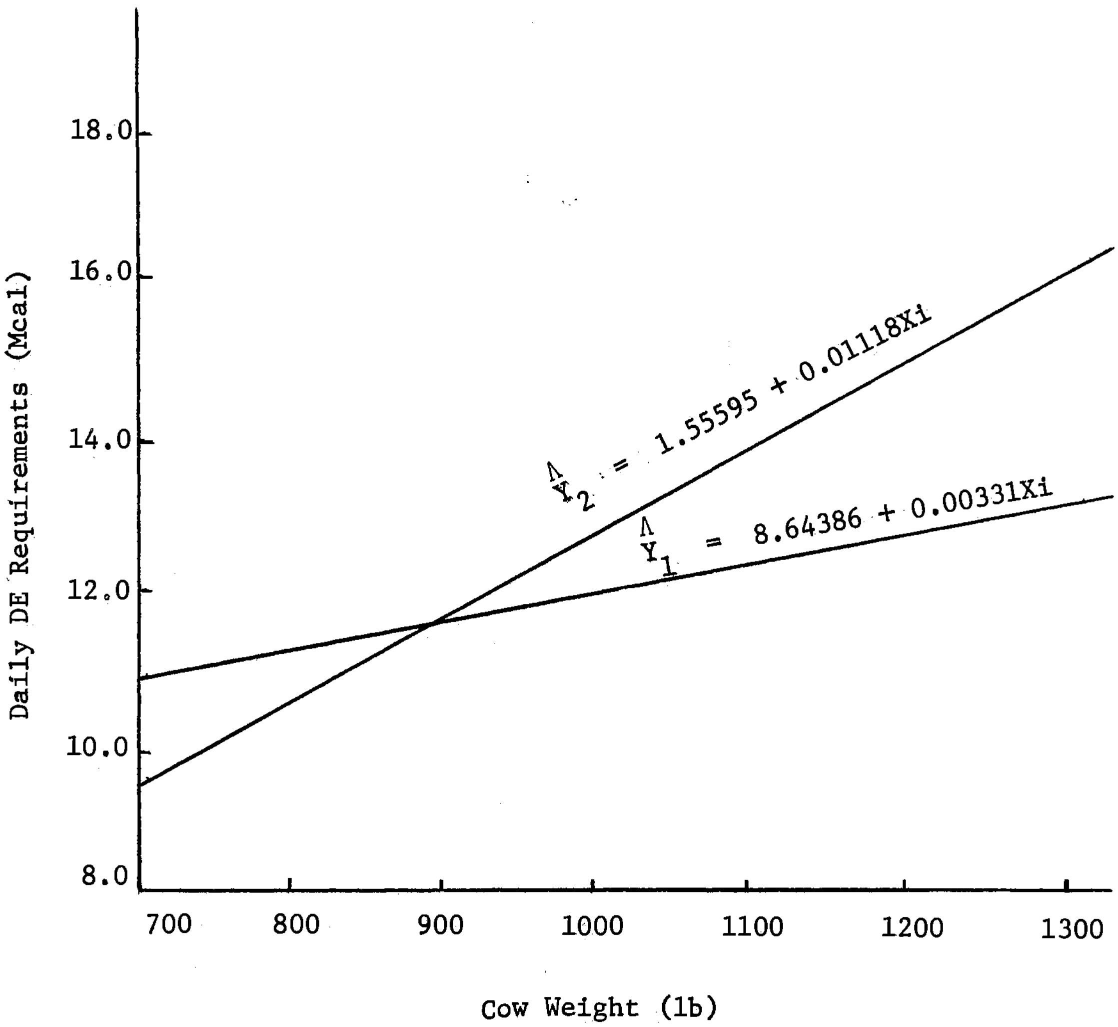

Figure 9. Daily Digestible Energy Required With Corrected Feed Intake for Maintenance (Y_1), Maintenance and Cow Gain Plus Fetal Growth (Y_2) During the Non-Lactation Phase

trial did not have the same effect. When comparing Figures 8 and 9 and the slope of the regression lines, it is evident that correcting feed intake did change the regression lines markedly.

Representing maintenance requirements in both Figures 8 and 9 is the line $\hat{Y}_1$. With actual feed consumption data (Figure 8), an increase of 100 lb in cow weight required an additional 0.74 Mcal of DE to support maintenance. With the feed intake corrected (Figure 9), the regression coefficient was 0.0033, indicating that 0.33 Mcal were required to support maintenance for each additional 100 lb of cow weight.

In Figure 8, if it is assumed that area "a" represents maintenance requirements and area "b" represents the additional DE required to support body weight gain plus fetal growth, a 1000 lb cow requires 9.86 and 1.57 Mcal of DE, respectively, for the two body functions during non-lactation. The estimated total of 9.86 Mcal to support maintenance is somewhat lower than the 14.10 Mcal recommended for 1000 lb dairy cows by N.R.C. (1966) or the 13.97 Mcal estimated by Smithson (1968).

Using the regression equations from Figure 8, a 900 lb cow would require 9.12 and 1.55 Mcal for maintenance and body weight gain plus fetal growth, respectively, while a 1300 lb cow would require 12.07 and 1.63 Mcal for the identical functions. Whereas the 1300 lb animal uses 88.10 percent of her estimated energy requirements for maintenance during non-lactation, a 900 lb cow utilized 85.47 percent for maintenance.

During the non-lactation phase of the experiment with corrected feed consumption, only 20 percent of the variation observed in daily DE requirements for producing cows could be accounted for by cow weight as compared with at least 55 percent during the lactation period. The reason or reasons for this are not apparent since one would assume that body weight would account for a larger portion of the variation in daily DE requirements when fewer productive functions were included in the regression analysis. A possible explanation of this is the low recovery of chromium oxide during the non-lactation portion of the experiment as explained in materials and methods. The low recovery of chromium oxide during this portion of the experiment caused lower than normal digestion coefficients and, consequently, altered body weight's effect on energy requirements.

Contrary to the lactation phase of the trial where $\hat{Y}_1$ and $\hat{Y}_2$ intersected with actual feed consumption data, in the non-lactation phase intersecting of the same lines occurred when feed intake was corrected (Figure 9) for variation from the predetermined cow weight. Correcting feed intake caused an increase in the regression coefficient for producing cows, but decreased the regression coefficient representing maintenance cows. Total production DE estimated requirements are not affected largely by the intersecting of the two lines, however, the partitioning of the energy requirements into total production and maintenance can be somewhat misleading because where the lines intersect, it indicates that maintenance requirements are greater than total production requirements.

Calculated regression lines for TDN requirements during non-lactation are presented in Figures 10 and 11 with a summary of data analysis in Table XIV showing the TDN intercept, regression coefficient, the standard error of the regression coefficient, standard error of the estimate and the variation in daily TDN requirements accounted for by body weight. Regression coefficients for producing cows with actual and

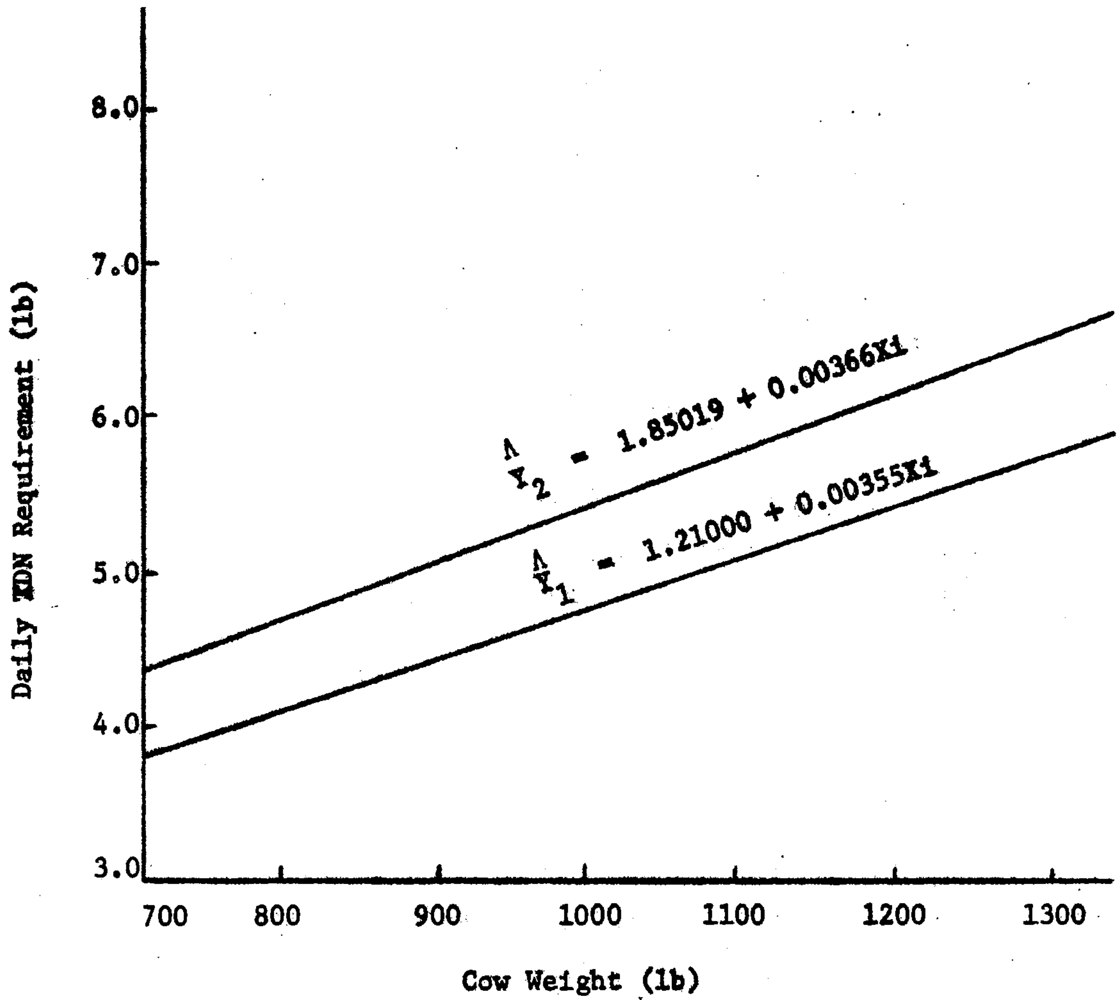

Figure 10. Daily Total Digestible Nutrients With Actual Feed Intake Required for Maintenance (Y_1), Maintenance and Cow Gain Plus Fetal Growth (Y_2) During the Non-Lactation Phase.

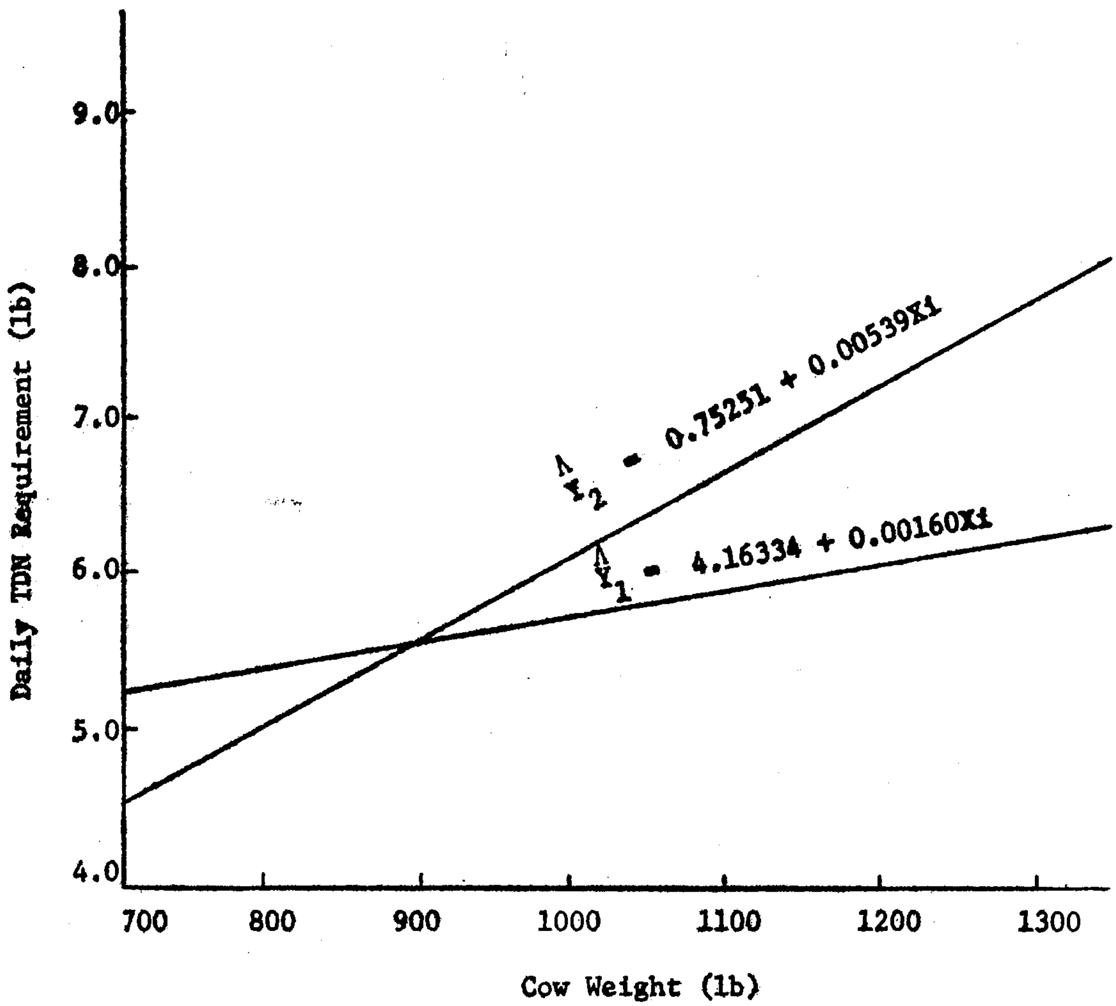

Figure 11. Daily Total Digestible Nutrients With Corrected Feed Intake Required for Maintenance (Y_1), Maintenance and Cow Gain Plus Fetal Growth (Y_2) During the Non-Lactation Phase

corrected feed intake were 0.0037 and 0.0054, respectively, indicating an increase of 0.37 and 0.54 lb of TDN per 100 lb of cow weight to support maintenance plus body weight gain and fetal growth, respectively. Using the regression formula to calculate estimated daily TDN requirements, values of 4.76 and 0.85 lb of TDN were obtained for maintenance and body weight plus fetal growth, respectively, for a 1000 lb cow. The maintenance TDN estimate is much lower than the 7.10 lb of TDN recommended for maintenance of 1000 lb dairy cows by N.R.C. (1966).

Regression lines and equations for estimated TDN requirements followed the same pattern as did DE regression equations during the non-lactation period with percentage of TDN used for maintenance and body weight gain plus fetal growth being the same as those listed in the DE requirement discussion earlier.

Complete Year

Results of the complete year analysis presented in this section deal with each cow having a calf, raising the calf to 215 days postpartum and again calving approximately one year after the first calf was born. Cows used for the non-lactation portion of the study were the same as those used for the complete year analysis.

Analysis of the complete year's data is presented in Figures 12, 13, 14 and 15 with a summary of the data such as the intercepts, regression coefficients, standard error of the regression coefficients, standard error of the estimates and the percent variation in daily energy requirements accounted for by body weight in Tables XIII and XIV. Digestible energy regression coefficients (Figures 12 and 13) of 0.0115 and 0.0120 for actual and corrected yearly feed intake, respectively,

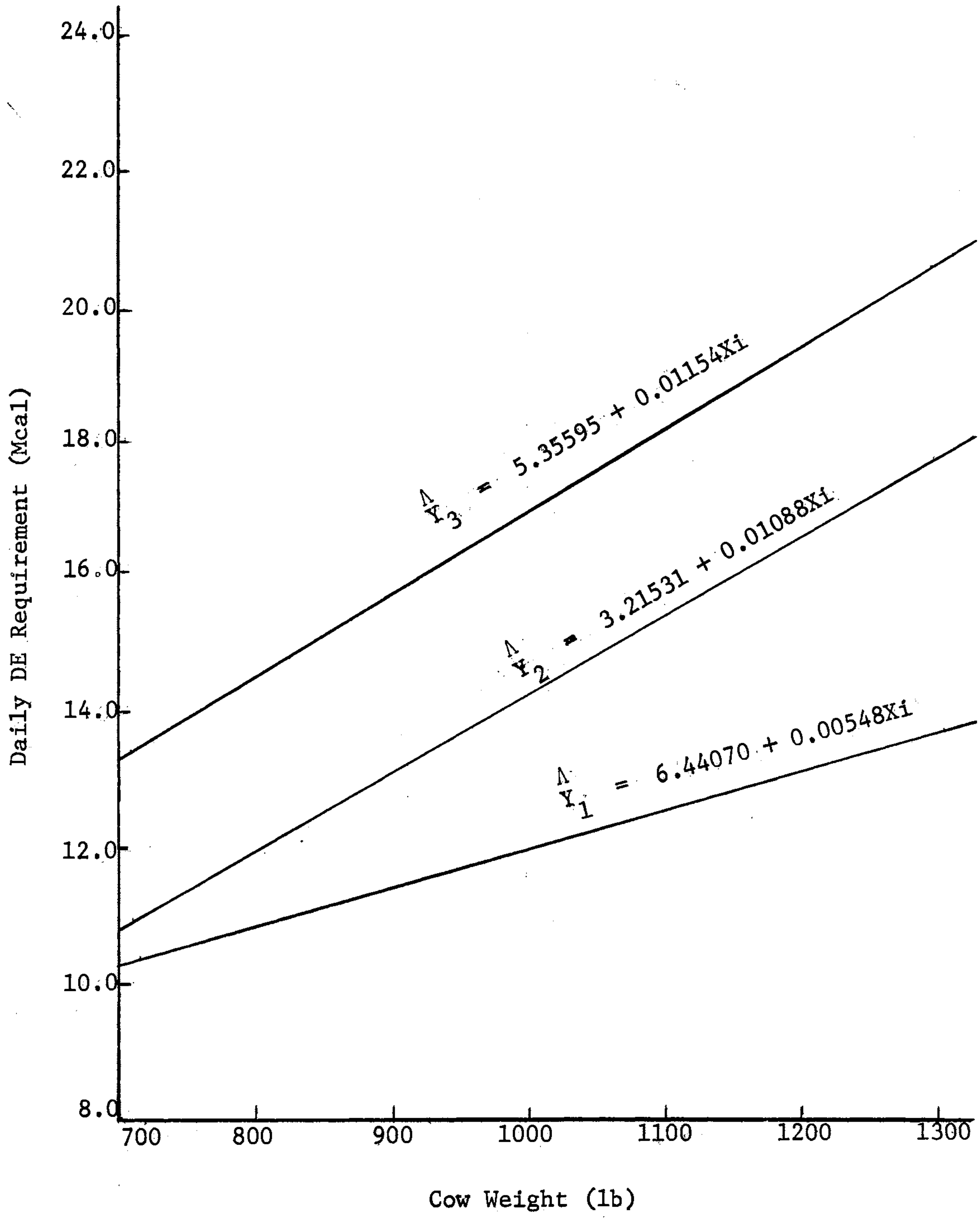

Figure 12. Daily Digestible Energy With Actual Feed Intake for Maintenance (Y_1), Maintenance and Cow Gain Plus Fetal Growth (Y_2), and Total Production (Y_3) During the Entire Year

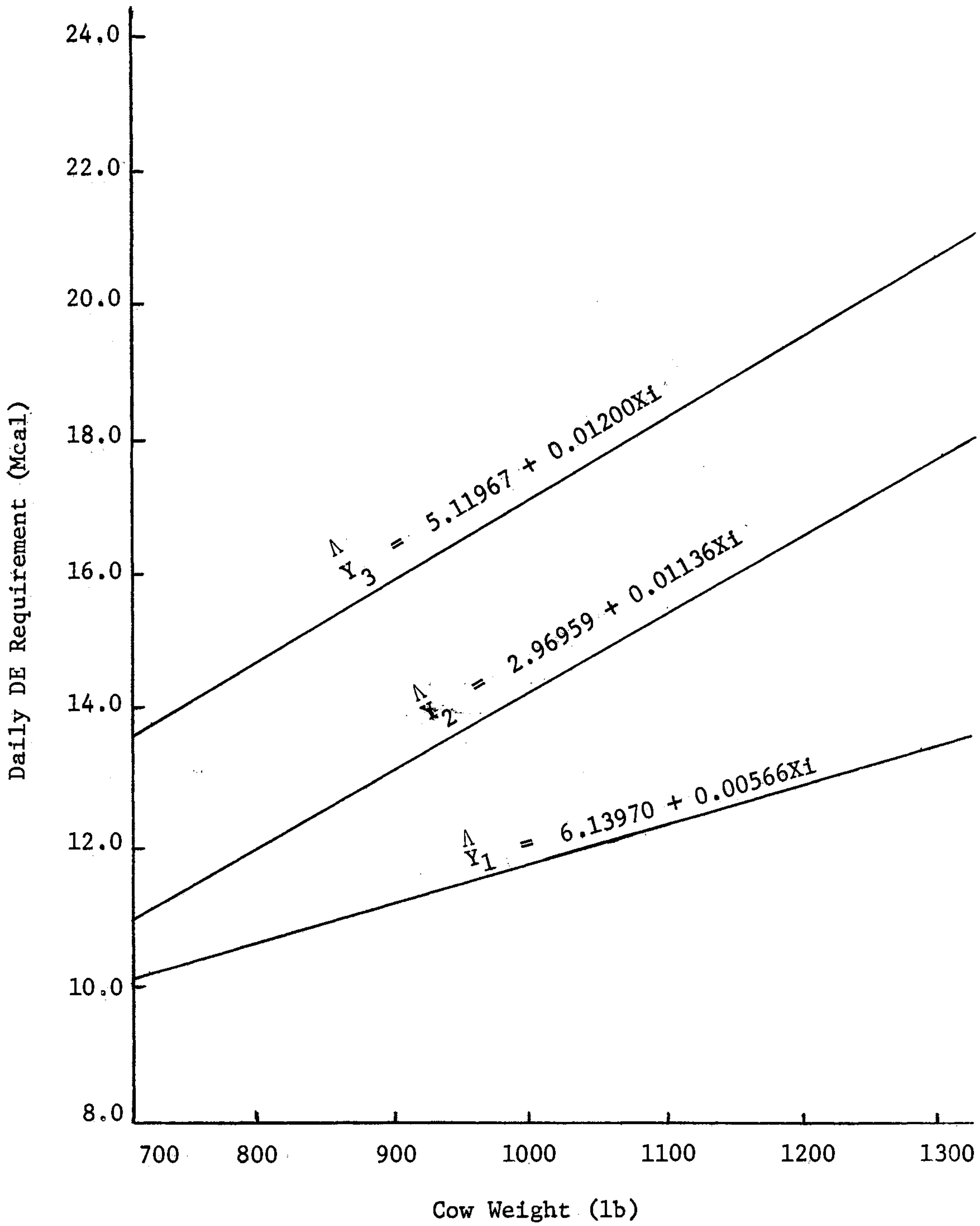

Figure 13. Daily Digestible Energy Required With Corrected Feed Intake for Maintenance (Y_1), Maintenance and Cow Gain Plus Fetal Growth (Y_2), and Total Production (Y_3) During the Entire Year

indicate that for each 100 lb of additional cow weight an additional 1.15 and 1.20 Mcal of DE per day is required to support total production during the complete year. A 1300 lb cow would require 4.61 Mcal more daily and 1683.65 Mcal more annually than a 900 lb cow. On the corrected feed intake basis, the 1300 lb cow would require 4.80 Mcal more daily and 1752.00 Mcal DE annually more than a 900 lb cow, which does not differ largely from the actual feed intake data. The increase in energy requirement of a 1300 lb cow over a 900 lb cow calculated for this study for either the actual or corrected feed intake is in close agreement with the additional energy required by the 1300 lb cow over a 900 lb cow reported by Smithson (1968). In each case, whether feed consumption was corrected or not, over 44 percent of the variation in daily DE requirements for total production over the entire year could be accounted for by cow weight. Correcting feed intake for the entire year increased the amount of variation in daily DE accounted for by body weight 5.58 percent.

Subtracting the energy requirement of milk production from total energy requirement, the regression coefficients were 0.0109 and 0.0114, respectively, for actual and corrected feed intake data. This indicates that for each 100 lb increase in body weight, approximately 1.12 Mcal of additional DE were required per day for the complete year to support maintenance plus body weight gain and fetal growth. On a yearly basis, a 1300 lb cow would require 1635.20 Mcal more DE to support total production minus energy requirements for milk production than a 900 lb cow. Without milk production energy requirements, cow weight accounted for 51.29 and 56.14 percent of the variation in estimated daily DE requirements for actual and corrected feed intake, respectively.

Regression coefficients for actual and corrected feed consumption for maintenance were 0.0055 and 0.0057, respectively. To support maintenance of a 100 lb increase in cow weight, 0.55 and 0.57 Mcal of additional DE would be required per day. On a yearly basis this would amount to 200.75 and 208.05 Mcal extra DE to maintain an added 100 lb of cow weight. Using the coefficient 0.0055, a 1300 lb cow would require 2.20 daily and 802.00 Mcal more DE annually to support maintenance than a 900 lb cow. Body weight accounted for over 97 percent of the variation in daily DE requirements for maintenance over the complete year, but again one must remember that only three maintenance cows were used in this study and results may be misleading since such a small number of experimental animals were used.

Using Figure 12 to partition the daily DE requirements, a 900 lb cow would require 11.37 Mcal for maintenance, 1.64 Mcal for body weight gain and fetal growth, and 2.74 Mcal for production of 10.24 lb of milk daily for 215 days for the entire year. The daily DE requirements for the respective functions for a 1300 lb cow would be 13.56, 3.80 and 3.00 Mcal per day. Expressing the same figures on a percentage basis, they become 72.19, 10.41 and 17.40 percent for the 900 lb cow, and 66.60, 18.66 and 14.74 percent for the 1300 lb cow.

A 1000 lb cow producing 10 lb of milk for 215 days and using the entire year analysis would require 16.90 Mcal of DE per day which is in close agreement with 19.43 Mcal of DE per day found by Smithson (1968) for a cow producing 12 lb of milk for 215 days. Recommendations for a 1000 lb beef cow nursing a calf the first three to four months postpartum by N.R.C. (1963) is 27.18 Mcal per day. The requirements recommended by N.R.C. (1963) for 1000 lb beef cows nursing a calf are 60.83

percent greater than the DE requirement found in this study for the same size cow.

Complete year data are also expressed on a TDN basis in Figures 14 and 15 and Table XIV. Like the DE analysis, correcting feed intake over the entire experimental period had little effect on regression coefficients or variation accounted for in daily TDN requirements due to body weight, however, the accuracy of both were improved by the correction of feed intake.

The regression coefficients of 0.0059 and 0.0061 (Figures 14 and 15) for actual and corrected feed intake, respectively, indicate that approximately 0.60 lb of TDN per day is required for each additional 100 lb of body weight to support total production. Cow weight accounted for 44.76 and 49.95 percent of the variation in daily TDN and DE requirements with actual and corrected feed intake, respectively. Using a regression coefficient of 0.0059, a 1300 lb cow would require 2.36 lb more TDN daily and 861.40 lb more TDN annually than a 900 lb cow requires. A 1000 lb cow producing 10.24 lb of milk per day for 215 days would require 8.68 lb of TDN per day annually as estimated by the regression equation. This is in close agreement with 9.23 lb per day annually for a 1000 lb cow producing 12 lb of milk for 215 days found by Smithson (1968).

Subtracting milk production TDN requirements from total production requirements gave regression coefficients of 0.0055 and 0.0057 for actual and corrected feed intake, respectively. Thus, without milk production, approximately 0.56 lb of TDN per day is required to support maintenance plus body weight gain and fetal growth for each 100 lb increase in cow weight. A 1300 lb cow would, in this case, require 2.24

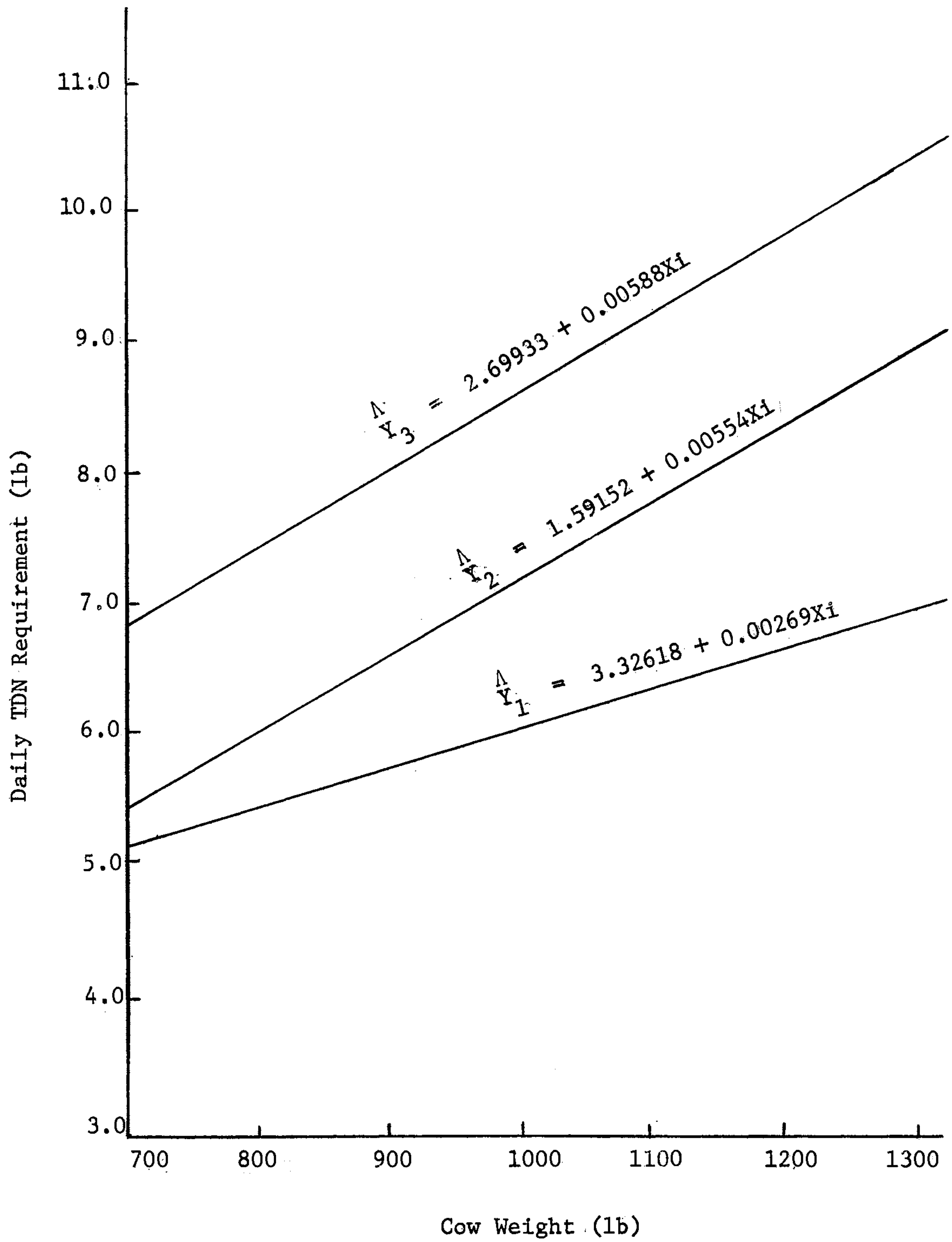

Figure 14. Daily Total Digestible Nutrients Required With Actual Feed Intake for Maintenance (Y_1), Maintenance and Cow Gain Plus Fetal Growth (Y_2), and Total Production (Y_3) During the Entire Year

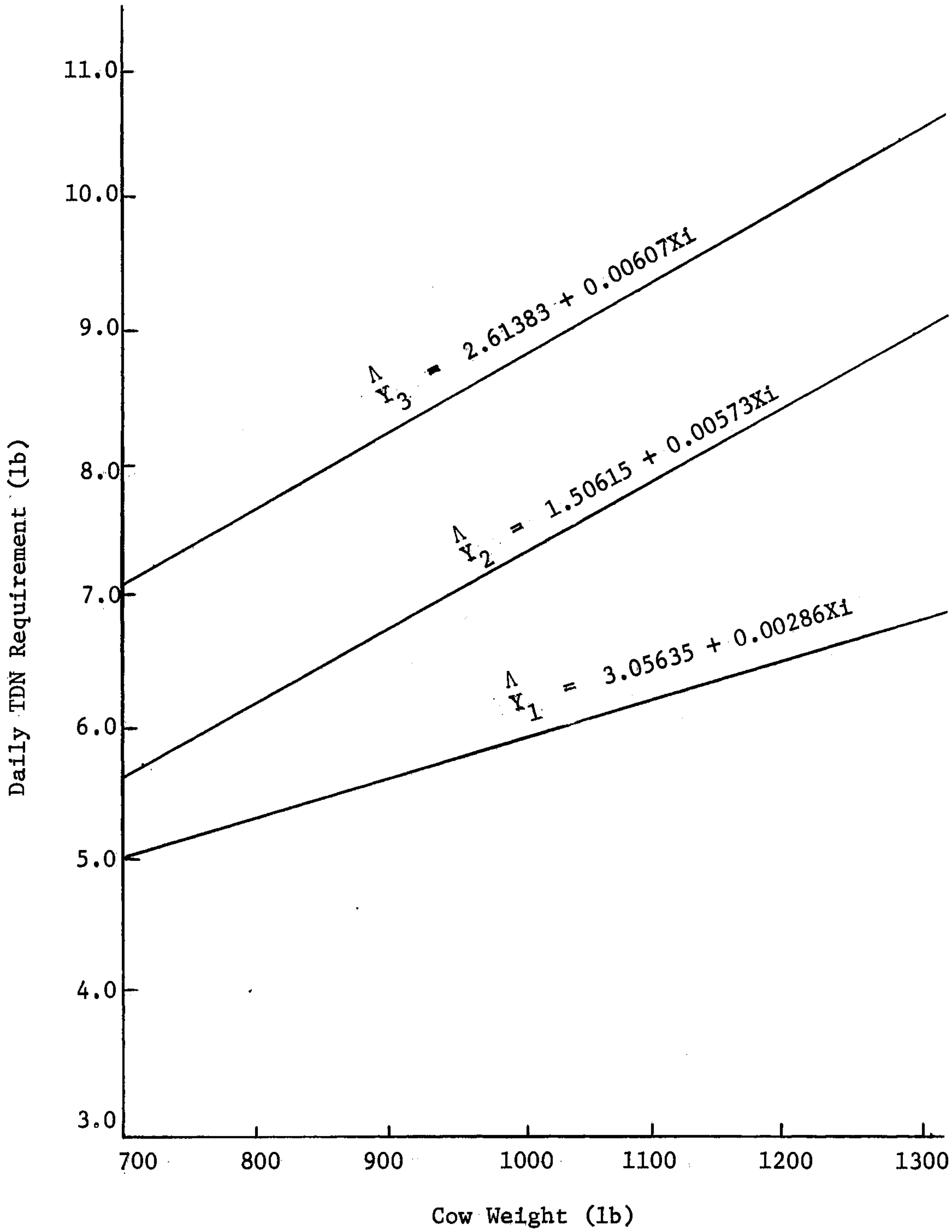

Figure 15. Daily Total Digestible Nutrients Required With Corrected Feed Intake for Maintenance (Y_1), Maintenance and Cow Gain Plus Fetal Growth (Y_2), and Total Production (Y_3) During the Entire Year

lb more TDN per day than a 900 lb cow. On a yearly basis, the larger cow requires 817.60 lb more TDN. With milk production TDN requirements subtracted from total TDN requirements, body weight accounted for 52.39 and 56.81 percent of the variation observed in daily TDN requirements for actual and corrected feed consumption, respectively.

Maintenance regression coefficients of 0.0027 and 0.0028 (Figures 14 and 15) indicate that over a period of a year, 0.27 and 0.28 lb of additional TDN is required for each 100 lb increase in cow weight. To support maintenance only, a 1300 lb cow would require 1.10 lb daily and 401.5 lb annually more TDN than would a 900 lb cow. The estimated TDN requirements for maintenance of a 1000 lb cow would be 6.02 lb per day which is in close agreement with the 6.64 lb Smithson (1968) reported and the summary of maintenance requirements by other workers in Table I and only 1.08 lb lower than that recommended for a 1000 lb dairy cow by N.R.C. (1966).

Using actual feed consumption data (Figure 14) and partitioning total production TDN requirements into maintenance, maintenance plus body weight gain and fetal growth, and milk production, the values are 71.96, 10.39 and 17.65 percent for the 900 lb cow and 66.05, 18.95 and 14.99 percent for the 1300 lb cow, respectively.

Other Variables

In addition to the calculated regressions of energy requirements on body weight, other body measurements and data were collected for incorporation into a multiple regression in an attempt to account for additional daily energy variation observed. Multiple regression equations for daily and yearly DE requirements regressed on body measurements, milk production and calf weight are presented in Tables XV and XVI.

The amount of variation accounted for in daily DE requirements (Table XV) increased when any of the additional measurements were included with body weight in multiple regression analysis. Body weight (Equation 1) accounted for 60.55 percent of the variation observed in daily DE requirements. When daily milk production, annual milk yield, or calf weaning weight was considered separately with body weight in a multiple regression, 80 percent or more variation in daily DE requirements was accounted for. This was more variation accounted for in daily DE requirements than when any other single factor alone was considered with body weight.

The percent variation accounted for when daily milk production, annual milk yield and calf weaning weight were individually used in a multiple regression equation with cow weight was 82.44, 82.42 and 80.20 percent. Length of body in combination with body weight accounted for 78.96 percent of the variation. Smithson (1968) also found body length increased the variation accounted for in daily DE requirements when used in a multiple regression along with body weight, but the value observed by Smithson (1968) was less than 50 percent of the value observed in this study. The use of hearth girth measurement in multiple regressions with body weight considerably increased the variation in daily DE requirements accounted for in a study by Smithson (1968), but had little effect in this trial.

Fat thickness with body weight in a multiple regression analysis increased the variation in daily DE requirements accounted for by 27.22 percent. This is in close agreement with the 25.99 percent increase observed by Smithson (1968), indicating that body condition as measured

TABLE XV

MULTIPLE REGRESSION EQUATIONS FOR DAILY DIGESTIBLE ENERGY REQUIREMENTS REGRESSED

ON COW WEIGHT, VARIOUS BODY MEASUREMENTS AND MILK PRODUCTION

Eqn. No.	DE Inter- cept	Body Weight	Wither Height	Length of Body	Heart Girth	Total Fat Thickness	Depth of Chest	Chest to Ground	Milk/Day	Annual Milk Yield	Calf Wn. Weight	Variation Accounted For
	(Mcal)	(lb)	(in)	(in)	(in)	(mm)	(in)	(in)	(lb)	(lb)	(lb)	(%)
1	4.7238	0.01580										60.55
2	- 6.2661	0.00678	0.37217									71.64
3	30.8690	0.02228		-0.67806								78.96
4	-16.3399	0.00107			0.4777							71.55
5	2.1798	0.00642				1.16572						77.03
6	-12.0847	0.00346					1.07568					76.53
7	8.8729	0.01301						-0.23005				70.63
8	1.3450	0.01105							0.57778			82.44
9	1.3408	0.01106								0.00269		82.42
10	- 1.3845	0.01025									0.01867	80.20
11	12.9466	0.01363	0.81837	-0.86584								83.45
12	-17.2472	0.00102	0.26342		0.31847							72.03
13	0.6986	0.00666		-0.73824	0.72229							81.17
14	1.2646	0.00749	0.70325	-0.86775	0.34003							83.83

by fat thickness over the loin does have a marked effect on energy requirements and should be considered when making energy recommendations. These same results were found by Klosterman et al. (1968) when they found that cows carrying more fat over the loin tended to gain more weight than thinner cows when feed allowances were based on body weight. This data would indicate that even though fat thickness over the loin was the same when based on a 100 lb basis, the cows with more total fat tended to utilize their daily energy allowance more efficiently for total production than cows not carrying as much total fat over the loin.

In addition, wither height, heart girth, depth of chest and distance from the chest floor to the ground used individually with body weight in a multiple regression increased the amount of variation in daily DE accounted for from 44.76 percent to 71.64, 71.55, 76.53 and 70.63 percent, respectively.

Multiple regression equations further indicate that beyond body weight and calf weaning weight, or possibly daily and annual milk production, additional measurements will provide little increased accuracy in predicting energy requirements of mature producing cows. Because of the ease in measuring calf weaning weights and the difficulty in measuring milk production, cow weight and calf weight would be the most economical and practical objective measurements with which to predict DE requirements for producing cows under normal conditions.

Yearly DE (Table XVI), daily TDN (Table XVII), and yearly TDN (Table XVIII) multiple regression equations are also presented for convenience. While the regression coefficients and intercept values for these multiple regression equations are different from those calculated

TABLE XVI

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

Eqn. No.	DE Inter-cept	Body Weight	Wither Height	Length of Body	Heart Girth	Total Fat Thickness	Depth of Chest	Chest to Ground	Milk/Day	Annual Milk Yield	Calf Wn. Weight	Variation Accounted For
	(Mcal)	(lb)	(in)	(in)	(in)	(mm)	(in)	(in)	(lb)	(lb)	(lb)	(%)
1	1954.94	4.19750										44.02
2	1948.70	3.58256	10.59961									64.06
3	8465.75	6.20281		-163.11343								68.80
4	-2799.37	1.14856			112.89156							64.64
5	1273.72	1.83678				395.39258						71.14
6	-1073.79	2.06961					209.18127					66.28
7	2207.42	3.71374						4.03725				64.05
8	943.46	3.39729							203.17555			77.75
9	940.95	3.39941								0.94518		77.75
10	514.08	3.25683									5.04336	70.87
11	6114.72	5.06846	107.35207	-187.74461								69.58
12	-2678.27	1.15594	-35.22298		134.19121							64.72
13	1294.91	2.49197		-177.41447	171.67050							70.04
14	1343.67	2.56335	60.33255	-188.52513	138.87279							70.23

TABLE XVII

MULTIPLE REGRESSION EQUATIONS FOR DAILY TOTAL DIGESTIBLE NUTRIENT REQUIREMENTS

REGRESSED ON COW WEIGHT, VARIOUS BODY MEASUREMENTS AND MILK PRODUCTION

Eqn. No.	TDN Intercept	Body Weight	Wither Height	Length of Body	Heart Girth	Total Fat Thickness	Depth of Chest	Chest to Ground	Milk/Day	Annual Milk Yield	Calf Wn. Weight	Variation Accounted For
	(Mcal)	(lb)	(in)	(in)	(in)	(mm)	(in)	(in)	(lb)	(lb)	(lb)	(%)
1	2.69933	0.00588										44.76
2	- 2.65252	0.00375	0.17007									72.40
3	15.38737	0.01126		-0.33804								79.66
4	- 7.67194	0.00093			0.22757							72.41
5	1.11615	0.00341				0.56867						77.53
6	- 5.99100	0.00190					0.53403					77.26
7	4.69784	0.00672						-0.13166				71.67
8	0.63018	0.00566							0.29390			83.48
9	0.62786	0.00566								0.00137		83.45
10	- 0.74773	0.00525									0.00947	81.17
11	6.83653	0.00714	0.39045	-0.42763								83.66
12	- 8.07369	0.00091	0.11639		0.15722							72.77
13	0.80071	0.00371		-0.36713	0.34921							81.68
14	1.06953	0.00411	0.33362	-0.42857	0.16786							84.02

TABLE XVIII

MULTIPLE REGRESSION EQUATIONS FOR YEARLY TOTAL DIGESTIBLE NUTRIENT REQUIREMENTS

REGRESSED ON COW WEIGHT, VARIOUS BODY MEASUREMENTS AND MILK PRODUCTION

Eqn. No.	TDN Intercept	Body Weight	Wither Height	Length of Body	Heart Girth	Total Fat Thickness	Depth of Chest	Chest to Ground	Milk/Day	Annual Milk Yield	Calf Wn. Weight	Variation Accounted For
	(Mcal)	(lb)	(in)	(in)	(in)	(mm)	(in)	(in)	(lb)	(lb)	(lb)	(%)
1	985.24	2.15350										44.76
2	1044.50	1.83048	3.78541									64.18
3	4238.05	3.11191		-81.06639								68.80
4	-1201.25	0.68116			52.5588							64.68
5	667.57	0.94944				194.95882						70.97
6	- 488.17	1.06512					103.03262					66.30
7	1184.13	1.89002						-1.45858				64.18
8	483.17	1.71347							103.47578			78.13
9	481.89	1.71455								0.48138		78.12
10	265.39	1.64219									2.56595	71.11
11	3106.43	2.56591	51.67191	-92.92213								69.50
12	-1139.96	0.68492	-17.84705		63.35181							64.76
13	826.62	1.34650		-87.86990	81.67047							69.90
14	850.46	1.38135	29.43851	-93.29138	65.66637							70.08

for daily DE, the trend and amount of variation accounted for in variation of energy requirements is the same as when the same variable was used in conjunction with body weight in the daily DE multiple regression analysis.

CHAPTER V

DISCUSSION

The need for data concerning the energy requirements of mature beef cows of different sizes under semi-practical conditions is evident when one considers that little research to date has examined these requirements except under laboratory conditions with a specific body function the single subject of investigation. While the animals used in this study were maintained in drylot, they were subjected to activity and environmental influences such as rain, snow, wind and heat. The energy requirements of producing beef cows in this study were influenced by activity, environment, tissue repair, body weight gain, lipogenesis, gestation, lactation and maintenance. Under such conditions, actual or working energy requirements become a complex interaction of many factors because the cow calves, nurses the calf for 215 days, is rebred, and develops another fetus, all within a period of one year.

This section will be devoted to the discussion of two individual subjects: (1) predicted energy requirements based on this study in comparison to those observed by Smithson (1968) and published requirements most commonly used for energy recommendations, and (2) a comparison of the energy required to wean 100 lb of calf as influenced by cow weight, in order to evaluate overall efficiency of feeder calf production as influenced by cow size.

Predicted Values Compared With Other Recommendations

Regression equations developed by this study allowed for the comparison of predicted energy requirements with other recommended requirements. Assuming the energy equivalent of a pound of 4 percent FCM to be 0.662 Mcal (N.R.C., 1966), one can add milk production requirements to energy requirements for maintenance plus body weight gain and fetal growth predicted by the equation (Figure 4).

$$\text{Daily DE (Mcal)} = 0.28813 + 0.01570 \text{ Weight (lb)}$$

Using cow weight and daily 4 percent FCM as independent variables, one can predict daily DE requirements with the equation:

$$\text{Daily DE (Mcal)} = 2.06358 + 0.01183 \text{ Weight (lb)} + 2.77287 \text{ daily } 4\% \text{ FCM (lb)}$$

This equation accounted for 83.69 percent of the variation in daily DE requirements and had a standard error of the estimate of 1.56. Results of the two methods of calculation are shown in Table XIX, along with those values obtained by Smithson (1968) and dairy cattle recommendations by N.R.C. (1966). Both methods of predicting DE requirements agreed closely and were nearly identical to recommendations by N.R.C. (1966). While the predicted values agreed closely with those calculated by Smithson (1966), they were consistently lower in each of the two methods of calculating DE requirements.

The recommended daily allowance of DE for a 900 to 1100 lb lactating beef cow by N.R.C. (1963) is 33.6 Mcal. This exceeds any value in Table XIX and exceeds the highest predicted value for a 1100 lb cow by 25.23 percent. These data, along with observations by Smithson (1968), indi-

TABLE XIX

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

Body Weight (lb)	lb 4% FCM	Daily DE (Mcal)				
		Predicted		N.R.C.	Smithson	
		I[1]	II[2]	(1966)[3]	I[4]	II[5]
800	6	16.82	16.16	16.45	18.58	17.31
	8	18.15	17.71	17.77	19.90	19.19
	10	19.47	19.26	19.10	21.21	21.07
	12	20.79	20.80	20.42	22.55	22.95
	14	22.12	22.35	21.75	23.87	24.84
900	6	18.39	17.35	17.15	19.56	18.40
	8	19.72	18.89	18.48	20.89	20.28
	10	21.04	20.44	19.80	22.20	22.16
	12	22.36	21.98	21.12	23.53	24.04
	14	23.69	23.53	22.42	24.85	25.93
1000	6	19.96	18.53	18.15	20.54	19.49
	8	21.29	20.07	19.48	21.86	21.37
	10	22.61	21.62	20.80	23.18	23.25
	12	23.93	23.16	22.12	24.51	25.14
	14	25.26	24.71	23.45	25.83	27.02
1100	6	21.53	19.71	19.15	21.52	20.58
	8	22.86	21.26	20.48	22.83	22.46
	10	24.18	22.81	21.80	24.14	24.34
	12	25.50	24.35	23.12	26.47	26.23
	14	26.83	25.90	24.45	27.79	28.11
1200	6	23.10	20.90	20.50	22.50	21.67
	8	24.43	22.44	21.82	23.82	23.55
	10	25.76	23.99	23.14	25.14	25.44
	12	27.07	25.53	24.47	26.47	27.32
	14	28.40	27.08	25.79	27.79	29.20
1300	6	24.67	22.08	21.23	23.48	22.76
	8	26.00	23.62	22.55	24.80	24.64
	10	27.32	25.17	23.87	26.42	26.53
	12	28.64	26.71	25.20	27.45	28.41
	14	29.97	28.26	26.52	28.77	30.28

[1]Calculated by the formula: Daily DE (Mcal) = 0.28813 + 0.01570 weight (lb) + 0.662 4% FCM (lb).

TABLE XIX (Continued)

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[2]Calculated by the formula: Daily DE (Mcal) = 2.06358 + 0.01183 weight (lb) + 0.77287 4%·FCM (lb).

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

[4]Calculated requirements by Smithson (1968) by the formula: Daily DE (Mcal) = 6.764 + 0.00980 weight (lb) + 0.662 (FCM) and determined on the same basis as predicted I.

[5]Calculated requirements by Smithson (1968) by the formula: Daily DE (Mcal) = 2.934 + 0.01091 weight (lb) + 0.941 4% FCM (lb) and determined on the same basis as predicted II.

cate that recommendations for lactating beef cows (N.R.C., 1963) are too high. However, dairy cattle recommendations for lactation (N.R.C., 1966) compare favorably with both these data and those collected by Smithson (1968), indicating that N.R.C. dairy requirements (1966) may be a better guide for nutrient requirements for beef cows during lactation than the requirements designated specifically for beef cows (N.R.C., 1963).

Daily TDN can be predicted by the same two methods as was DE. Using maintenance plus cow gain and fetal growth (Figure 6) and adding 0.330 lb of TDN per pound of 4 percent FCM (N.R.C., 1966), the prediction equation is:

$$\text{Daily TDN (lb)} = 0.14806 + 0.00812 \text{ Weight (lb)}$$

The multiple regression equation developed from this study can also be used to predict TDN requirements and is:

$$\text{Daily TDN (lb)} = 1.05924 + 0.00612 \text{ Weight (lb)} + 0.39994 \text{ daily 4\% FCM (lb)}$$

This multiple regression equation accounted for 83.72 percent of the variation observed in estimated daily TDN requirements and had a standard error of the estimate 0.81. A comparison between predicted values, the values obtained by Smithson (1968) and N.R.C. (1966) dairy recommendations is presented in Table XX. Estimated TDN values follow the same trend as the DE estimated requirements. Either prediction equation gave close to the same values recommended by N.R.C. (1966) and slightly less than TDN recommendations made by Smithson (1968). Beef cattle recommendations (N.R.C., 1963) of 16.8 lb of TDN for a 900 to 1100 lb lactating beef cow is considerably higher in TDN recommendations

TABLE XX

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

Body Weight (lb)	lb 4% FCM	Daily TDN (lb)				
		Predicted		N.R.C.	Smithson	
		I[1]	II[2]	(1966)[3]	I[4]	II[5]
800	6	8.62	8.35	8.24	7.99	8.81
	8	9.28	9.16	8.90	8.95	9.47
	10	9.94	9.96	9.56	9.92	10.13
	12	10.60	10.76	10.22	10.89	10.79
	14	11.26	11.56	10.88	11.86	11.45
900	6	9.44	8.97	8.58	8.61	9.35
	8	10.10	9.77	9.24	9.57	10.01
	10	10.76	10.57	9.90	10.54	10.67
	12	11.42	11.37	10.56	11.51	11.33
	14	12.08	12.17	11.22	12.48	11.99
1000	6	10.25	9.58	9.08	9.23	9.89
	8	10.91	10.38	9.74	10.19	10.55
	10	11.57	11.18	10.40	11.16	11.21
	12	12.23	11.98	11.06	12.13	11.87
	14	12.89	12.78	11.72	13.10	12.53
1100	6	11.06	10.19	9.58	9.85	10.43
	8	11.72	10.99	10.24	10.81	11.09
	10	12.38	11.79	10.90	11.78	11.75
	12	13.04	12.59	11.56	12.75	12.41
	14	13.70	13.39	12.22	13.77	13.07
1200	6	11.87	10.80	10.27	10.47	10.96
	8	12.53	11.60	10.93	11.43	11.62
	10	13.19	12.40	11.59	12.40	12.28
	12	13.85	13.20	12.25	13.37	12.94
	14	14.51	14.00	12.91	14.34	13.60
1300	6	12.68	11.42	10.62	11.09	11.50
	8	13.34	12.22	11.28	12.05	12.16
	10	14.00	13.02	11.94	13.02	12.82
	12	14.66	13.82	12.60	13.99	13.48
	14	15.32	14.62	13.26	14.96	14.14

[1]Calculated by the formula: Daily TDN (lb) = 0.14806 + 0.00812 weight (lb) + 0.330 4% FCM (lb).

TABLE XX (Continued)

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[2]Calculated by the formula: Daily TDN (lb) = 1.05924 + 0.00612 weight (lb) + 0.39994 4% FCM (lb).

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

[4]Calculated requirements by Smithson (1968) by the formula: Daily TDN (lb) = 0.122 + 0.0062 weight (lb) + 0.484 4% FCM (lb) and determined on the basis as predicted I.

[5]Calculated requirements by Smithson (1968) by the formula: Daily TDN (lb) = 2.529 + 0.0053 weight (lb) and determined on the basis as predicted II.

than results of this trial indicate are necessary. The 16.8 lb of TDN is higher than any of the predicted values in Table XX and 22.62 percent greater than the highest predicted energy requirement for a 1100 lb cow from this data.

During the non-lactation phase of this experiment, energy requirements were calculated by the following regression (Figure 8):

$$\text{Daily DE (Mcal)} + 3.84532 + 0.00758 \text{ Weight (lb)}$$

Total digestible nutrient requirements for wintering pregnant beef cows of different weights were calculated from the equation (Figure 10):

$$\text{Daily TDN (lb)} = 1.85019 - 0.00366 \text{ Weight (lb)}$$

Results of the above two prediction equations and the following equations which predict maintenance requirements are shown in Table XXI.

Maintenance requirements for DE were predicted from the following equation (Figure 8):

$$\text{Daily DE (Mcal)} = 2.50138 + 0.00736 \text{ Weight (lb)}$$

Daily TDN estimated requirements for maintenance were calculated and predicted from the equation (Figure 10):

$$\text{Daily TDN (lb)} = 1.85019 + 0.00366 \text{ Weight (lb)}$$

These predicted maintenance requirement values, along with predicted wintering levels, are compared in Table XXI with N.R.C. (1966) dairy recommendations and values observed by Smithson (1968). All maintenance requirements estimated from this study are approximately 30 percent lower than either N.R.C. (1966) dairy requirements or Smithson (1968)

TABLE XXI

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

Body Weight (lb)	Predicted Values		N.R.C. (1966)		Smithson (1968)	
	DE[1] (Mcal)	TDN[2] (lb)	DE (Mcal)	TDN (lb)	DE (Mcal)	TDN (lb)
			Maintenance of Mature Cows			
800	8.39	4.05	12.48	6.26	12.67	5.75
900	9.13	4.41	13.18	6.60	13.32	6.30
1000	9.86	4.76	14.18	7.10	14.06	6.64
1100	10.60	5.12	15.18	7.60	14.80	6.99
1200	11.33	5.47	16.52	8.29	15.54	7.34
1300	12.07	5.83	17.25	8.64	16.28	7.68
			Wintering Mature, Pregnant Beef Cows			
800	9.91	4.78			12.31	5.80
900	10.67	5.14			13.14	6.28
1000	11.43	5.51			13.97	6.56
1100	12.18	5.88			14.80	6.94
1200	12.94	6.24			15.64	7.32
1300	13.70	6.61			16.47	7.70

[1]Daily DE (Mcal) = 2.50138 + 0.00736 weight (lb) for maintenance and DE (Mcal) = 3.84532 + 0.00758 weight (lb) for wintering.

[2]Daily TDN (lb) = 1.21000 + 0.00355 weight (lb) for maintenance and TDN (lb) = 1.85019 + 0.00366 weight (lb) for wintering.

recommendations. However, Smithson used the complete year's data to estimate maintenance requirements whereas, in this study, the maintenance requirements established during the non-lactation portion of the trial were used. If complete year maintenance estimates (Figure 12) were used in this study, the DE equation would have been:

$$\text{Daily DE (Mcal)} = 6.44070 + 0.00548 \text{ Weight (lb)}$$

For an 800 lb cow, the daily DE estimated for maintenance would have been 10.82 Mcal. If this value is compared to predicted values in Table XXI for wintering an 800 lb beef cow, one notes that maintenance requirements would exceed wintering requirements (9.91 Mcal per day). Because such a small number of cows were used to determine energy requirements for maintenance, they could have required more energy requirements for maintenance over the entire year than producing cows required for total production during the non-lactation phase of the trial simply due to chance and sampling error. A better estimate of energy for maintenance could undoubtedly have been obtained with more experimental units used to determine the maintenance requirements of mature beef cows. Also, the energy required for slight body weight gain and fetal growth does not appear to exceed maintenance requirements very much. Little energy would be required for weight gain since a major portion of the fetal growth takes place during non-lactation and much of this growth is in the form of water retained by the fetus.

Energy Required by Various Size Cows Per 100 lb of Calf Weaned

The end result by which efficiency in a cow-calf operation can be measured is calf weight at weaning. The total amount of TDN consumed by both the cow and calf was used to calculate TDN per 100 lb of calf weaned regressed on cow weight (Figure 16). For each additional 100 lb of cow weight, an additional 55.72 lb of TDN was required per 100 lb of calf weaning weight. Comparing the total TDN requirements for a 900 lb cow and a 1300 lb cow to wean a calf, the values are 767.59 lb and 990.47 lb of TDN per 100 lb of calf weaned, respectively, per year. While larger cows did wean heavier calves, the greater weaned weight did not offset the additional TDN required by larger cows and calves and thus a regression coefficient of 0.55720 was observed. The smaller cows produced as much milk as the larger cows but required less energy for maintenance and, therefore, less total energy annually. Calf weaning weight is largely dependent on milk production and because milk production was not directly related to cow size, TDN per 100 lb of calf weaned was in favor of the smaller cows.

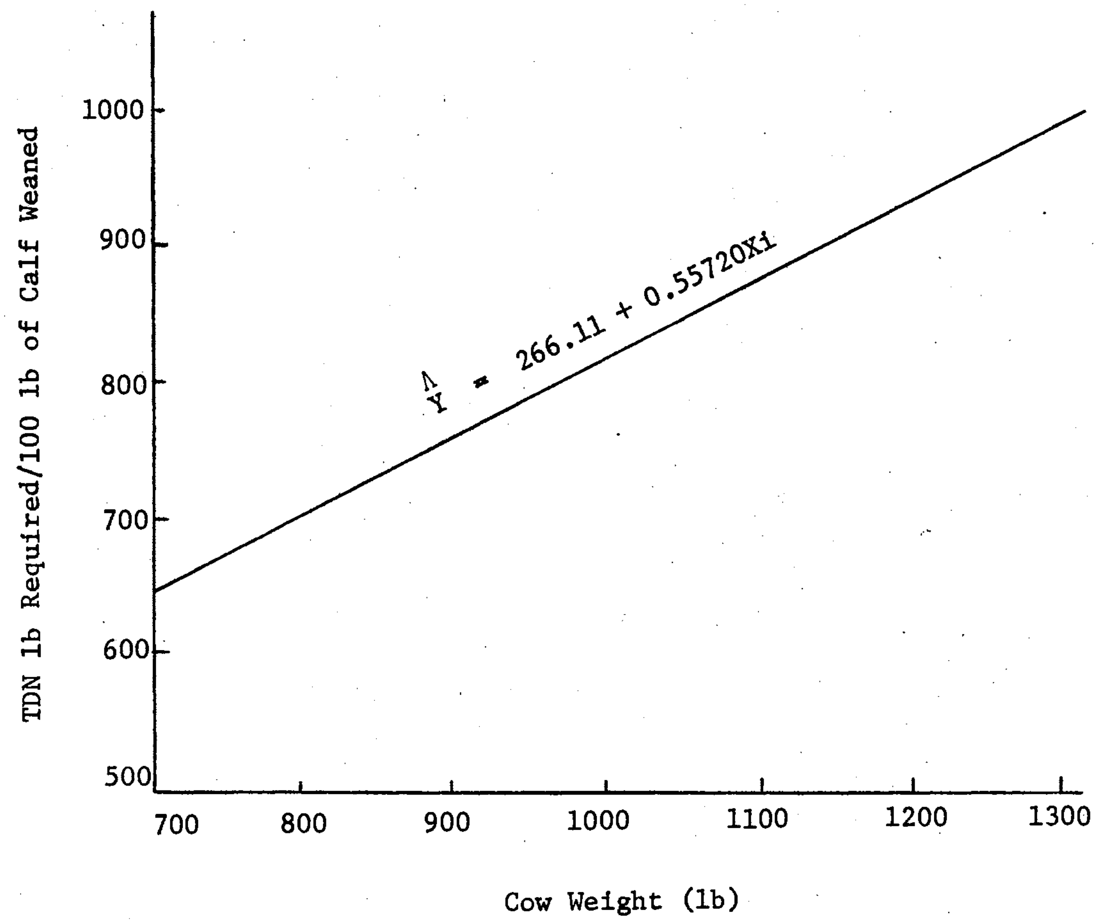

Figure 16. Total Digestible Nutrients Per 100 lb of Calf Weaned for a One-Year Period

CHAPTER VI

SUMMARY

This experiment was designed as a second year study to determine energy requirements for maintenance and production for mature beef cows of various sizes. The trial was conducted at the Fort Reno Livestock Research Station, El Reno, Oklahoma. All experimental cows were maintained in a drylot where they were individually fed a predetermined amount of feed daily. Daily feed allowances were fed to allow all cows to follow a set weight change pattern from one calving to the next, which comprised the experimental period. Cows were divided into two groups, producing cows which were allowed to follow a predetermined weight change pattern, and maintenance cows which were maintained at a constant weight throughout the study. The study was divided into two phases: (1) a lactation phase during which producing cows were fed to follow a set weight change pattern of losing 15 percent of their pre-calving weight and regaining 8.5 percent of their body weight prior to 215 days post-partum, and (2) a non-lactation phase during which producing cows were fed to gain 6.5 percent of their body weight while producing a fetus prior to calving. Weekly weight changes were measured after a 12-hour shrink and feed allowances were adjusted to maintain the proper weight change pattern.

Digestible energy (DE) and total digestible nutrient (TDN) requirements were determined by two digestion trials using the chromium oxide

reference technique. Daily energy requirements were then estimated by regression analysis and predicted energy requirements for increasing body weight were made.

Energy requirements during the lactation phase increased by 1.58 Mcal per 100 lb increase in cow weight for total production. With milk production omitted from total production requirements, DE requirements increased 1.57 Mcal for each 100 lb increase in cow weight, whereas maintenance cows required an additional 0.50 Mcal for an increase of 100 lb in cow weight. Variation accounted for in daily DE requirements by cow weight alone in total production, maintenance plus body weight gain and fetal growth, and maintenance were 60.53, 68.68 and 97.30 percent, respectively.

During the non-lactation portions of the experiment, energy requirements were partitioned into the energy required for maintenance plus body weight gain and fetal growth, and maintenance alone; During this phase of the trial, producing cows required an additional 0.76 Mcal of DE for a 100 lb increase in body weight and maintenance cows required an additional 0.74 Mcal for the same amount of increased body weight. Variation accounted for in daily DE requirements by body weight was 13.06 and 97.09 percent, respectively, for maintenance plus body weight gain and fetal growth, and maintenance alone.

Complete year energy requirements, including both the lactation and non-lactation phases, were partitioned into the energy required for total production, total production minus milk production and maintenance. Daily DE requirements increased 1.15, 1.09 and 0.55 Mcal for each 100 lb increase in cow weight, respectively. For the respective segments of the partitioned DE requirements, body weight accounted for

44.02, 51.29 and 99.95 percent of the daily DE requirement variation.

The data also were analyzed on a corrected feed intake basis for DE and on a TDN actual feed intake and corrected feed intake basis. Correcting the feed intake for body weight variation from the predetermined body weight increased the amount of variation accounted for in daily energy requirements for the non-lactation phase and complete year data analysis. However, corrected feed intake did not increase the amount of variation accounted for in daily energy requirements by body weight during the lactation phase of the experiment. Analysis of the data on a TDN basis gave different regression coefficients and standard errors of the estimate than did the DE analysis simply because of the different scale of energy values. Trends and relative values were the same. However, some difficulty was encountered during the non-lactation portions of the experiment; low digestion coefficients were obtained and believed to be caused, at least in part, by the high roughage level in the ration during this phase of the trial.

Various body measurements and cow productivity measurements were also used in conjunction with body weight in a multiple regression analysis to predict DE requirements. Over the whole year, body weight alone accounted for 44.02 percent of variation in daily DE requirements. Body weight, along with either annual or daily milk production, accounted for over 77 percent of the variation observed in daily DE requirements. Calf weaning weight, an easily obtained item, used in a multiple regression with cow weight, accounted for over 70 percent of the variation in daily DE requirements. By using weight, length of body and heart girth of the cow, the amount of variation in daily DE requirements accounted for was 70.00 percent. Wither height included with weight, length of body and heart girth did not increase the amount of variation accounted for in daily DE requirements.

Predicted energy requirements from this data for lactation were calculated and compared to published energy requirements and were in close agreement with other authors' recommendations. Energy requirements predicted from the non-lactation equations from these data appear to be lower than published data by other workers.

For a comparative measure of cow efficiency, total TDN required per 100 lb of calf weaned was regressed on cow weight. For each additional 100 lb of cow weight, 55.72 lb more TDN was required annually to wean 100 lb of calf.

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APPENDIX

TABLE XXII

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

Cow No.[1]	Body Weight	Lactating Phase DE/day	Lactating Phase Corr. DE/day[2]	Non-Lactating Phase DE/day	Non-Lactating Phase Corr. DE/day[2]	Entire Year DE/day	Entire Year Corr. DE/day[2]
	(lb)	(Mcal)	(Mcal)	(Mcal)	(Mcal)	(Mcal)	(Mcal)
57	922	19.234	18.302	9.520	12.891	16.006	16.503
58	1030	21.401	20.352				
60	1180	22.064	20.877	11.709	13.282	17.947	17.854
62	1082	21.995	23.044	14.117	12.489	18.769	18.723
63	1050	23.902	21.269	10.883	15.645	18.637	18.992
64	1200	24.893	24.384	10.707	12.555	19.420	19.820
65	1160	20.352	19.080	11.741	15.239	17.234	17.688
66	1207	24.787	24.618				
67	1205	23.404	23.462	17.341	17.481	20.983	21.073
68	1113	24.840	25.357				
69	1335	26.652	26.313				
71	945	18.233	17.782	12.039	12.674	15.854	15.819
72	887	21.401	20.919	10.935	11.573	17.221	17.187
73	823	18.804	18.068	9.313	9.803	14.950	14.710
74	928	19.626	19.854	11.753	11.753	16.330	16.462
75	860	19.186	20.432	10.868	8.957	15.754	15.697
76	910	17.586	16.765	9.479	10.820	14.576	14.556
77	1055	18.927	18.529	11.390	14.271	16.453	17.131
78	950	14.497	14.836	7.830	10.976	12.095	13.443
79	770	16.966	17.533	8.844	8.271	13.115	13.139
82	912	20.527	19.478	18.977	22.573	20.028	20.473

[1]Some cows were not used in all phases of the study because they failed to rebreed during the lactation phase of the trial and were excluded in the analysis from that point on.

[2]Daily DE requirements were corrected for variation in cow weight from the predetermined should be weight during any of the phases.

TABLE XXIII

INDIVIDUAL WEIGHTS AND DIGESTIBLE ENERGY REQUIREMENTS MINUS MILK PRODUCTION ENERGY REQUIREMENTS FOR 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	Corr. DE/day[2]	DE/day	Corr. DE/day[2]
	(lb)	(Mcal)	(Mcal)	(Mcal)	(Mcal)	(Mcal)	(Mcal)
57	922	15.250	14.317	9.520	12.891	13.348	13.842
58	1030	17.067	16.018				
60	1180	17.401	16.214	11.709	13.282	15.137	15.048
62	1082	16.987	18.037	14.117	12.489	15.810	15.764
63	1050	19.510	16.876	10.883	15.645	16.019	16.377
64	1200	19.907	19.398	10.707	12.555	16.357	16.757
65	1160	16.876	15.605	11.741	15.239	15.015	15.472
66	1207	20.188	20.018				
67	1205	18.238	18.296	17.341	17.481	17.880	17.972
68	1113	19.584	20.119				
69	1335	22.927	22.588				
71	945	13.082	12.632	12.039	12.674	12.682	12.648
72	887	14.656	14.174	10.935	11.573	13.170	13.134
73	823	14.391	13.654	9.313	9.803	12.329	12.091
74	928	14.969	15.197	11.753	11.753	13.622	13.754
75	860	14.529	15.774	10.868	8.957	13.019	12.959
76	910	12.505	11.684	9.479	10.820	11.383	11.363
77	1055	14.264	13.867	11.390	14.271	13.322	13.997
78	950	12.150	12.489	7.830	10.976	10.592	11.943
79	770	13.920	14.486	8.844	8.271	11.511	11.538
82	912	15.578	14.529	18.977	22.573	16.672	17.117

[1]Some cows were not used in all phases of the study because they failed to rebreed during the lactation phase of the trial and were excluded in the analysis from that point on.

[2]Daily DE requirements were corrected for variation in cow weight from the predetermined should be weight during any of the phases.

TABLE XXIV

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	Corr. TDN/day[2]	TDN/day	Corr. TDN/day[2]
	(lb)	(lb)	(lb)	(lb)	(lb)	(lb)	(lb)
57	922	9.947	9.464	4.592	6.217	8.168	8.385
58	1030	11.067	10.525				
60	1180	11.410	10.796	5.647	6.406	9.118	9.050
62	1082	11.374	11.917	6.808	6.023	9.503	9.503
63	1050	12.361	10.999	5.249	7.546	9.482	9.601
64	1200	12.873	12.610	5.164	6.055	9.900	10.080
65	1160	10.525	9.867	5.663	7.350	8.766	8.953
66	1207	12.813	12.731				
67	1205	12.103	12.133	8.363	8.431	10.606	10.651
68	1113	12.846	13.123				
69	1335	13.783	13.608				
71	945	9.429	9.196	5.806	6.113	8.037	8.011
72	887	11.067	10.818	5.274	5.581	8.751	8.726
73	823	9.725	9.344	4.491	4.728	7.599	7.467
74	928	10.149	10.267	5.669	5.669	8.257	8.338
75	860	9.922	10.566	5.241	4.320	7.989	7.986
76	910	9.095	8.670	4.572	5.218	7.415	7.389
77	1055	9.788	9.582	5.493	6.883	8.378	8.697
78	950	7.497	7.672	3.776	5.294	6.158	6.818
79	770	8.774	9.067	4.265	3.989	6.633	6.658
82	912	10.615	10.073	9.152	10.887	10.142	10.334

[1]Some cows were not used in all phases of the study because they failed to rebreed during the lactation phase of the trial and were excluded from the analysis from that point on.

[2]Daily TDN requirements were corrected for variation in cow weight from the predetermined should be weight during any of the phases.

TABLE XXV

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

Cow No.[1]	Body Weight	Lactation Phase		Non-Lactation Phase		Entire Year	
		TDN/day	Corr. TDN/day[2]	TDN/day	Corr. TDN/day[2]	TDN/day	Corr. TDN/day[2]
	(lb)	(lb)	(lb)	(lb)	(lb)	(lb)	(lb)
57	922	7.886	7.404	4.592	6.217	6.792	7.009
58	1030	8.826	8.283				
60	1180	8.999	8.385	5.647	6.406	7.667	7.599
62	1082	8.785	9.327	6.808	6.023	7.975	7.973
63	1050	10.089	8.727	5.249	7.546	8.130	8.247
64	1200	10.295	10.032	5.164	6.055	8.314	8.497
65	1160	8.727	8.070	5.663	7.350	7.617	7.807
66	1207	10.440	10.353				
67	1205	9.432	9.462	8.363	8.431	9.003	9.047
68	1113	10.128	10.404				
69	1335	11.857	11.681				
71	945	6.765	6.532	5.806	6.113	6.398	6.370
72	887	7.579	7.330	5.274	5.581	6.656	6.631
73	823	7.442	7.061	4.491	4.728	6.243	6.113
74	928	7.741	7.859	5.669	5.669	6.857	6.941
75	860	7.513	8.157	5.241	4.320	6.574	6.574
76	910	6.467	6.042	4.572	5.218	5.763	5.937
77	1055	7.376	7.171	5.493	6.883	6.759	7.078
78	950	6.283	6.459	3.776	5.294	5.381	6.042
79	770	7.198	7.492	4.265	3.989	5.807	5.831
82	912	8.056	7.513	9.152	10.887	8.407	8.596

[1]Some cows were not used in all phases of the study because they failed to rebreed during the lactation phase of the trial and were excluded in the analysis from that point on.

[2]Daily DE requirements were corrected for variation in cow weight from the predetermined should be weight during any of the phases.

TABLE XXVI

INDIVIDUAL WEIGHTS AND DIGESTIBLE ENERGY REQUIREMENTS OF

MAINTENANCE COWS USED IN VARIOUS PHASES OF THE STUDY

Cow No.	Body Weight	Lactation Phase		Non-Lactation Phase		Entire Year	
		DE/day	Corr. DE/day[1]	DE/day	Corr. DE/day[1]	DE/day	Corr. DE/day[1]
	(lb)	(Mcal)	(Mcal)	(Mcal)	(Mcal)	(Mcal)	(Mcal)
81	815	12.660	10.299	8.524	11.335	10.908	10.737
83	1280	14.542	13.562	12.256	12.728	13.494	13.180
84	1255	14.829	13.850	11.401	12.969	13.294	13.457

[1]Daily DE requirements were corrected for variation in cow weight from the predetermined should be weight during any of the phases.

TABLE XXVII

INDIVIDUAL WEIGHTS AND TOTAL DIGESTIBLE NUTRIENT REQUIREMENTS

OF MAINTENANCE COWS IN VARIOUS PHASES OF THE STUDY

Cow No.	Body Weight	Lactation Phase		Non-Lactation Phase		Entire Year	
		TDN/day	Corr. TDN/day[1]	TDN/day	Corr. TDN/day[1]	TDN/day	Corr. TDN/day[1]
	(lb)	(lb)	(lb)	(lb)	(lb)	(lb)	(lb)
81	815	6.548	5.327	4.113	5.466	5.518	5.383
83	1280	7.521	7.014	5.911	6.137	6.781	6.610
84	1255	7.670	7.163	5.502	6.260	6.697	6.757

[1]Daily TDN requirements were corrected for variation in cow weight from the predetermined should be weight during any of the phases.

TABLE XXVIII

DATA FROM PRODUCING COWS USED FOR CALCULATION OF MULTIPLE REGRESSION EQUATIONS

Cow No.	Body Weight	Wither Height	Length of Body	Heart Girth	Fat Thickness	Depth of Chest	Chest to Ground	Milk / Day	Annual Milk Yield	Calf Weaning Weight	DE/Day	Annual DE	TDN / Day	Annual TDN
	(lb)	(in)	(in)	(in)	(mm)	(in)	(in)	(lb)	(lb)	(lb)	(Mcal)	(Mcal)	(lb)	(lb)
57	992	44.59	53.64	65.59	6.34	23.68	19.77	7.23	1554	536	16.50	5314	8.39	2700
60	1180	46.14	55.82	71.98	7.91	25.32	21.32	8.46	1820	449	17.85	6374	6.25	2231
62	1082	45.14	53.95	69.33	8.44	24.55	20.55	9.08	1952	395	18.72	6815	9.50	3459
63	1050	46.18	54.77	70.65	9.23	25.14	20.95	7.96	1711	487	18.99	6856	9.60	3466
64	1200	47.86	55.45	71.88	7.39	25.45	20.95	9.05	1945	491	19.82	6937	10.08	3528
65	1160	48.14	56.14	72.02	7.44	25.36	22.00	6.31	1356	399	17.69	5961	8.95	3017
67	1205	47.35	56.32	71.79	8.36	24.86	22.18	9.37	2014	508	21.07	7544	10.65	3813
71	945	45.18	54.23	67.08	6.73	24.82	20.41	7.89	1696	404	15.82	5521	8.01	2796
72	887	42.32	51.27	64.79	6.95	23.45	19.55	12.24	2631	461	17.19	6153	8.73	3124
73	823	42.55	50.09	63.37	6.65	21.95	20.45	8.00	1721	393	14.71	5325	7.47	2703
74	928	42.82	51.14	65.63	7.17	22.64	20.86	8.44	1816	433	16.46	6091	8.34	3085
75	860	42.64	51.36	64.88	6.20	22.68	20.36	8.45	1817	481	15.70	5745	7.99	2923
76	910	43.82	52.45	65.88	6.82	22.05	21.36	9.22	1983	459	14.56	4978	7.39	2527
77	1055	44.36	53.95	69.31	7.86	24.55	20.68	8.46	1819	418	17.13	5482	8.70	2783
78	950	43.00	51.64	65.98	7.06	23.05	19.73	4.24	912	368	13.44	4517	6.82	2291
79	770	40.91	50.18	62.63	5.59	22.00	19.36	5.52	1188	370	13.14	5374	6.66	2723
82	912	43.86	48.14	66.33	7.52	24.23	20.05	9.03	1941	462	20.47	6490	10.33	3276

TABLE XXIX

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

	Producing Cows			Maintenance Cows		
	Weight	DE/day	Corr. DE/day[1]	Weight	DE/day	Corr. DE/day[1]
Lactating Phase						
n[2]	21	21	21	3	3	3
s[3]	21,524	439.27	431.27	3,350	42.04	37.72
ss[4]	22,518,252	9,377.47	9,043.03	3,877,650	591.91	482.06
scp[5]		457,465.19	448,875.56		47,553.55	43,145.85
Non-Lactation Phase						
n[2]	17	17	17	3	3	3
s[3]	16,839	197.44	221.25	3,350	32.17	37.02
ss[4]	16,979,509	2,425.35	3,066.97	3,877,650	352.61	458.39
scp[5]		197,849.63	222,511.31		36,930.80	41,792.90
Entire Year						
s[2]	17	17	17	3	3	3
s[3]	16,839	285.37	289.27	3,350	37.69	37.38
ss[4]	16,979,509	4,881.23	5,009.41	3,877,650	477.63	470.23
scp[5]		286,132.69	290,133.56		42,837.80	42,515.80

[1] Daily energy requirements were corrected for cow weight variation from the should be weight at the various phases of the study.

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

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

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

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

TABLE XXX

SUMS, SUMS OF SQUARES AND SUMS OF CROSS-PRODUCTS FOR COW WEIGHT AND DIGESTIBLE ENERGY REQUIREMENTS MINUS MILK PRODUCTION ENERGY REQUIREMENTS CALCULATED ON ACTUAL AND CORRECTED FEED CONSUMPTION DATA

	Producing Cows		
	Weight	DE/day	Corr. DE/day[1]
Lactation Phase			
n[2]	21	21	21
s[3]	21,524	343.98	335.97
ss[4]	22,518,252	5,798.34	5,537.21
scp[5]		359,737.31	351,147.56
Entire Year			
n[2]	17	17	17
s[3]	16,839	237.87	241.77
ss[4]	16,979,509	3,397.62	3,507.43
scp[5]		238,881.13	242,890.94

[1] Daily energy requirements were corrected for cow weight variation from the should be weight at the various phases of the study.

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

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

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

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

TABLE XXXI

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

	Producing Cows			Maintenance Cows		
	Weight	TDN/day	Corr. TDN/day[1]	Weight	TDN/day	Corr. TDN/day[1]
Lactating Phase						
n[2]	21	21	21	3	3	3
s[3]	21,524	227.17	223.03	3,350	21.74	19.51
ss[4]	22,518,252	2,507.84	2,418.40	3,877,650	158.28	128.95
scp[5]		236,573.00	232,130.69		24,589.70	22,315.35
Non-Lactation Phase						
n[2]	17	17	17	3	3	3
s[3]	16,839	95.23	106.71	3,350	15.52	17.85
ss[4]	16,979,509	564.15	713.40	3,877,650	82.07	106.58
scp[5]		95,421.31	107,315.44		17,816.95	20,152.60
Entire Year						
n[2]	17	17	17	3	3	3
s[3]	16,839	144.90	146.65	3,350	19.00	18.75
ss[4]	16,979,509	1,258.29	1,287.13	3,877,650	121.33	118.33
scp[5]		145,294.19	147,078.63		21,585.70	21,329.30

[1] Daily total digestible energy requirements were corrected for cow weight variation from the should be weight at the various phases of the study.

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

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

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

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

TABLE XXXII

SUMS, SUMS OF SQUARES AND SUMS OF CROSS-PRODUCTS FOR COW WEIGHT AND TOTAL DIGESTIBLE NUTRIENT REQUIREMENTS MINUS MILK PRODUCTION ENERGY REQUIREMENTS CALCULATED ON ACTUAL AND CORRECTED FEED CONSUMPTION DATA

	Producing Cows		
	Weight	TDN/day	Corr. TDN/day[1]
Lactation Phase			
n[2]	21	21	21
s[3]	21,524	177.88	173.74
ss[4]	22,518,252	550.67	1,480.83
scp[5]		186,034.13	181,592.00
Entire Year			
n[2]	17	17	17
s[3]	16,839	120.34	122.09
ss[4]	16,979,509	869.52	894.17
scp[5]		120,867.13	122,653.94

[1] Daily total digestible energy requirements were corrected for cow weight variation from the should be weight at the various phases of the study.

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

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

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

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

VITA

Craig Gary Ludwig

Candidate for the Degree of

Doctor of Philosophy

Thesis: ENERGY REQUIREMENTS OF MATURE BEEF COWS AS INFLUENCED BY BODY SIZE

Major Field: Animal Nutrition

Biographical:

Personal Data: Born in Charter Oak, Iowa, January 9, 1941, the son of Arnold and Marjorie Ludwig. Married Nancy Jeanne Stark, May 27, 1967.

Education: Graduated from Moorhead Community School, Moorhead, Iowa, in 1959; received Bachelor of Science degree from Iowa State University with a major in Farm Operation in November, 1963; received Master of Science degree from Iowa State University with a major in Animal Science in November, 1968.

Experience: Raised on a farm in western Iowa, Graduate Assistant, Iowa State University and Oklahoma State University.