NET ENERGY AND PROTEIN REQUIREMENTS FOR GAIN AND MAINTENANCE OF BEEF BULLS

by

CARMEN ANA JUARBE

B. S., Kansas State University, 1970

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1971

Approved by:

Robert R. Schalles
Major Professor

TABLE OF CONTENTS

ACKNOWLEDGMENTS

The author gives deepest gratitude to Dr. Robert R. Schalles, major professor, for without his assistance, encouragement, understanding and patience, the attainment of the degree would have never been possible.

Special thanks are expressed to Mr. Thomas Bement, who helped considerably with the statistical analysis of the data.

Sincere appreciation is extended to Dr. Don L. Good, Head of the Department of Animal Science and Industry, for allowing the author to carry out her master's program at Kansas State University.

Acknowledgment is made to all the faculty members, graduate students and technical personnel for their thoughtfulness and considerations throughout the author's master program.

THIS BOOK CONTAINS NUMEROUS PAGES THAT WERE BOUND WITHOUT PAGE NUMBERS.

THIS IS AS RECEIVED FROM CUSTOMER.

INTRODUCTION

The systems of beef production in this and many other countries have undergone profound changes during the past score of years, and these trends are still continuing. One of the major changes has been the marketing of younger finished cattle. This change has made it even more necessary than before that the beef producer have a thorough knowledge of the nutrient requirements and efficiency of his cattle, in order to secure the best possible returns.

All those with considerable experience in the cattle business know that "blood tells" in beef production, just as it does in other types of stock farming. Good returns cannot be expected when cattle for beef are raised out of inferior parents.

In order to determine the genetic merit of prospective herd sires a postweaning performance test is necessary. Rations used for postweaning performance testing have varied with only poor estimates as to the expected performance on a particular ration.

Numerous research reports have clearly shown the advantages of bulls compared to steers or heifers in feed efficiency, rate of gain and yield of retail cuts. Also, sex influences the onset of fattening with heifers fattening at lighter weight than steers, and steers at lighter weights than intact males. Therefore the feeding of young bulls could be of importance not only in performance testing but also in the production of beef for consumption.

Moreover, curtailment of castration would enable breeders to select young sires after they have had an opportunity to demonstrate their growth potential.

Considering the advantages that bulls have for the present day beef demands, a study of carcass composition was generated to determine the net protein and energy requirements for maintenance and production of young beef bulls. This thesis consists of the presentation of the referred study and the results obtained.

REVIEW OF LITERATURE

Composition and Gain

Hankins (1946) presented a carcass study on 120 head of cattle based on physical and chemical composition of the ninth-tenth-eleventh rib cut and of the entire dressed carcass. The following relationships were found:

Separable lean of dressed carcass = 16.08 + 0.80 (separable lean of ninth-tenth-eleventh rib cut)

Separable fat of dressed carcass = 3.54 + 0.80 (separable fat of ninth-tenth-eleventh rib cut)

Separable bone of dressed carcass = 5.52 + 0.57 (separable bone of ninth-tenth-eleventh rib cut)

Loosli and Guilbert (1951) concluded that the total feed capacities of the various livestock species are proportional to the same fractional power of body weight as maintenance requirement and basal heat production. The ratio of required protein to available energy intake is the same for the various species at physiologically equivalent growth stages; however this ratio changes with alterations in the composition of growth increments with advancing age.

Garrett, Meyer and Lofgreen (1959) presented a comparative slaughter technique for net energy studies. The technique involved carcass specific gravity determined by underwater weighting. The following equations were used to derive body composition:

(1) $Y = 0.9955X - .0013$ where Y and X are the specific gravities of the whole body and dressed carcass, respectively (Kraybill, et al., 1952)

(2) percent body water = $100\ (4.008 - \frac{3.620}{Y})$, deriving Y from 1 above (Reid, et al., 1955)

(3) percent body fat = 337.88 + 0.2406X - 188.91 logX where X is the percent body water (formula 2)

(4) percent protein in fat free dry matter = 80.93 - .00101 (age) where age is in days.

(5) percent body protein = (percent protein in 4 above) (percent fat-free dry-matter)

(6) The caloric value of fat and protein were considered to be 9367 kcal per kg of fat (Blaxter and Rook, 1953) and 5686 kcal per kg of protein (Garret, 1958).

Using this procedure Lofgreen concluded that net energy for maintenance can be approximated by the expression $35\ W_{lbs}^{3/4}$ = NEm in kcal. Also $ME_{kcal} = 62\ W_{lbs}^{3/4}$ and $DE_{kcal} = 76\ W_{lbs}^{3/4}$, where NEm is the net energy for maintenance, ME is the metabolizable energy and DE is the digestible energy, W is the weight in pounds.

Bailey, et al. (1966) concluded that bulls and steers were similar in preweaning growth rate from growth rate, feed utilization and body composition data. Bulls grew more rapidly in the feedlot than steers, were more efficient in feed conversion and produced leaner carcasses. Steers appeared to have a consistent advantage in carcass grade perhaps due to the higher fat content.

From the Biological Energy Interrelationships and Glossary of Energy Terms (revised 1966) the following formulas were obtained:

GE_i = (Dry wt of food consumed) (GE of food per unit dry weight)

FE = (Dry wt of feces) (GE of feces per unit dry weight)

$DE = GE_i - FE$

$$GE \left(\begin{smallmatrix}\text{digestion}\\ \text{coefficient}\end{smallmatrix}\right) = \frac{DE_i}{GE_i}(100)$$

$$ME = GE_i - FE - GPD - UE = NEp + NEm + HP$$

$$HP = HI + HA + HB \text{ with energy intake on the feed}$$

$$HP = ME - NEp \text{ at zero energy intake}$$

Where GE_i is the gross energy intake, FE is the fecal energy, DE is the digestible energy, ME is metabolizable energy, GPD is gaseous products of digestion, UE is urinary energy, NEp is net energy of production. NEm is net energy of maintenance and HP is heat production. HA is the heat for activity, HI is the heat increment for gain and HB is the basal heat.

Lofgreen and Garret (1968) used the comparative slaughter technique for steers and heifers and determined that $NEm_{(megacal)} = 0.077\ W_{kg}^{3/4}$ for both steers and heifers. Also the $NEg_{(kilocals)} = (52.72\ g + 6.84\ g^2)$ where g is the average daily gain in kilograms and NEg is per unit of metabolic body size ($W_{kg}^{3/4}$). The equation for heifers is presented as $NEg = (56.03\ g + 12.65\ g^2)\ W_{kg}^{3/4}$. It was shown that heifers deposit more energy as fat per unit of weight than do steers and that the difference is larger at higher rates of gain.

Berg and Butterfield (1968) examined growth patterns of muscle, fat and bone in relation to their influence on carcass composition and conformation. Bone growth occurred during early development, muscle growth during intermediate development, and fat tissue deposition during late development. Fat increasing its rate after the fattening phase begins. Sexes differed in weight at the onset of the fattening phase. Bulls showed delayed fattening compared to steers and reached higher muscle-bone ratio in their carcasses.

According to Maynard and Loosli (1969), in the case of ruminants on full rations, the energy lost as methane is of the order of 7% of the gross energy intake (this related to roughage intake). Methane contains 13.34 kcal per gram. Urine contains energy in the order of 4 to 5 percent of the gross energy intake (as related to N intake).

Chemical analysis on one cm. sections of the 12th rib cuts, showed that cuts from bulls contained 11 percent more protein and 11 percent less fat than their steer mates, (Arthaud, et al., 1969). Bull carcasses weighed 24.5 kg more than steers and yielded 26.8 kg more boneless trimmed retail product. When trait means were adjusted to a common carcass weight of 235 kg, bull carcasses yielded 13.2 kg more total retail product.

Hendrick, et al. (1969) used half-sib bulls, steers and heifers for live gain and carcass comparisons. The Warner-Bratzler shear was used to measure tenderness. Bulls were observed to be superior to steers and heifers in both live weight gain ($P < .05$) and feed conversion. Steers and heifers were similar in this respect. Total weight and percent retail cuts of the carcass were consistently greater ($P < .05$) for bulls than for steers and heifers and in most instances, greater for steers than for heifers. Shear values and sensory panel scores indicated that steaks from bulls less than 16 months of age were comparable in tenderness to steaks from steers and heifers of similar chronological age. Flavor and juiciness of cooked steaks were not significantly affected by sex condition.

Bidart, et al. (1970) found that when bulls and steers are fed for the same time interval, the faster gaining bulls would have a higher maintenance requirement due to their heavier average weight during the period even if the energy expenditure per unit weight were equal in bulls and steers. The partial regression for bulls of 6.0 Mcal digestible energy (DE) consumed per kg of edible product produced was significantly less than the requirement of 20.3 Mcal DE per kg of carcass trim. One can speculate that differences in gain of edible product in bulls were due largely to gain in protein and water, whereas differences in gain of carcass trim were primarily fat. In steers the partial regressions were 12.8 Mcal DE per kg of edible product and 15.3 Mcal DE per kg of carcass trim. Differences between sexes was significant. The edible portion of steers undoubtedly had a higher proportion of fat than bulls.

Protein Utilization

Mitchell (1929) concluded that light weight, rapidly gaining feedlot cattle have nearly as large, if not larger, needs (gms per day) for abomasal protein as do large feedlot cattle gaining at a similar rate. It becomes obvious that the lighter animal with more limited feed capacity has greater difficulty than the heavier animal in satisfying his abomasal need for amino acids from microbial protein.

Burroughs (1970) defined metabolizable protein as that quantity of protein digested absorbed in the post-ruminal portion of the digestive tract of cattle and other ruminants. It concerns itself with the quantity of feed protein consumed which escapes degradation in the rumen and with the quantity of degraded protein that is reformed into microbial protein before consideration is finally given to digestibility and absorbable quantity of amino acids arising from the two sources of protein from the feed consumed.

METHODS AND MATERIALS

Initial Procedures

Thirty-three half-sib Hereford bulls weighing approximately 200 kg at an age of 8 months were divided into three groups. Ten animals were slaughtered at the initiation of the trial to represent initial carcass composition. The remaining 23 bulls were individually fed for a period of 140 days. At the end of the feeding period 11 bulls were placed into metabolism stalls to determine digestion coefficients. The remaining 12 were slaughtered at the end of the feeding period to determine carcass composition. There was an average of 156.5 days feeding period prior to slaughter, this was due to limitations in slaughtering facilities.

The ration used for the feeding period consisted of 60% concentrate which included 41% milo, 10% dry molasses, 1% bone meal, 2% salt, .05% trace minerals, 21% dehydrated alfalfa and 25% soybean meal. The other 40% of the ration was prairie hay ground to about 7.5 cm.

Composition Analysis for Gain

Carcass composition was determined by the method presented by Hankins (1946). Results for both groups of slaughtered bulls are shown in Table 1.

Results from the first group were used to determine the initial composition of the group of 12 after proper half-sib grouping. From this data the net carcass gain was determined in terms of percent fat, lean and bone.

Samples (2 gms) of lean, fat and bone were analyzed for protein and dry matter content (AOAC, 1970). Energy was determined by oxygen bomb calorimetry following drying of wet sample on calorimeter cup. Bone samples from the femur, spine and rib showed no significant difference in composition, therefore, an average of these three measurements was utilized. Lean had 1401 cal per gram, 18.96% protein and 23.56% dry matter. Fat was 2.62% protein, 93.37% dry matter and had 8477 cal per gram. Bone contained 82.86% dry matter, 3154 cal per gram and 22.69% protein. These values were used to determine the net calories and protein gained in the carcass, following the procedure recommended by Berg and Butterfield (1968).

Metabolic Analysis for Maintenance

Prior to the metabolism trial the bulls were given a seven-day preliminary period to allow for adjustment to confinement and establish a constant feed intake. The metabolism trial consisted of 5 days of constant feed intake and total collection of feces, urine and feed weighbacks twice a day. Samples of feed and collection were submitted for proximate analysis (AOAC, 1970). The concentrate had 3930 cal per gram and 19.07 percent protein, hay was 4.79 percent protein and had 3970 cal per gram.

The digestion coefficients for energy and protein were calculated according to the procedure presented in Biological Energy Interrelationship and Glossary of Energy Terms (1966). Determined values are: Gross Energy Coefficient = 62.62; Gross Protein Coefficient = 60.50. These digestion coefficients were used to determine the digested energy and protein for the final group of 12 bulls.

The following interrelationships obtained from Lofgreen, et al. (1963) were used to determine the net energy for maintenance,

$$ME = DE - GPD - UE = HP + NEm + NEp$$

At zero energy intake:

$$HP = HA + HB = NEm = ME - NEg$$

where ME is the metabolizable energy, DE is the digestible energy determined

ILLEGIBLE DOCUMENT

THE FOLLOWING DOCUMENT(S) IS OF POOR LEGIBILITY IN THE ORIGINAL

THIS IS THE BEST COPY AVAILABLE

before. GPD is the gaseous products of digestion; amounting for about [illegible] of the gross energy intake. UE is the urinary energy, which is in the order of 4 to 5 percent of the gross energy intake (Maynard and Loosli, 19[illegible]). Values are in the zone of thermoneutrality. HA is the heat for activity and HB is the basal heat. HP is the heat production which is composed of HI (heat increment), HA and HB when fed above maintenance levels. NEp is the net energy for production (already determined) with NEm being the net energy for maintenance. Table 2 shows the energy analysis.

Digested protein was determined by means of the digestion coefficient. The net protein requirements for maintenance were determined by the data presented by Burroughs (1970). Degraded protein converted into microbial protein reaching the abomassum was estimated as a maximum of 51.2 gms of protein per kilogram of concentrate dry matter. A maximum conversion of 25.6 grams of microbial protein was used in the case of roughages. Finally the quantities of metabolizable protein were determined based upon an apparent coefficient of digestion of 78 for microbial protein (Johnson, et al., 1944).

The literature (Burroughs, 1970) indicates that approximately 40% of the metabolizable protein needs is lost in metabolism. This value was used to determine the total net protein. Net protein for production was already determined from the carcass analysis. Net protein for production was the remaining component of total net protein. Protein analysis is shown in Table 3.

Statistical Analysis

Regression analysis of bull data was used for determination of the protein and energy requirements for gain and maintenance on a carcass basis.

Coefficients were obtained by passing the regression line through the origin. The relationship of total feed capacities being proportional to the mid-weight $\left(\frac{\text{final weight} + \text{start weight}}{2}\right)$ to the three quarters power (Loosli, 1951) was included in the final analysis of the data. (See Appendices)

TABLE 1. CARCASS COMPOSITION

Bull no.	A.D.G. Kg	Dress. %	Lean %	Fat %	Bone %	Slg. Wgt. Kg
Starting composition						
017		50.18	67.77	18.19	15.25	244.90
080		49.27	66.34	16.01	17.82	193.70
026		57.58	68.10	18.34	14.92	239.50
044		53.71	61.19	20.54	18.27	183.25
059		61.67	68.57	17.56	15.13	217.70
067		58.46	67.5	19.46	14.54	241.30
019		53.50	69.97	16.17	15.12	205.03
032		56.40	65.47	19.07	16.26	214.10
031		58.50	68.83	17.68	14.86	217.70
035		52.40	61.53	25.93	14.18	192.30
Final composition						
007	1.06	61.85	63.76	20.07	16.77	405.50
082	0.97	61.66	60.96	23.74	16.15	350.18
056	1.21	63.03	61.40	25.23	14.78	344.70
039	1.08	63.08	59.91	26.94	14.62	350.20
022	1.16	60.00	67.35	19.06	14.93	322.05
054	1.08	59.86	64.56	22.86	14.21	337.90
050	1.01	62.1	62.49	24.82	14.29	367.40
034	0.97	61.72	63.37	23.9	14.32	342.50
038	1.07	60.42	70.02	18.93	13.12	326.60
051	1.13	61.46	69.45	17.04	14.88	328.40
058	0.99	64.40	67.47	22.22	12.60	346.50
045	0.74	61.25	66.51	18.84	15.68	254.00

TABLE 2. ENERGY ANALYSIS IN MEGACALORIES PER DAY

Bull no.	D.E.(1)	U.E.(2)	G.P.E.(3)	M.E.(4)	N.E.m(5)	N.E.g.(6)
007	12.45	0.895	1.39	10.16	8.70	2.441
082	12.14	0.872	1.36	9.91	8.40	2.524
056	13.22	0.950	1.48	10.79	8.88	3.178
039	12.75	0.916	1.42	10.41	8.56	3.082
022	12.29	0.883	1.37	10.04	8.69	2.245
054	12.02	0.863	1.34	9.81	8.33	2.470
050	12.00	0.863	1.34	9.80	8.16	2.731
034	12.32	0.885	1.38	10.06	8.54	2.526
038	11.73	0.843	1.31	9.58	8.33	2.080
051	11.86	0.852	1.32	9.68	8.41	2.111
058	11.80	0.848	1.32	9.63	8.11	2.536
045	8.80	0.633	0.98	7.19	6.27	1.526

(1) DE = GE_i (Digestion Coefficient determined from feed analysis)
(2) UE = 4 $\div$ 5% of gross energy intake (Maynard and Loosli, 1969)
(3) GPE = GPD = 7% of gross energy intake (Maynard and Loosli, 1969)
(4) ME = DE - UE - GPE (Lofgreen, 1963)
(5) NEm = ME - NEp (Lofgreen, 1963)
(6) NEp determined from carcass analysis

TABLE 3. PROTEIN ANALYSIS IN GRAMS PER DAY

Bull no.	Microbial P.(1)	M.P.(2)	Net P.(3)	N.P.g.(4)	N.P.m.(5)
007	344.142	268.431	161.06	120.0	40.60
082	335.311	261.543	156.93	101.0	55.93
056	364.557	284.354	170.61	126.0	44.61
039	352.358	274.839	164.90	111.0	53.90
022	339.402	264.734	158.84	123.0	35.84
054	331.958	258.927	155.36	108.6	46.76
050	331.846	258.840	155.30	106.0	49.30
034	340.379	265.496	159.30	102.0	57.30
038	323.538	252.353	151.41	117.0	34.41
051	327.446	255.408	153.24	130.6	22.64
058	324.691	253.259	151.96	118.0	33.96
045	242.802	189.386	113.63	84.0	29.63

(1) 51.2 gms of microbial protein per kg of concentrate dry matter
25.6 gms of microbial protein per kg of roughage dry matter
(Burroughs, 1970)
(2) (Total microbial protein) .78 = metabolizable protein (Johnson, 1944)
(3) (metabolizable protein) .60 = Total net protein (Burroughs, 1970)
(4) Net protein for gain determined from carcass analysis
(5) Net protein for maintenance = NP - NPg or (3) - (4)

RESULTS AND DISCUSSIONS

Maintenance

The daily energy and protein requirements of bulls for maintenance obtained were:

$NEm(megacal) = 0.129\ W^{3/4}$ variation from 0.114 to 0.145

$NPm(gms) = 0.660\ W^{3/4}$ variation from 0.400 to 0.860

Maintenance studies by Lofgreen, et al. (1968) give a value of 0.077 megacal per unit of metabolic body size as the requirement for maintenance for steers and heifers. In our study the bulls were non-confined under severe winter conditions. This apparently increases the amount of energy utilized for maintenance.

Smuts (1935) reported $NPm = 0.88\ W^{.734}$ based on data obtained from small laboratory animals. Differences in specific amino acid requirements among species and testosterone anabolic influence on protein synthesis could account for the difference between these two values.

Gain

Net energy requirements for daily carcass gain analysis gave the equation:

$$NE_g(kilocal) = (45.37\ g - 8.4335\ g^2)\ W^{3/4}$$

where g is the average daily gain in kilograms and W is the mid-weight in kilograms. The quadratic coefficient was nonsignificant (F = 0.37), resulting in a linear analysis that gave as a final result:

$NEg = 36.41\ g\ W^{3/4}$ s.d. = ± 4.92

Lofgreen (1968) did a similar study with yearling steers and heifers on a live weight basis and obtained the following results: for steers,

$NEg = (52.72g + 6.84g^2)W^{3/4}$ and for heifers, $NEg = (56.03 + 12.65g^2)W^{3/4}$. When the bull carcass data was adjusted to a live weight basis the resulting equation was: $NEg = (51.09g + 0.8g^2)\ W^{3/4}$, where the quadratic coefficient also showed to be non-significant (F = 0.00).

Protein carcass requirements for gain was also analyzed concluding that:

$$NPg(gms) = 1.670\ g\ W^{3/4} \qquad s.d. = \pm\ 0.18$$

Adjustment to a live weight basis gave:

$$NPg = 2.273\ g\ W^{3/4} \qquad s.d. = \pm\ 0.462$$

These results show that bulls deposit less energy per unit weight gain than do steers or heifers, indicating a higher gain efficiency (Bailey, et al., 1966; Brown, et al., 1962; Field, et al., 1966; Hendrick, et al., 1969; Klosterman, et al., 1954; Turton, 1962) and a different composition and ratio of muscle, bone and fat during growth (Arthaud, et al., 1969; Berg, et al., 1968; Bidart, et al., 1970).

Application

Limitations in the variation range and the number of observations prevents absolute reliability in this results specially for different environmental conditions and breeds. Research in this area is needed in order to arrive at more definite conclusions.

The most useful application of these results would be in the calculation of feed required to produce a desired rate of gain. It is also possible to evaluate beef bulls based on their expected performance from their feed consumption.

LITERATURE CITED

Arthaud, V. H., C. H. Adams, D. R. Jacobs and R. M. Koch. 1969. Comparison of carcass traits of bulls and steers. J. Anim. Sci. 28:742.

Bailey, C. M., C. L. Probert and V. R. Bohman. 1966. Growth rate, feed utilization and body composition of young bulls and steers. J. Anim. Sci. 25:132.

Berg, R. T. and R. M. Butterfield. 1968. Growth patterns of bovine muscle, fat and bone. J. Anim. Sci. 23:611.

Bidart, J. B., R. M. Koch and V. H. Arthaud. 1970. Comparative energy use in bulls and steers. J. Anim. Sci. 30:1019.

Biological Energy Interrelationships and Glossary of Energy Terms. Revised edition 1966. National Academy of Sciences. National Research Council Publ. 1411.

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

Brown, C. J., John D. Bartee and P. K. Lewis, Jr. 1962. Relationships among performance records, carcass cut-out data and eating quality of bulls and steers. Ark. Agr. Exp. Sta. Bull. 655.

Burroughs, Wise. 1970. Some new concepts of protein nutrition of feedlot cattle. (Metabolizable Protein or Metabolizable amino acids). Iowa State Univ., Ames, Iowa. Fourth Beef Swine nutrition seminar, Kansas City, Missouri.

Field, R. A., G. E. Nelms and C. O. Schoonover. 1966. Effects of age, marbling and sex on palatability of beef. J. Anim. Sci. 25:360.

Garrett, W. N. 1958. The comparative energy requirements of sheep and cattle for maintenance and gain. PhD thesis. University of California, Davis, California.

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

Hankins, O. G. and Paul E. Howe. 1946. Estimation of the composition of beef carcasses and cuts. USDA Technical Bulletin No. 926:October.

Hendrick, H. B., G. B. Thomson and G. F. Krause. 1969. Comparison of feedlot performance and carcass characteristics of half-sibs bulls, steers and heifers. J. Anim. Sci. 29:687.

Johnson, B. C., T. S. Hamilton, W. B. Robinson and J. C. Garray. 1944. On the mechanism of non-protein-nitrogen utilization by ruminants. J. Anim. Sc. 3:287.

Kraybill, H. F., H. L. Bitter and O. G. Hankins. 1951-52. Determination of fat and water content from measurement of body specific gravity. J. Applied Physiol. 4:575.

Klosterman, Earle W., L. E. Kunkle, Paul Gerlaugh and V. R. Cahil. 1954. The effect of age of castration upon rate and economy of gain and carcass quality of beef calves. J. Anim. Sc. 13:817.

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

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

Lofgreen, G. P. and W. N. Garrett. 1968. A system for expressing net energy requirements and feed values for growing and finishing beef cattle. J. Anim. Sc. 27:793.

Loosli, J. K. and H. R. Guilbert. 1951. Comparative nutrition of farm animals. J. Anim. Sc. 10:22.

Maynard and Loosli. 1969. Animal Nutrition. Sixth edition. McGraw-Hill publishing company.

Mitchell, H. H. 1929. The minimum protein requirements of cattle. National Research Council Bull. 67, Washington, D. C.

Official Methods of Analysis of the AOAC. Ninth edition, 1970. Published by the Association of Official Agricultural Chemists. Wash. 4, D. C.

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

Smuts, D. B. 1935. The relation between the basal metabolism and the endogenous nitrogen metabolism, with particular reference to the maintenance requirements of protein. J. of Nutrition. 9:403.

Turton, J. D. 1962. The effect of castration on meat production and quality in cattle, sheep and pigs. Anim. Breed Abstr. 30:447.

APPENDICES

APPENDIX A

Net energy and protein utilized for maintenance

Equation: $Y_i = bx_i + e_i$

Y_i = energy or protein used for maintenance per day.

x_i = metabolic body size or $W^{3/4}$ where W is the mid-weight in kilograms.

e_i = sampling error (non-significant)

$$b = \frac{\text{Sum } x_i Y_i}{\text{Sum } x_i^2}$$

where b is in grams for protein and in megacalories for energy.

APPENDIX B

Carcass energy gain analysis

linear coeff. = 45.373

quad. coeff. = -8.433

Analysis of Variance

Source	d. f.	mean sq.	F ratio
Total	12	1471.30	
linear	1	17389.60	716.77*
residual	11	24.30	
quadratic	1	9.41	.37
residual	10	25.75	
reduction	2	8699.50	3378.90

* (P less than .005)

Final linear coefficient = 36.41 ± 4.92

Analysis of Variance

Source	d. f.	mean sq.	F ratio
Total	12	1471.38	
linear	1	17389.70	716.77
residual	11	24.26	
reduction	1	17389.70	7167.68

APPENDIX C

Carcass protein gain analysis

linear coeff. = 2.068

quad. coeff. = -.369

Analysis of Variance

Source	d. f.	mean sq.	F ratio
Total	12	3.099	
linear	1	36.840	1128.3*
residual	11	0.032	
quadratic	1	0.018	0.53
residual	10	0.034	
reduction	2	18.429	

* (P less than .005)

Final linear coefficient = 1.675 ± 0.18

Analysis of Variance

Source	d. f.	mean sq.	F ratio
Total	12	3.099	
linear	1	36.840	1128.3
residual	11	0.032	
reduction	1	36.840	11282.9

NET ENERGY AND PROTEIN REQUIREMENTS FOR GAIN AND MAINTENANCE OF BEEF BULLS

by

CARMEN ANA JUARBE

B. S., Kansas State University, 1970

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1971

ABSTRACT

A study is presented for determination of net energy and net protein for maintenance and gain on a daily basis. Data from thirty-three bulls on trial indicate that for these animals net energy for maintenance requirements are approximately 0.129 megacalories per unit of metabolic body size ($W_{kg}^{3/4}$) and net protein for maintenance requirements near 0.66 gms. per unit of metabolic body size. The energy deposited in the weight gain of bull carcasses (NEg requirements) is represented by the equation NEg = 36.41 g $W^{3/4}$ where g is the average daily gain in kilograms. The protein deposited in the gain is defined by the equation NPg = 1.67 g $W^{3/4}$. Utilization of these requirements for ration calculation and performance evaluation can be very helpful.