ENERGY AND PROTEIN STUDIES WITH MILO RATIONS FOR BEEF CATTLE

I. THE INFLUENCE OF AUTOCLAVING SOYBEAN MEAL ON MILO RATIONS. II. THE COMPARATIVE NET ENERGY OF MILO AND CORN

By

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INTRODUCTION

Sorghum grain, or milo, represents a valuable source of energy for fattening beef cattle in the southwestern part of the United States, and the prospects for wide usage of this grain in feedlots are enhanced by its ready availability and competitive price. However, cattle feeders generally consider corn and barley superior to milo in terms of feedlot performance, especially with regard to feed efficiency.

Previous research indicates that the level and solubility of protein in milo may be partially responsible for the poor feedlot performance of milo rations. One purpose of this study was to determine the influence of solubility of supplemental protein on the utilization of milo rations.

Net energy is considered the optimum measure of the productive value of a feed since it considers only that energy left after the expenses of utilization have been deducted from gross energy. However, the expense and intricacy of the procedures used to obtain net energy values as well as their somewhat empirical nature have not warranted their wide-scale acceptance in the field of applied nutrition. In evaluating milo for productive purposes a consideration of its net energy would appear to be of value since this grain is a major energy source. A previous trial at this station involved a comparison of milo and corn on a net energy basis in fattening rations for beef calves. The second part of this study comprises an additional net energy comparison.

It is hoped that this study will contribute information useful in elucidating the nature of the poor utilization of milo by fattening cattle.

REVIEW OF LITERATURE

Recent work at the Arizona, Kansas and Oklahoma experiment stations indicates milo is 10 to 16 percent less efficient than corn or barley for fattening cattle. Smaller differences in the same direction were obtained with respect to average gains. Hale *et al.* (1963a) summarized seven trials conducted at the Arizona station comparing milo and barley for cattle. He showed a seven percent advantage in average daily gain and an 11 percent advantage in feed efficiency for barley. Richardson *et al.* (1956) observed a 13 percent advantage in feed efficiency for corn over milo in a series of Kansas trials.

Protein in Milo

Morrison (1959) listed protein and total digestible nutrient (TDN) values for milo, corn and barley of 10.9, 8.7 and 8.7, and 79.4, 80.1 and 78.8 percent, respectively. This indicates milo has a comparable TDN value, and a protein value in excess of that of the other two grains. A compilation of more recent estimates by Hale *et al.* (1962), Hubbert *et al.* (1962), Taylor *et al.* (1960), Taylor *et al.* (1961) and Totusek *et al.* (1963) indicates a protein value for milo of about 8.5 percent. Trogdon (1960), in an extensive study involving 67 sorghum grains, found that crude protein content ranged from 7 to 12 percent and averaged 9.5 percent.

Digestibility of proximate components in recent trials is in disagreement with the earlier figures of Morrison (1959). Hale *et al.*

(1963b) reported that the digestibility of milo protein by cattle was 40 percent below those values commonly used. Using high concentrate rations, Saba et al. (1964) found that milo protein was 30 percent less digestible than barley protein. However, differences between the grains were considerably smaller in higher roughage rations containing 50 percent alfalfa hay (Hale et al., 1964). These results suggest that the solubility of milo protein may be of major importance in high concentrate rations, which are widely used at the present time.

Several workers have shown that highly soluble protein contributed directly to increased protein degradation and the accompanying production of large quantities of ammonia (Chalmers et al., 1954; Chalmers and Synge, 1954; Lewis, 1957; Sherrod and Tillman, 1962, 1964; and Danke, 1965). Even though the apparent digestibility of these readily soluble proteins was high, the urinary nitrogen loss was also high. This resulted in a lower nitrogen retention than was observed with proteins of lower solubility. Using cold-extracted meals autoclaved at 1.05 kg. per sq. cm. and 121 degrees C., a quadratic function of nitrogen retention was observed with sheep. Sherrod and Tillman (1964) found that 60 minutes of autoclaving time gave best performance results, while Danke et al. (1965) found 45 minutes to be the optimum length of autoclaving for maximum nitrogen retention. Tillman and Kruse (1962) reported that autoclaving a commercial soybean meal for 45 minutes did not affect protein digestibility by sheep.

Woods et al. (1957), using two cottonseed meals of differing nitrogen solubilities, found that nitrogen retention favored the meal with low nitrogen solubility. In a later study Woods et al. (1958) compared cottonseed meal, sesame oil meal and soybean meal and found that the lowered digestibility of the cottonseed protein resulted in decreased nitrogen retention as compared to the other two meals for sheep.

These results indicate that continued improvement in nitrogen retention might be expected as long as increased fecal nitrogen loss obtained by denaturization is more than compensated for by decreased urinary loss.

Energy of Milo

The use of the energy concept for the evaluation of feeds for productive purposes is a logical one because it utilizes calories, which can be measured in both the feed and the animal. Both Armsby (1914) and Kellner (1915) established feeding standards involving the use of the net energy principle. Many modifications of their systems have been proposed: in Hansson's Scandinavian feed unit system (Woll, 1912) barley replaces Kellner's starch as the standard and recognition is given those feeds differing in protein content but having the same energy value; Mollgaard's values for dairy cows recognize the higher net energy value of a feed for milk production than for storing fat (Preston, 1965); Fraps' (1931) productive energy values were obtained from the results of feeding trials; and Morrison's (1959) estimated net energy values were compiled from many sources.

Two basic flaws in many of these earlier systems were the assumptions (1) that the utilization of feeds for maintenance and for fat deposition were simple multiples of one another, and (2) that any one feed had the same relative nutritive value for various productive purposes, such as lactogenesis or lipogenesis (Blaxter, 1962).

The first assumption has been widely challenged, and the weight of scientific opinion and experimental results tends toward its refutation (Forbes et al., 1926; Forbes et al., 1930; Mitchell et al., 1932; Kriss, 1943; Lofgreen et al., 1963; Garrett et al., 1964; and Absher, 1965). Forbes et al. (1930) found that the net energy value of a feed for maintenance was approximately 20 percent greater than when fed at higher levels. Furthermore, a constant net energy value has been obtained for each succeeding increment of a given feed above maintenance (Lofgreen et al., 1963; Garrett et al., 1964; and Absher, 1965).

Morrison (1959) defined the net energy of a feed as the amount of energy left after deducting energy losses in the feces, combustible gases, urine and work of digestion (heat increment). Kriss (1943) considered net energy as a correct basis of expression of the ultimate energy value of a ration, but cautioned that it lends itself particularly to fundamental research under intensive experimental control. Abbreviations for use in net energy studies have been proposed by Harris (1963).

Caloric values for feeds have been obtained by calculation and by actual experimentation. Morrison's (1959) estimated net energy values constitute, in part, an example of the first method. He used an assumed caloric value per unit of TDN in converting TDN to energy values. Brody (1945) proposed an energy value of 1914 kcal. digestible energy per pound of TDN. Schneider (1947) suggested a figure of 1987 kcal. of digestible energy per pound of TDN, and this was endorsed by Maynard (1953). Based on averages obtained from work with sheep and cattle, the caloric value of TDN is at present assumed to be 2000 kcal. per pound, or 4.4 kcal. per gram (Crampton, 1956; Crampton et al., 1957; and Swift, 1957).

Experimentally, net energy values may be obtained by the use of a respiration calorimeter, a technique used by Forbes et al. (1930), Mitchell et al. (1932), and other earlier workers. The operation of the respiration calorimeter was explained in a paper by Braman (1933). An experimental method that does not require a costly respiration calorimeter, has been used at the California station and elsewhere by Garrett et al. (1959), Lofgreen and Otagaki (1960), Lofgreen et al. (1962a), Lofgreen et al. (1963), Garrett et al. (1964), Absher (1965) and Garrett (1965). This technique, the so-called "direct" method, involves slaughtering test animals for the estimation of body caloric content at the start and finish of a feeding trial, and attributing the caloric gain to the ration used. The slaughtering process appears to be mandatory until a suitable method is found to determine body water *in vivo* in the ruminant (Lofgreen and Otagaki, 1960). The major difficulty in obtaining the *in vivo* measure is rumen fill (Garrett et al., 1959). Lofgreen et al. (1962b) have used equations to estimate empty body weights from warm carcass and live weights.

The "direct" technique involves the use of carcass specific gravity to estimate the percent body water, fat and protein. The first analysis relating body fat content of mammals to their specific gravities was conducted by Rathbun and Pace (1945) with guinea pigs. Da Costa and Clayton (1950) used rats in a similar analysis and found that specific gravities could also be used effectively as indices of body water content. Brown et al. (1951) and Whiteman et al. (1953) applied the specific gravity measurement to pork carcasses. Kraybill et al. (1952)

and Reid et al. (1955) used the method in estimating the body water and fat content of cattle.

Morrison's (1959) estimated net energy values place milo almost on a par with corn, and show it to be superior to barley. His values for the three grains, converted to megcal. per 100 kg. feed, are respectively, 174, 177 and 155. Garrett et al. (1964), Absher (1965) and Garrett (1965) have obtained net energy values using the slaughter method, and these are given in Table I. No significant differences among the net energies of the grains were obtained by Garrett et al. (1964) or Absher (1965), suggesting little basis for discriminating against milo as an energy source.

TABLE I

EXPERIMENTALLY OBTAINED NET ENERGY VALUES OF MILO, BARLEY AND CORN

Reference	Net Energy Used for	Milo	Barley	Corn
Garrett et al. (1964)	Maintenance	202[a] ± 7[b]	185 ± 7	----
	Production	131 ± 8	123 ± 8	----
	Maint. + Prod.	157 ± 7	141 ± 7	----
Absher (1965)	Maintenance	169 ± 11	----	171 ± 11
	Production	133 ± 15	----	120 ± 13
	Maint. + Prod.	155 ± 6	----	152 ± 6
Garrett (1965)	Production	143	131	----

[a]Megcal. per 100 kg.
[b]Standard error.

EXPERIMENT I - THE INFLUENCE OF AUTOCLAVING SOYBEAN MEAL ON MILO RATIONS

Experimental Procedure

Trial A - Feedlot Performance of Fattening Calves

Twelve sets of twin calves of diverse origin, breed and initial weight were used in this trial. The animals were of beef breeding with a range in initial weight from 152 to 329 kg. The twin pairs were chosen by visual appraisal for maximum similarity in size, structure, shape of head and legs, and color pattern. They were fed sorghum silage for five months, then gradually switched to the experimental ration over a period of three weeks.

Solvent-extracted soybean meal (50% protein guarantee) was obtained locally for this trial. Portions of the meal were subjected to one of three treatments: (1) no heat, (2) autoclaved at 1.05 kg. per sq. cm. of steam pressure (121° C.) for 45 minutes and (3) autoclaved at the same pressure and temperature for 90 minutes. For autoclaving, the meal was spread evenly to a depth of 2 cm. in metal pans lined with heavy paper. Upon completion of autoclaving the meal was mixed and stored for the feeding trial. The meals were analyzed for nitrogen solubility by the method of Lyman et al. (1953).

The animals were kept away from feed and water for 18 hours (shrink) and initial weights were taken to the nearest pound. They were then allotted to the three treatments in pairs in an incomplete randomized block design, illustrated in Table II. One calf was randomly chosen from each pair and placed on treatment 2, and its twin was placed on either treatment 1 or 3 to give six animals on each of these two comparisons.

The experimental animals were placed in two pens sheltered on the north side by an open shed. The 12 calves on the 45-minute autoclaved meal (treatment 2) were put in one pen and their twins in an adjacent pen. At feeding time the 12 animals in the second pen were separated into the two treatment groups by a swinging gate. Individual feeding was accomplished by securing all animals in head stanchions during the feeding period. They were fed twice daily for maximum intake, with feed intake equated within each pair to the lowest consuming twin, as described by Maynard and Loosli (1962). The calves had free access to water between feeding periods.

TABLE II

EXPERIMENTAL DESIGN FOR EXPERIMENT I, TRIAL A

	Treatment Number		
	1	2	3
Autoclaving time (minutes)	0	45	90
Twin pair I	a	b	-
Twin pair II	-	a	b
No. of animals	6	12	6

The soybean meal was fed at the rate of 454 gm. per head daily, and was mixed at each feeding period into the basal ration given in Table III. Steam-rolled milo supplied over 80 percent of the protein in the basal ration. Proximate analyses of the basal ration and the three soybean oil meals are given in Table IV (A.O.A.C., 1960).

TABLE III

COMPOSITION OF THE BASAL RATION USED IN EXPERIMENT I

Ingredient	Percent
Steam rolled milo	80.0
Cottonseed hulls	12.0
Dehydrated alfalfa meal (17%)	7.0
Salt	0.5
Steamed bonemeal	0.5
	100.0

TABLE IV

PROXIMATE ANALYSES OF THE FEEDS USED IN EXPERIMENT I

Feed	Dry Matter	Crude Protein	Crude Fiber	Ether Extract	Ash	N. Free Extract
Basal ration	89.48	10.20	5.02	2.88	2.38	69.00
Soybean meal - 0	89.98	44.99	2.78	0.93	6.89	34.39
Soybean meal - 45	89.52	47.16	3.20	1.03	6.79	31.34
Soybean meal - 90	90.98	46.45	3.00	0.82	6.78	33.93

Interim weights were taken every 21 days following an eight hour shrink. The trial was concluded after 93 days, at which time final weights were obtained to the nearest pound after an 18 hour shrink. Final average gains and feed efficiencies were subjected to "t" tests for paired comparisons (Steel and Torrie, 1960).

Trial B - Rumen Ammonia Concentration in Sheep

A short-term trial was designed to test the effect of protein solubility of the soybean meals used in Trial A upon rumen ammonia concentration.

Nine crossbred wethers averaging 52 kg. were fitted with permanent rumen fistulae and three were randomly assigned to each treatment. At the initiation of the trial the animals were weighed to the nearest kg. They were placed in individual metabolism stalls measuring 1.75 by 0.90 m., and fed twice daily at the rate of 0.063 pounds of feed per pound of metabolic weight ($W^{.75}$). The ration consisted of 90 percent of the basal mix from Trial A and 10 percent of the appropiate soybean meal. The sheep had free access to water at all times.

The first 15 days were used to allow the animals to adjust to the rations and stalls. On the morning of the sixteenth day all the sheep were weighed to the nearest kg. following a 14 hour shrink, and fed their respective rations in accordance with the expression: 0.063 $W^{.75}$ pounds of feed. Each ration was mixed with 500 ml. of water 15 minutes prior to feeding and given to the wethers through the fistulae. Subsequently five rumen samples were taken at intervals of 30 minutes through the fistulae. The rumen samples, approximately 100 to 150 ml. of fluid, were thoroughly mixed with three ml. of a preservative, 2.7 percent mercuric chloride, to retard bacterial action, and were stored under refrigeration until analyzed for ammonia by the method of Conway (1957).

The data were subjected to an analysis of variance for a 3 x 5 factorial arrangement of treatments (Steel and Torrie, 1960).

Results and Discussion

Trial A - Feedlot Performance of Fattening Calves

The results of Trial A are shown in Table V. Gains were poor in all cattle. It is thought that the effect of individual feeding in stanchions caused low feed intake and offers a possible explanation. In comparison 1, animals consuming the meal autoclaved for 45 minutes apparently gained faster ($P < .15$) and required less feed per unit of gain ($P < .15$) but these differences were not significant ($P < .05$). Calves receiving the meal autoclaved for 90 minutes in comparison 2 made slower gains ($P < .01$) and required more feed ($P < .01$) per unit of gain than those which received the 45-minute meal.

TABLE V

THE EFFECT OF AUTOCLAVING SOYBEAN MEAL ON FEEDLOT PERFORMANCE OF TWIN CALVES

Item	Comparison 1		Comparison 2		Standard Error
	Autoclaving Time (minutes)				
	0	45	45	90	
Initial weight, kg.	241.9	240.0	211.3	203.7	11.5
Final weight, kg.	305.4	313.6	295.3	270.2	22.8
Average daily gain, kg.	0.68	0.80	0.90	0.72	0.04
Average daily feed, kg.	5.76	5.76	5.53	5.53	0.16
Kg. feed per 100 kg. gain	844	721	612	774	21

The solubilities of the soybean proteins autoclaved for 0, 45 and 90 minutes were 85.2, 34.5 and 18.0 percent, respectively. Increased autoclaving time had a highly significant ($P < .0001$) effect on the solubility of the protein fraction.

Previous results from this laboratory have shown that the autoclaving of cold hexane-extracted cottonseed or soybean meal for 45 minutes (Sherrod and Tillman, 1962; Danke et al., 1965) gave improved nitrogen retention in sheep over that obtained in sheep fed the raw meal or that heated for 90 minutes or longer. In their experiments any increase in autoclaving time resulted in decreased nitrogen digestibility; however, urinary nitrogen decreased with increasing autoclaving time. Nitrogen retention was expressed by a quadratic equation in which maximum nitrogen retention was obtained at 45 minutes. However, the meals used by the previously mentioned workers were specially prepared cold-extracted meals. The soybean meal used in the present trial was a commercial solvent-extracted meal, which under normal processing conditions is subjected to elevated temperatures for a short period of time. This may have accounted for the failure of meal autoclaved for 45 minutes in this trial to produce a significant positive response in terms of feedlot performance. Factors contributing to this observation were the rather large variation in response within treatments and the small numbers per treatment. Further, it must be pointed out that the differences between the gains of calves receiving the non-autoclaved meal and that autoclaved for 45 minutes became evident only in the last two weeks of the trial. Because of experimental design, it is impossible to compare the performance of the animals receiving the meal which was autoclaved for 90 minutes to that which was not heated.

The results of Chalmers et al. (1954) indicate that one way of overcoming the increased urinary nitrogen loss associated with highly soluble dietary protein is to include an abundant source of soluble carbohydrate, which supplies the necessary carbon fragments needed for the microbial synthesis of amino acids and protein. The rations used in the present trial may be considered high energy diets containing a high level of potentially available soluble carbohydrate, starch, from the milo grain. Results of the present trial, if real, would indicate that the starch fraction of milo is hydrolyzed too slowly. Further research in this field is indicated.

Trial B - Rumen Ammonia Concentration in Sheep

The influence of autoclaving and sampling time on rumen ammonia concentration of fistulated sheep is shown in Table VI. The analysis of variance for the results is given in Table VII. Length of autoclaving, sampling time and their interaction had no significant effect ($P < .05$) on the concentration of rumen ammonia. An apparent inverse relationship between ammonia levels and time of autoclaving was observed, however.

TABLE VI

THE EFFECT OF AUTOCLAVING TIME AND TIME OF SAMPLING ON RUMEN AMMONIA CONCENTRATION IN SHEEP

Autoclaving Time (minutes)	Time of Sampling After Feeding (minutes) 30	60	90	120	150	Means
0	17.90[a]	17.87	18.32	18.83	17.06	18.00
45	17.90	17.80	17.87	17.13	17.80	17.70
90	14.95	13.60	13.46	13.49	13.91	13.88

[a]Mg. ammonia per 100 ml. rumen fluid.

TABLE VII

ANALYSIS OF VARIANCE FOR THE EFFECT OF AUTOCLAVING TIME AND TIME OF SAMPLING ON RUMEN AMMONIA CONCENTRATION OF SHEEP

Source of Variation	Degrees of Freedom	Mean Square	Calculated F Values
Total	44		
Treatment	14	12.0648	0.4032
A, time of autoclaving	2	78.9303	2.6380
B, time of sampling	4	0.5342	0.0179
A x B, interaction	8	1.1137	0.0372
Sampling error	30	29.9206	

Sherrod and Tillman (1962) reported that the ruminal ammonia levels of sheep fed unheated hexane-extracted meals increased rapidly after feeding and reached a peak in three hours, but with autoclaved meals the rumen ammonia concentration remained more stable and at lower levels. In the present trial rumen ammonia levels for each meal remained fairly constant from 30 to 150 minutes after feeding.

Rumen ammonia concentration was apparently lower in the 90-minute meal and agrees with the results of Sherrod and Tillman (1962). As El-Shazley (1952) and others have shown that rumen ammonia production is associated with protein solubility, autoclaving would be expected to decrease ruminal ammonia levels.

Summary and Conclusions

Portions of a commercially-produced 50 percent crude protein soybean meal were subjected to (1) no heat, (2) autoclaved under 1.05 kg. per sq. cm. steam pressure (120° C.) for 45 minutes and (3) autoclaved under the same conditions for 90 minutes. Nitrogen solubility was significantly decreased by autoclaving. Twelve sets of twin calves were fed fattening-type rations containing milo and the designated meals for 93 days. The animals were assigned to the treatments in such a way that six sets of twins were paired on the 0 vs. 45-minute meal while the remaining six sets were paired on the 45 vs. 90-minute meal. The 45-minute meal apparently increased gains ($P < .15$) and feed efficiency ($P < .15$) but these differences were not significant ($P < .05$). The 90-minute meal produced slower gains ($P < .01$) and required more feed ($P < .01$) per unit of gain than the 45-minute meal. Rumen ammonia concentrations were not affected significantly by treatment or sampling time; however, there was a trend toward lower rumen ammonia levels with increased autoclaving time.

EXPERIMENT II - THE COMPARATIVE NET ENERGY OF MILO AND CORN

Experimental Procedure

Forty-seven Aberdeen-Angus steer calves of similar breeding were obtained from the Ft. Reno Livestock Research Station in December, 1964. They were vaccinated against leptospirosis and blackleg and drenched with phenothiazine. The calves were maintained on a basal ration high in cottonseed hulls for 30 days prior to the initiation of the feeding trial. They were weighed to the nearest five pounds seven days before starting the test, and scored on the basis of outside fat covering. These data were plotted on a dispersion diagram sectioned diagonally into ten equal groups chosen from each of these groups to form a representative sample, subsequently referred to as the slaughter group. Initial weights were then taken to the nearest pound on all animals after a 20 hour shrink, after which the slaughter group was sacrificed and the 37 remaining animals were placed on feed.

The slaughter procedure for the ten animals in the slaughter group involved taking the weight of the contents of the rumen and reticulum to the nearest pound for each animal and subtracting this from the live shrunk weight to obtain individual empty body weights. The carcasses were chilled for 48 hours and then quartered and weighed in air to the nearest half-pound. Each quarter was then weighed on a gram balance in water to the nearest five grams. The carcass specific gravities were subquently calculated using the data from the two weighings.

Specific gravities on the empty bodies were obtained by using a regression formula derived by Kraybill *et al.* (1952),

$$Y = 0.9955X - 0.0013$$

where X is the carcass specific gravity and Y the estimated empty body specific gravity. The percent body water was estimated using another formula from Kraybill *et al.* (1952),

$$W = 100\ (4.008 - \frac{3.620}{Y})$$

where W is the percent body water. Body fat and protein were then estimated using formulae derived by Reid *et al.* (1955),

$$F = 337.88 + 0.2406W - 188.91\ (\log W), \text{ and}$$
$$P = \frac{(80.93 - 0.00101Z)\ (100 - (W + F))}{100}$$

where F represents the percent body fat, P the percent body protein and Z the age of the animals in days.

Factors of 9367 kcal. per kg. fat (Blaxter and Rook, 1953) and 5686 kcal. per kg. protein (Lofgreen and Otagaki, 1960) were used in converting estimated fat and protein in the empty body to their caloric equivalents, and from these the total caloric content per unit of empty body weight in the slaughter group was used to estimate the initial caloric content of the 37 animals left to complete the feeding trial, hereafter referred to as the experimental group.

An unrealistic negative correlation of -.29 was obtained for condition score and kcal. per kg. of empty body weight, indicating that unreliable condition scores had been taken. Thus it was not possible to consider condition score in the allotment of cattle to experimental treatments as in a previous trial by Absher (1965).

The experimental design, essentially a 3 x 2 factorial arrangement of treatments in a completely randomized design, was the same as that used by Absher (1965). The calves were allotted to seven treatments at three planes of nutrition, maintenance, intermediate and high, as shown in Table VIII.

TABLE VIII

EXPERIMENTAL DESIGN FOR EXPERIMENT II

Treatment	No. of Animals	Feeding Regime Basal, lb.	Added Grain
Basal maintenance	7	0.662 $W^{.75}$	None
Milo maintenance	5	0.331 $W^{.75}$	Milo to maintain body wt.
Corn maintenance	5	0.331 $W^{.75}$	Corn to maintain body wt.
Milo intermediate	5	0.331 $W^{.75}$	Milo to equal ½ gain of milo high treatment
Corn intermediate	5	0.331 $W^{.75}$	Corn to equal ½ gain of corn high treatment
Milo high	5	0.331 $W^{.75}$	Milo at maximum intake.
Corn high	5	0.331 $W^{.75}$	Corn to equal gain of milo high treatment

The amount of TDN required for maintenance was calculated using an equation derived by Garrett et al. (1959), lbs. of TDN for maintenance = 0.036 $W^{.75}$, where W is the weight of the animal in pounds. The basal ration, shown in Table IX (Absher, 1965), was estimated to contain 54.4 percent TDN. Using these values it was calculated that 0.662 pounds

TABLE IX

COMPOSITION OF THE BASAL RATION USED IN EXPERIMENT II

Ingredient		Percent
Dehydrated alfalfa pellets (17 %)		35.0
Cottonseed hulls		23.0
Cottonseed meal (41 % solvent)		40.0
Salt		1.0
Dicalcium phosphate		1.0
		100.0
Added per ton:		
Santoquin	114 gm.	
Vit. A supplement (30,000 I.U./gm.)	200 gm.	

of basal were required per pound $W^{.75}$ for maintenance. For treatments other than the basal maintenance, the basal ration supplied one-half the maintenance requirement and finely ground milo or corn were added to attain the desired planes of nutrition. An attempt was made to equate gain between animals on the corn and milo rations at the three levels by giving tacit recognition to the possible superior value of corn, and feeding it at a rate of 90 percent that of milo at all three levels. The proximate analyses of the feeds used are given in Table X (A.O.A.C., 1960). The grains were analyzed for the solubility of the protein fractions by the method of Lyman et al. (1953). Values obtained were 73.9 and 84.0 percent nitrogen soluble in .02 N NaOH for milo and corn, respectively.

TABLE X

PROXIMATE ANALYSES OF THE FEEDS USED IN EXPERIMENT II

Feed	Dry Matter	Crude Protein	Crude Fiber	Ether Extract	Ash	N. Free Extract
Basal	91.99	20.40	21.83	1.21	8.48	40.07
Milo	89.39	10.17	0.85	2.01	1.80	74.46
Corn	89.72	10.10	1.71	3.53	1.37	73.01

The calves were fed twice daily in individual stalls measuring 3.0 by 0.75 m., and were allowed approximately one hour in which to consume their feed. No water was available during the feeding period. During the remainder of the day they were allowed access to four outside pens and had free access to water.

Feed was weighed out to the nearest one-eighth pound and mixed at each feeding. Refused feed was fed back to the animals at the following feeding period, a corresponding adjustment being made for the amount refused. In this way accurate feed records were kept of the feed consumed by individual animals.

Intermediate gain and efficiency data were obtained every 21 days from weights taken to the nearest five pounds after a seven hour shrink. The amount of feed fed the calves was adjusted in accordance with the weight gains or losses observed in these interim periods. It was necessary on occasion to adjust a given ration to correct for inordinate losses or gains made during a particular period, and to maintain similar gains between grains.

During the course of the trial, two steers died of unspecified causes, one had to be removed due to a hip injury, and two more were dropped from the high to the intermediate corn treatment due to low feed intake. This created disproportionate group numbers for subsequent analysis. Final weights were taken following a 20 hour shrink. The animals were then allowed access to water before being shipped from Stillwater to Oklahoma City for slaughter following another 20 hour shrink. Available facilities and time made it expedient to slaughter the experimental animals on three separate days covering a span of one week. The average length of time on feed was 155 days for all treatments. Measurements and calculations used to obtain final caloric content in the experimental animals were as previously described for the slaughter group. A prediction equation was developed from slaughter group data to estimate the empty body weights of the experimental calves at the start of the trial. The average value in kcal. per kg. of empty body weight obtained for the slaughter group calves was used to estimate the starting caloric content for each of the experimental animals. The estimated gain in calories was obtained by difference.

The maintenance requirement was assumed to be 35 kcal. per lb. $W^{.75}$ daily (Garrett *et al.*, 1959) and was added to the estimated gain in energy to obtain the energy used by the animal for maintenance and production. In order to determine the calories coming specifically from the grain in the ration, a correction was made for the energy of the basal consumed. The energy provided by the basal was determined by dividing the kg. of basal consumed for each of the animals on the basal maintenance ration into the respective kcal. used for maintenance and production. The resultant net energy value of the basal in kcal. per kg. was multiplied by the kg. of basal consumed for each of the experimental animals and by subtracting this product from the kcal. provided by the total ration, the kcal. attributed to the grain were estimated for each steer.

The net energies of the grains for maintenance and production (NE_{m+p}) at the various levels of feeding were determined for each steer by dividing the amount of grain consumed into the energy stored in the body and used for maintenance. NE_{m+p} values were subjected to an analysis of variance for unequal class numbers (Steel and Torrie, 1960).

The net energies for production above maintenance (NE_p) were obtained by dividing the incremental feed intake above maintenance into the energy it produced. NE_p values were obtained for the intervals between the maintenance and intermediate, maintenance and high and intermediate and high levels. Changes in feed consumed and energy produced at the various levels were determined by using as base lines the average of the group on the lower plane of nutrition, and subtracting this average from each individual value for the steer on the higher plane of nutrition. The NE_p values were subjected to the appropriate "t" tests (Steel and Torrie, 1960).

Results and Discussion

The data on the initial slaughter group of 10 steers are shown in Table XI. The following regression equation was developed from the data to predict the empty body weight of the experimental steers:

$$Y = -6.99 + 0.9625X, \pm 1.85$$

where Y is the kg. empty body weight and X the kg. live shrunk weight.

TABLE XI

INITIAL SLAUGHTER GROUP DATA

Item	Mean	Range
Live shrunk weight, kg.	231.7	196.0 - 269.9
Empty body weight, kg.	216.1	181.5 - 252.7
Carcass specific gravity	1.0788	1.0718 - 1.0871
Water in empty body, %	63.24	61.1 - 65.9
Fat in empty body, %	12.85	10.12 - 15.24
Protein im empty body, %	19.24	19.07 - 19.33
Energy from fat, kcal.	160,805	183,874 - 320,726
Energy from protein, kcal.	236,423	198,043 - 276,282
Energy/kg. empty body, kcal.	2,304.3	2,046.9 - 2,516.4

The body composition of the calves in the slaughter group was used to estimate the amounts of water, fat and protein in the experimental group at the time the experiment was initiated. The following regression equation was derived to estimate the amount of fat in the empty bodies of the experimental calves:

$$Y' = -7.35 + 0.163X', \pm 3.69$$

where Y' is the kg. fat and X' the kg. empty body weight. Since a high correlation existed between estimated protein and empty body weight in the slaughter group steers ($r = 0.9993$, $P < .001$), an average value of 0.1924 kg. protein per kg. empty body weight was used to derive the initial amount of protein in the experimental steers. Estimated water content was also closely correlated with empty body weight ($r = 0.9748$,

$P < .001$). The average value of 0.6324 kg. water per kg. empty body weight was used to determine initial water in the empty body. The amounts of water, fat and protein gained by the animals while on feed were obtained by subtraction.

Treatment means for final carcass composition of the experimental steers are given in Table XII. As would be expected, steers fed at the maintenance level lost considerable amounts of fat, which was replaced on a percentage basis by water. The amounts of fat gained under the different treatments were subjected to statistical analysis by the method of Steel and Torrie (1960) for disproportionate subclass numbers. Level of intake affected amount of fat gained ($P < .01$) but kind of grain had no significant effect ($P < .05$). Absher (1965) found that steers fed milo were fatter at the end of the trial than those on corn rations, and suggested this as a possible explanation for the poor feed efficiency of milo in producing live weight gain. No such conclusions could be drawn from the present trial. In terms of protein, the steers gained from essentially none on the maintenance level to approximately 15 kg. on the high level. Protein expressed as a percent of empty body was not affected by level of feeding. Gain in water was highly correlated ($r = 0.9720$, $P < .001$) with that of protein. As 76 percent of lean tissue on a fat free basis is water (Callow, 1947) any increase in lean tissue is expected to include a corresponding increase in water. Differences between total weight gain and the sum of estimated gains in protein, fat and water were attributed mainly to bone and connective tissue. These values were fairly constant for all treatments except the high corn group. A high estimated water gain in one of the two animals in the high corn group resulted in a negative difference. This was

TABLE XII

TERMINAL CARCASS COMPOSITION AND COMPONENTS OF GAIN OF CALVES FED MILO AND CORN AT THREE LEVELS OF INTAKE

Item	Treatment						
	Maintenance			Intermediate		High	
	Basal	Milo	Corn	Milo	Corn	Milo	Corn
Water in empty body, %	69.0	68.0	68.3	65.7	65.6	64.0	62.5
Prot. in empty body, %	19.35	19.27	19.26	19.24	19.26	19.24	19.16
Fat in empty body, %	7.00	8.10	7.77	10.35	10.46	12.06	13.70
Gain in water, kg.	5.72	15.88	12.16	34.76	36.16	53.28	41.70
Gain in protein, kg.	- 1.45	1.80	0.31	8.50	9.23	15.61	13.12
Gain in fat, kg.	-13.17	-8.89	-11.44	-1.32	0.14	8.33	10.94
Other gain[a] kg.	10.49	8.67	10.67	9.59	7.95	11.59	4.09

[a]Total weight gain - (estimated gains in water, protein and fat).

traced to a low value for rumeno-reticular fill which affected the final empty body weight calculated for the animal in question. Regurgitation at slaughter is thought to have caused such an error.

Data relating to the feedlot performance of the experimental steers are given in Table XIII. The data illustrate the effectiveness of feeding animals to gain at different levels by controlling feed intake. However, some trouble was encountered in obtaining the desired consumption of grain, especially by the high level groups. Two steers originally assigned to the high level corn treatment actually consumed a level of corn comparable to the intermediate level, and therefore were included in the intermediate group for the analysis of results. A further disparity in numbers on certain treatments was caused by the death of two steers and the removal of a third due to a hip injury.

Tables XIV and XV illustrate the steps involved in calculating caloric gain and NE_{m+p} values. Data on one steer was taken from each of the milo maintenance and milo high groups to illustrate the method.

Estimated caloric gains for the experimental steers on an empty body basis is given in Table XVI. While all steers gained weight in varying amounts depending on the treatments imposed, a considerable loss in total empty body caloric content was observed for steers at the maintenance level. This was due to the effect of the level of feeding on body composition, and more specifically to changes in fat content.

Net energy values for maintenance and production (NE_{m+p}) and the associated standard errors were obtained for the experimental steers, and these figures are given in Table XVII. NE_{m+p} at the maintenance level was approximately 30 percent greater for both grains than corresponding values at the intermediate and high levels of feeding.

TABLE XIII

FEEDLOT PERFORMANCE OF CALVES FED MILO AND CORN AT THREE LEVELS OF INTAKE

Item	Treatment						
	Maintenance			Intermediate		High	
	Basal	Milo	Corn	Milo	Corn	Milo	Corn
Calves slaughtered	6	4	5	5	7	5	2
Initial live wt., kg.	227.9	224.0	237.3	236.3	228.4	230.4	242.7
Final live wt., kg.	229.5	241.4	248.9	287.9	282.5	319.2	312.6
Ave. daily gain, kg.	0.01	0.11	0.08	0.33	0.34	0.57	0.45
Basal intake, gm.[a]	54.6	27.0	27.3	26.5	25.8	25.9	27.2
Grain intake, gm.[a]	---	18.5	16.7	37.7	36.5	51.4	51.3
Feed/100 kg. gain, kg.	188320	2397	3579	1258	1161	913	1195

[a]Expressed on a daily basis, per kg $W^{.75}$.

TABLE XIV

THE CALCULATION OF CALORIC GAIN AND NE_{m+p} VALUES [a]

Item	Milo Maintenance	Milo High
Steer no.	44	21
Initial shrunk wt., kg.	206.4	254.0
Initial empty body wt., kg. (a)	191.7	237.5
Initial energy in empty body, kcal. (b)	441,727	547,262
Final shrunk wt., kg.	234.5	334.3
Rumeno-reticular content, kg.	24.0	20.9
Final empty body wt., kg.	210.5	313.4
Specific gravity carcass (c)	1.0942	1.0735
Specific gravity empty body (d)	1.0880	1.0674
Water in empty body, % (e)	68.1	61.7
Fat in empty body, % (f)	7.99	14.45
Protein in empty body, % (g)	19.24	19.19
Fat in empty body, kg.	16.82	45.29
Protein in empty body, kg.	40.50	60.14
Energy in empty body from fat, kcal. (h)	157,553	424,231
Energy in empty body from protein, kcal. (i)	230,283	341,956
Final total energy in empty body, kcal.	387,836	766,187
Energy gain, kcal.	-53,891	218,925
Mean test wt., kg.	220.5	294.2
(Mean test wt.)$^{.75}$, kg.	57.23	71.02
Days on feed	151	156
Energy gain/day/$W^{.75}$, kcal.	-6.24	19.70
Energy for gain and maintenance, kcal. (j)	57.06	83.00
Basal consumed/day/$W^{.75}$, kg.	0.0264	0.0262
Basal correction, kcal. (k)	23.61	23.42
Energy from grain/day/$W^{.75}$, kcal.	33.45	59.58
Grain consumed/day/$W^{.75}$, kg.	0.0183	0.0517
NE_{m+p}, kcal. per kg.	1,828	1,152

[a]The steps in the procedure are keyed in Table XV.

TABLE XV

KEY TO STEPS IN THE PROCEDURE FOR CALCULATION OF CALORIC GAIN AND NE_{m+p} VALUES[a]

(a)	Predicted by equation: Empty body wt. = -6.99 + 0.9625
(b)	Empty body wt. x 2304.26 (average kcal. energy per kg. empty body wt. - Table XI).
(c)	Specific gravity = $\frac{\text{Wt. in air}}{\text{Wt. in air - wt. in water}}$
(d)	Specific gravity empty body = 0.9955 x specific gravity carcass.
(e)	Water in empty body = 100 x $\left(4.008 - \frac{3.620}{\text{Sp. gravity empty body}}\right)$
(f)	Fat in empty body = 337.88 + (0.2406 x % water) - (188.91 x log % water).
(g)	Protein in empty body = (80.93 - 0.00101 (age in days)) (100 - (% water + % fat)).
(h)	Energy from fat = kg. fat x 9367.
(i)	Energy from protein = kg. protein x 5686.
(j)	35 kcal. per lb. of $(\text{mean test wt.})^{.75}$ considered maintenance. Converted to metric system: $35 \times (2.205)^{.75}$
(k)	Basal correction, the energy supplied by basal = kg. basal consumed x 894.2 (estimated net energy value of basal).

[a]For use with Table XIV.

TABLE XVI

CALORIC GAIN OF CALVES FED AT THREE LEVELS OF INTAKE

Energy in Empty Body, kcal.	Level of Intake		
	Maintenance	Intermediate	High
Initial	493,917	497,755	502,703
Final, total	385,101	544,822	673,218
from fat	150,578	257,755	349,817
from protein	234,523	287,067	323,401
Gain	-108,816	47,067	170,515

TABLE XVII

NE_{m+p} VALUES OF MILO AND CORN FED TO CALVES AT THREE LEVELS OF INTAKE

Feeding Regime	Megcal./ 100 kg.	Standard Error
Basal maintenance	89.4	4.7
Milo maintenance	164.4	10.8
Corn maintenance	167.6	9.2
Milo intermediate	114.7	5.7
Corn intermediate	123.2	6.3
Milo high	108.6	5.5
Corn high	110.4	17.5

The final analysis of variance adjusted for disproportionate subclass numbers (Table XVIII) showed that there was a highly significant effect ($P < .01$) of the level of feeding on the NE_{m+p} values, whereas the NE_{m+p} of corn and milo did not differ significantly ($P < .05$) at any one level of feeding. The results confirm previous work at this station (Absher, 1965) and indicate further that the net energy values for maintenance or production are similar for milo and corn, and that level of intake above maintenance does not influence the net energy value of a feed.

TABLE XVIII

ANALYSIS OF VARIANCE FOR NE_{m+p} VALUES OF MILO AND CORN FED TO CALVES AT THREE LEVELS OF INTAKE

Source	Degrees of Freedom	Mean Square	Calculated F Values
A, level, adjusted for grain	2	7,569.0250	25.2868**
B, grain, adjusted for level	1	180.9791	0.6406
A x B interaction, adjusted for grain and level	2	28.5787	0.0955
Error	22	299.3277	

**Significant at the $P < .01$ level.

A somewhat larger difference was obtained herein than in an earlier trial at this station (Absher, 1965) for the NE_{m+p} at the maintenance as compared to the higher levels of intake. This might be partly attributed to the fact that a lower energy value for the basal ration was obtained in this test although the same basal ration was used, while the basal was fed at a constant level per $W^{.75}$ in all rations involving corn and milo. The use of a smaller value for the basal ration then tended to be more pronounced at the lower ("maintenance") level of intake, and showed up in proportionately larger NE_{m+p} figures for the grains at this level than in those succeedingly higher levels of intake where the amount of basal consumed was smaller in comparison to the grain intake.

Figure 1 describes a straight-line relationship between grain consumed and gain in energy, both expressed on a daily basis per kg. of metabolic weight. Since the values plotted represent caloric gain per unit of grain above maintenance, the slope of the regression line, 78.7 ± 0.5, can be taken as the net energy for production (NE_p) of the grains. The regression obtained was:

$$Y = 1.526 + 78.728X$$

where Y estimates the gain in megcal. per day per kg. $W^{.75}$ and X represents the kg. grain consumed to achieve this gain. Values obtained by the increment method for the NE_p of corn and milo are given in Table XIX. The net energy values did not differ significantly ($P < .05$) with respect to either the grain or the level of intake. No simple explanation exists to explain the rather low NE_p figures obtained, when these are contrasted with those in recent literature (Table I), and the abnormally large error precludes a sound basis for theorizing.

Although a workable range in gains was obtained between levels of intake in this trial, the "high" regime resulted in daily gains not exceeding 0.6 kg., which is hardly a desirable maximum. The feed efficiency for both milo and corn rations was lower than would be expected for this type of ration. Feed consumption at the high levels was poor and undoubtedly the major cause of poor gain and efficiency.

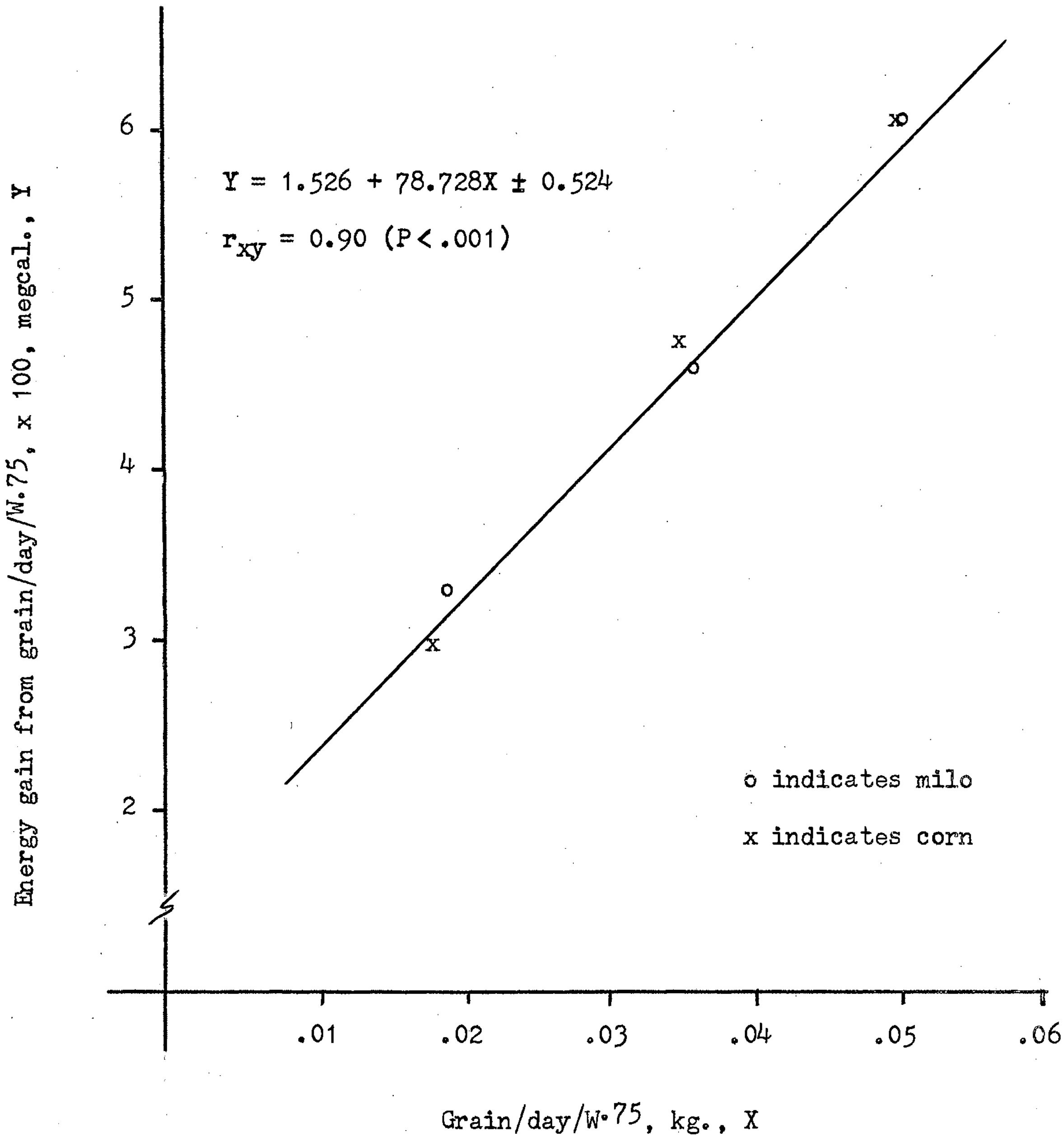

Figure 1. The regression of grain intake (kg.) on energy gain (megcal.).

TABLE XIX

NE_p VALUES OF MILO AND CORN FED TO CALVES AT THREE LEVELS OF INTAKE

Feeding Levels	Milo	Corn
Maintenance - Intermediate	66.7 ± 13.2	86.3 ± 11.6
Intermediate - High	91.0 ± 22.4	88.8 ± 54.3
Maintenance - High	77.1 ± 8.9	83.5 ± 22.6

Some possible contributory factors are forwarded in an attempt to explain the poor feedlot response of steers on the high levels of intake. The animals were not sufficiently adapted to the individual feeding stalls prior to the initiation of the trial. Intermediate live weight gain data confirm a considerable setback during the first three weeks of the trial for all treatments, and in all probability complete acceptance of confinement feeding was not achieved throughout the duration of the test. Totusek et al. (1963) observed decreased consumption with finely ground grain when compared to coarsely ground grain. In this respect a steam-rolled or cracked grain might possibly have increased feed intake somewhat over the finely ground grain fed in this trial. Bloating on both the intermediate and high feeding regimes was another problem, and is thought to have been responsible in the latter part of the trial for a reduction in performance. It is possible that bloat might have been reduced and intake increased by redistributing the feed into a third feeding period. Insect annoyance and elevated temperatures may have played a small part in lowering performance toward the end of the test.

The comparative slaughter technique involves several assumptions from the taking of measurements through the calculation and interpretation of results. The validity of some of these assumptions is questionable. Carcass specific gravity was shown by Whiteman et al. (1953) to be subject to considerable error. From this measure body composition is obtained and converted to caloric equivalents. In the calculations involved in determining body composition the only consideration which is extraneous to the initial measure is an extremely small correction for age in the estimation of percent protein. The original equation was developed by Kraybill et al. (1952) from a sample of animals ranging in percent separable body fat from 13.6 to 39.5, in a test specifically designed to bring about a wide variation in body composition. The indiscriminate use of these equations for one group of relatively homogenous cattle in the expectation they will yield results comparable to a different group under varying conditions appears dangerous.

Summary and Conclusions

Finely ground milo and corn were fed with a basal ration to steer calves at three levels of intake: maintenance, intermediate and high. The initial body composition of the calves was estimated from specific gravity on the basis of a representative group slaughtered at the start of the trial. At the completion of the feeding trial all animals were slaughtered, and final body composition calculated as for the slaughter group. Differences in initial and final caloric content were ascribed to the grains fed, following appropriate corrections for the energy used for maintenance and for that coming from the basal mixture. Net energy values for milo and corn were obtained for maintenance (NE_m), maintenance and production (NE_{m+p}) and production above maintenance (NE_p).

Mean net energy values for milo and corn at maintenance were 164 ± 11 and 168 ± 9, at maintenance and production 129 ± 4 and 134 ± 4, and at production above maintenance 86 ± 9 and 78 ± 11 megcal. per 100 kg., respectively. Milo and corn did not differ significantly in NE_{m+p} at any level of feed intake, indicating that milo is comparable to corn as an energy source. The level of intake significantly affected NE_{m+p} values but net energy for productive purposes was not significantly affected by increments of grain above maintenance. This infers a constant relationship between incremental feed for productive purposes and incremental energy retained.

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II. THE COMPARATIVE NET ENERGY OF MILO AND CORN

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