INFLUENCE OF ENERGY CONCENTRATION OF FATTENING RATIONS ON NITROGEN UTILIZATION BY STEERS

by

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INTRODUCTION

On October 1, 1963, there were 18,000 calves and yearlings in Virginia feedlots. It was estimated that by November there would be 24,000 head (Virginia Crop Reporting Service, 1963). Virginia feeders have a relatively high operating cost as well as a large capital investment in cattle feeding. The largest cost is feed, of which protein is a major item. Therefore, it is of practical and fundamental interest to study factors affecting protein utilization and requirement.

Recently, there has been much interest in high energy fattening rations for beef cattle. Another area of interest is in high-fiber fattening rations, composed primarily of silage. The fattening rations commonly used at present fall between these two extremes in energy concentration. Little is known about the protein requirement or utilization by fattening steers fed rations containing these extreme energy levels. According to the limited number of metabolism studies which have been conducted with ruminants, supplemental energy does influence nitrogen retention under certain conditions. Most of these experiments were conducted using wintering type rations which were rather low in energy and high in fiber. Metabolism studies with fattening rations are needed. Therefore, a series of metabolism trials were conducted to study the effects of variation in energy concentration of a fattening ration on nitrogen metabolism by steers.

REVIEW OF LITERATURE

Influence of Dietary Energy on Nitrogen Metabolism in Ruminants

As early as 1896 Wicke and Weiske reported that energy added to a basal ration resulted in increased nitrogen retention. They fed a basal ration consisting of 800 gm. of meadow hay plus 200 gm. of flaxseed (fat partially extracted). Two sheep received the basal ration alone or with added energy in the form of 174 gm. of starch, and another sheep received the basal plus 50 gm. of olive oil. The observed increases in nitrogen retention above the basal ration, resulting from starch or olive oil feeding was 0.79 and 0.35 gm. per day, respectively. This area of research was rather dormant until 1940.

Mitchell et al. (1940) reported an increase in nitrogen retention from the daily addition of approximately 1200 gm. of glucose to high roughage beef cattle rations containing 15 and 20% crude protein. No response resulted when glucose additions were made to six and 10% protein rations. The experimental animals were steer calves and the basal rations were composed of corn, cottonseed meal and timothy hay.

Lofgreen et al. (1951) reported an increase in nitrogen retention when the non-nitrogenous total digestible nutrient intake of Holstein heifers was increased. The experimental design was a 2x2 factorial, with two levels of protein and two levels of energy. The low and high protein levels were 100 and 160%, respectively, of the level recommended by Morrison (1936). The energy levels were 100 and 115% of the Morrison (1936) recommendations, respectively. The rations were composed of good quality hay plus a calf starter. When the calves reached 250 lb. body weight a simple growing ration replaced the calf starter. Nitrogen balance trials were conducted at 150, 200, 250 and 300 lb. An increase in energy intake from 3.2 to 3.9 lb. per day of non-nitrogenous total digestible nutrients by calves fed the low-protein ration resulted in a significant increase in nitrogen retention from 15.6 to 19.6 gm. per day. Increasing energy intake of calves fed the high-protein ration had no effect on nitrogen retention.

Using biological value as a measure of protein utilization Williams et al. (1953) showed an increase in protein utilization when either 99 or 149 gm. of starch were added to a 5% crude protein sheep ration. When these same amounts of starch were added to rations containing 10 and 13% protein there was no increase in biological value. The basal ration was composed of oat chaff, wheat starch and wheat gluten.

Fontenot et al. (1953) studied the effect of supplemental energy on nitrogen retention of steer calves fed wintering rations. The two rations fed were composed of seven pounds of prairie hay supplemented with either two pounds of 20% or one pound of 40% protein supplement. The two rations were approximately isonitrogenous. The two pounds of 20% supplement, which increased energy intake, resulted in an increase in fecal nitrogen, a decrease in urinary nitrogen and an increase in nitrogen retention. Nitrogen retention, expressed as per cent of consumed nitrogen, increased from 15.4 to 20.3% when the added energy was fed.

Fontenot et al. (1955) conducted further studies with calves fed wintering rations of prairie hay and cottonseed meal, alone or supplemented with different amounts of cerelose (corn sugar). Three levels of crude protein, 8, 10 and 12%, were fed, and each was supplemented with various levels of cerelose. Each increase in cerelose supplementation resulted in an increased dry matter intake and lower percentage of protein, since protein intake, on weight basis, was held constant. They found that cerelose supplements of 0, 350, 700 and 1050 gm. added to the 8% protein ration resulted in nitrogen retentions of 6.06, 5.90, 4.74 and 4.20 gm. per day, respectively. The decrease in nitrogen retention from 5.90 to 4.74 and 4.20 was significant. Biological values were 80.0, 83.0, 85.5 and 86.5% for the respective cerelose additions. Supplementation of the 10% protein ration with 700 or 1050 gm. cerelose resulted in significantly increased nitrogen retention from 6.66 to

8.73 and 7.79 gm. per day, respectively. Biological value was also significantly increased from 72.4 to 83.5 and 83.8%, respectively. Cerelose supplementation of the 12% protein ration tended to improve nitrogen retention but the increase was not significant. Biological values were increased significantly from 69.7 to 79.7 and 83.3% by adding 700 and 1050 gm. of cerelose, respectively. Nitrogen excretion followed the same general trends for the three protein levels. Fecal nitrogen increased and urinary nitrogen decreased with each level of increased cerelose intake. The increase in fecal nitrogen was nearly proportional to the amount of cerelose supplementation. Absorbed nitrogen values (corrected for fecal metabolic nitrogen) for a given protein intake were not affected by cerelose supplementation.

A slight improvement in nitrogen retention by the addition of cerelose to high roughage lamb rations was reported by Woods _et_ _al_. (1956). The basal ration was 650 gm. of chopped timothy hay per day. Soybeam oil meal was added in sufficient amounts to make three rations of 7, 11 or 14.5% crude protein. Each level of protein was supplemented with 0, 25 or 50 gm. of cerelose per day. The experimental design was a 3 x 3 factorial using 18 wether lambs for metabolism and digestion trials. Nitrogen retention tended to increase as cerelose consumption increased, but differences were not significant.

Matsushima *et al*. (1957) found that nitrogen retention was not related to protein-energy ratio of fattening-type beef cattle rations. In their experiment choice Hereford yearlings were fed three levels of protein and three of energy in a 3 x 3 factorial experiment using all possible combinations. The three protein levels were the NRC recommendations, plus or minus 18%, and the three energy levels were the NRC recommendations, plus or minus 10%. The basal ration was composed of ground shelled corn, molasses, soybean oil meal, corn cobs and chopped alfalfa hay. The protein and energy levels were adjusted with urea and stabilized beef tallow.

Winchester *et al*. (1957) found that 400 lb. calves required 18 gm. nitrogen per day for maintenance. For each therm increase in energy intake at the protein maintenance level, they found an increase of 0.5 gm. in daily nitrogen retention.

Brisson *et al*. (1957) reported that as digestible energy intake increased, so did nitrogen retention, when protein intake was adequate. They fed very young dairy heifers natural and purified diets in liquid form.

In metabolism trials Robinson (1958) studied the effect of adding energy as corn grain or corn oil to a wintering ration of 3000 gm. of prairie hay plus 454 gm. of cottonseed meal. In one ration a level of 512 gm. of corn replaced an isonitrogenous amount of the cottonseed meal and in another ration 200 gm. of corn oil were added to the basal ration. The increased energy from corn grain had little effect, but the increased energy from corn oil significantly increased nitrogen retention. The supplemental corn did reduce urinary nitrogen, but there was no net increase in nitrogen retention, since fecal nitrogen was increased. Corn oil also slightly increased fecal nitrogen, but the larger decrease in urinary nitrogen resulted in a net increase in nitrogen retention.

A large decrease in nitrogen retention due to exclusion of readily-available carbohydrate in a purified sheep ration was noted by Chappell and Fontenot (1963).

Under certain conditions energy supplemented to ruminant rations improves nitrogen retention. The conditions seem to be a rather low protein and energy intake such as a wintering ration. In such rations the nutrient intake is not designed to promote maximum performance. When cattle are fattened usually nutrients are fed in large amounts in an effort to obtain maximum performance. The experiment conducted with fattening type rations has shown that under these conditions increased energy intake had no effect on nitrogen retention.

Influence of Dietary Energy on Nitrogen Metabolism in Simple Stomached Animals

Cuthbertson and Munro (1937) fed three men a diet providing 4057 kcal. and protein in excess of maintenance needs. Caloric intake was reduced to 2627 kcal. per day by removing 900 kcal. from fat and 530 kcal. from carbohydrate. When this was done fecal nitrogen decreased and urinary nitrogen increased. There was, however, a decrease in nitrogen retention.

Forbes and Swift (1944) found that added energy greatly increased nitrogen retention of mature rats. They studied the effects of supplementing a basal dietywith cerelose and/or lard. The four rations fed consisted of 10 gm. of basal ration alone or supplemented with 4.0 gm. of cerelose, 1.5 gm. of lard, or 1.0 gm. of cerelose plus 0.74 gm. of lard. Nitrogen retentions expressed as percent of intake were 3.0, 20.6, 27.4 and 17.9, for the four rations, respectively. For each of the three supplementations, urinary nitrogen excretions were reduced. Lard was more effective than cerelose in increasing nitrogen retention and in decreasing urinary nitrogen.

Allison and Anderson (1945) conducted a metabolism trial in which they fed six adult dogs either a protein-containing or protein-free diet. When caloric intake was increased from 80 to 100 kcal. per kg. of body weight per day, they observed a decrease in urinary nitrogen for both diets.

Forbes et al. (1946) compared the relative value of fat and carbohydrate as nitrogen sparers when fed to growing rats. Three levels of fat, 2, 10 and 30% were fed in diets that provided equal caloric and nitrogen intakes. Nitrogen retention was measured by body composition and nitrogen excretion data. As the fat level of the diet increased and carbohydrate level decreased nitrogen retention significantly decreased. Their work indicated that carbohydrate was more effective in sparing protein than fat.

A study of emaciated humans who were recovering from a year of severe undernutrition was made by Beattie et al. (1947). The subjects were in slight negative balance when treatment was begun. A variety of types of diets of varying caloric and protein contents were fed. Balance periods averaged approximately 10 days. As caloric intake increased from 30 to 60 kcal. per kg. of body weight per day, nitrogen retention increased linearly from -.05 to 0.25 gm. nitrogen per kg. of body weight per day.

Benditt et al. (1948) found that as caloric intake of young protein depleted rats increased from 15 to 35 kcal. per day nitrogen retention increased, when measured as change in body composition. A further increase in caloric consumption had no further beneficial effect. All rats received 1.56 gm. of protein per day plus varying levels of dextrin.

A study by Swanson (1951) on protein-depleted rats fed a protein-free diet showed beneficial effects of a high-fat diet. Six-month-old rats were fed protein-free diets which were isocaloric, but contained either a high or low level of fat. When caloric intake was 100 or 75% of normal, rats fed the low and high fat diets lost the same amount of nitrogen. When caloric intake was reduced to 50%, the rats fed the low-fat diet lost nearly twice as much nitrogen as those on the high-fat diet. At 25% caloric intake, rats fed both diets lost considerable nitrogen, but rats on the low-fat diet lost much more.

Adult dogs consuming 3.82 gm. of nitrogen (from casein) per day per square meter of body surface showed a gradual increase in nitrogen retention when caloric intake was increased from 2860 to 4800 kcal. per day per square meter of body surface (Rosenthal and Allison, 1951). The added calories were mostly from carbohydrate, as fat level was maintained at 5% of the total caloric level.

Munro (1951) made an extensive review of the literature pertaining to protein-energy relationships. He concluded that: (1) a change in energy intake of either carbohydrate, fat or alcohol has an effect on nitrogen balance; (2) at least part of the sparing action of carbohydrate depends on its being fed along with the diet; and (3) carbohydrate has a special role in conserving endogenous protein, for it reduces nitrogen output of fasting animals whereas fat generally does not have an effect until body stores are depleted.

Sibbald et al. (1956) measured nitrogen retention of rats fed two isonitrogenous diets of different energy value. In one diet 10% of the cellulose was replaced with an equal weight of sucrose to give a high and low digestible energy diet. The diets were fed ad lib. but protein intake was nearly equal. The substitution of sucrose caused a decrease in urinary nitrogen from 505 to 408 mg. and an increase in nitrogen retention from 1008 to 1122 mg. during a 7-day period. They attributed 69% of the variation in nitrogen to variation in digestible energy intake.

Morimoto et al.(1961) studied protein-energy interrelationships in laying hens. They determined nitrogen balance, and measured protein recovered in eggs. As the TDN to crude protein ratio of the feed increased, nitrogen retention and nitrogen recovered in the eggs increased.

No difference in protein digestibility or nitrogen retention was found by Lowery et al. (1963) from increasing the fat content of diets of young pigs. Three-week-old pigs were fed purified diets containing casein, dextrin, cerelose, corn oil, cellulose, minerals and vitamins. Corn oil content was 3, 13 or 23%. It replaced an equal weight of cerelose, so the energy density of the ration increased with increasing fat content. A ration containing 5% casein was fed at 5% of body weight. As the corn oil level increased from 3 to 13 and 23%, energy intake increased from 1135 to 1329 and 1407 kcal. per day, respectively.

Workers using simple stomached animals have generally shown decreased nitrogen excretion and/or increased nitrogen retention when energy was added to rations ranging in protein from none to fairly high levels. The conditions for increasing nitrogen balances do not seem to be as critical as they are for ruminants.

Mechanism of Protein Sparing Action of Supplemental Energy

Larson and Chaikoff (1937) reported that for extra carbohydrate to have a nitrogen-sparing action it must be fed within four hours before or after the meal. They also reported that the closer to the meal the carbohydrate was fed, the greater the effect. They concluded that carbohydrate must be present concurrently with active protein metabolism for it to effect a nitrogen sparing action. A summary of several experiments conducted on humans by Cuthbertson and Munro (1939) shows that a mixed diet supported nitrogen equilibrium, but when carbohydrate was fed at a separate time from the rest of the diet a net loss of nitrogen occurred. The diets were of similar composition except that carbohydrate was fed separately in one. One diet was fed at approximately 8:00 A.M. and 12:00 noon. The main part of the other diet was fed at these same times, but the carbohydrate part was fed at 4:00 and 10:00 P.M. These workers also reported that there was not a substantial difference between night and day urinary nitrogen excretion for either mixed or separate carbohydrate feeding. They suggested that this was evidence of an endogenous sparing of protein. They further suggested that the carbohydrate sparing mechanism might be linked to an observation made by Krebs (1935) that deamination by liver slices is inhibited by the presence of easily oxidized compounds such as lactate,pyruvate and succinic acid, but not by glucose. Increased glucose does contribute, however, to the supply of easily oxidizable substances when it is oxidized by the body.

Geiger _et al_. (1950) reported that protein depleted rats had a nitrogen retention of 2768 mg. over a 12-day period when they were fed a basal diet. When the carbohydrate portion was fed at a separate time nitrogen retention dropped to 1521 mg. These workers suggested that carbohydrate has some physiological function which increases or enhances efficiency of utilization of dietary amino acids. Geiger (1951) has shown that sugar eaten with the diet delays the disappearance of protein and its cleaved products from the digestive tract, and fat has a more pronounced effect on the disappearance. This decrease in absorption rate may benefit the animal's body by supplying the building materials at a rate at which more of them can be used. Thus, fewer amino acids are deaminated and excreted, and a higher proportion of them are retained. According to Geiger another possible mechanism is that carbohydrate may supply materials for synthesis of nonessential amino acids.

Munro and Naismith (1953), in an effort to study the effect of energy _per se_, fed carbohydrate or fat in the morning and the rest of the diet in the evening. This was done to minimize the interaction between carbohydrate and protein within the digestive tract when fed at the same meal. They fed rats rations containing equal amounts of protein or no protein, with energy levels ranging from 850 to 1700 kcal. per square meter of body surface per day. When the protein-free diet was fed, increasing caloric intake by addition of fat to the diet had no effect on nitrogen balance of the rats. Increased carbohydrate feeding caused an increased nitrogen retention in a curvilinear fashion up to 1200 kcal. of energy intake. Additional carbohydrate was of no further benefit. When the diets contained adequate protein, both carbohydrate and fat additions caused increased nitrogen retention in a linear fashion with increases in energy intake. This led them to conclude that protein metabolism is in a state of dynamic equilibrium with energy intake.

Munro et al. (1959) attempted to elucidate the mechanism of the protein-sparing action of carbohydrate. They found that feeding glucose to rats for 24 hours decreased urinary nitrogen. The spared nitrogen was not stored in the liver, as total liver nitrogen also decreased. In further experiments they showed that (C^{14}) leucine uptake by muscle protein was increased 1 hour after glucose was fed and that (S^{35}) methionine and (C^{14}) glycine uptake increased in two hours. They stated that this does not definitely mean that protein synthesis had been increased. They concluded, after reviewing several papers, that the action of glucose on blood amino acids is through insulin. They proposed the following theory: Increased carbohydrate administration causes increased secretion of insulin which in turn causes an increased uptake of amino acids by the muscle. This increased amino acid uptake by the muscle lowers blood amino acids and consequently there is a decrease in urea production by the liver, and thus, a protein-sparing action.

Two possible explanations of the protein sparing-mechanism result from the limited number of studies that have been made. One is the possibility that both carbohydrate and fat slow down digestion and absorption of proteins. This may allow absorption to proceed at a rate more compatible with the rate of utilization within the body, and prevent wastage of amino acids. The other explanation is grossly defined as some sort of endogenous action of carbohydrate which promotes use of absorbed amino acids. One very plausible explanation offered for this endogenous action is that an increased insulin secretion promotes uptake of amino acids by the cells, especially muscle cells.

Effect of Energy Level on Digestibility in Ruminants

Wicke and Weiske (1896) in their experiment with two sheep observed a decrease in crude protein and crude fiber digestion and an increase in dry matter and nitrogen-free extract (NFE) digestion when starch was added to a basal ration. When olive oil was added the only changes were a slight increase in crude fiber and a decrease in NFE digestion, (one sheep was fed olive oil).

Mitchell et al. (1940) fed 400 to 500 lb. beef calves basal rations of corn, cottonseed meal and timothy hay, containing 6, 10, 15 or 20% crude protein. When the basal rations were supplemented with 1200 gm. of glucose per day, crude fiber digestion dropped from 39.94 to 29.74%. Addition of glucose to lamb rations had a similar effect according to Hamilton (1942). His basal ration was composed of ingredients similar to those of Mitchell et al. (1940).

Swift et al. (1947) studied digestibility in ruminants as affected by the proportions of various nutrients. The basal ration was alfalfa-timothy hay, corn meal and soybean oil meal. Seventy-two gm. of supplemental starch or cerelose caused a decreased apparent digestibility of protein and crude fiber, and increased digestion of NFE. Corn oil added at the rate of 34 gm. slightly increased crude protein, crude fiber, NFE and energy digestibility. Increasing the supplemental corn oil to 68 gm. reversed the trends and digestibilities were greatly decreased.

Burroughs et al. (1949) observed a significant decrease in roughage dry matter digestion by steers when starch was added to rations, with the roughage portion consisting of either corn cobs or corn cobs plus some alfalfa hay. When alfalfa hay alone was supplemented with starch there was no decrease in digestion of alfalfa dry matter.

Williams et al. (1953) have shown that a decrease in rumen bacteria populations occurred when starch was added to a 5 or 10% crude protein ration. On a 13% protein ration there was no effect.

In the experiments of Fontenot et al. (1955) at Oklahoma, cerelose was added to beef steer wintering rations of prairie hay and varying levels of cottonseed meal to obtain 8, 10 and 12% crude protein levels. Cerelose additions of 350, 700 and 1050 gm. to the 8% protein rations and of 700 and 1050 gm. to the 10 and 12% rations resulted in decreased apparent digestibility of crude protein and crude fiber, and increased digestion of NFE. In each case the initial addition of cerelose had the most pronounced effect. They found no difference in true digestibility of protein within a protein level; so the decrease in apparent crude protein digestibility was apparently due to increased metabolic fecal nitrogen.

Digestion trials using 18 wether lambs were conducted by Woods et al. (1956). The basal ration consisted of 650 gm.

of chopped timothy hay. This was supplemented with varying levels of soybean oil meal and cerelose. Additions of 25 and 50 gm. cerelose significantly increased NFE digestibility, while only the higher level of cerelose significantly decreased crude protein digestibility.

Matsushima et al. (1957) reported that digestibility of crude fiber in beef steer fattening rations decreased as ration gross energy content was increased by incorporating beef tallow.

In an Oklahoma experiment in which 3000 gm. of prairie hay plus 454 gm. cottonseed meal were fed, supplemental energy in the form of corn grain or corn oil significantly decreased crude fiber digestion (Robinson, 1958). The corn grain decreased crude protein digestion but corn oil did not. Corn oil decreased NFE digestion but corn grain increased it.

Whiting and Slen (1958) with ewes and Whiting et al. (1959) with lambs observed significant decreases in crude protein and crude fiber digestibility when digestible energy intake was increased. Also there were increases in dry matter and energy digestibilities.

Chappell and Fontenot (1963), using purified rations, found that a ration devoid of readily available carbohydrate had a much higher cellulose and slightly higher crude protein digestibility than a ration containing starch and sugar. When starch and sugar were included in the ration, organic matter and dry matter digestibilities were greater.

Most experiments with ruminants have shown that increased carbohydrate intake resulted in decreased apparent digestion of crude protein and crude fiber. Digestion of NFE generally increased with little change in digestibility of dry matter and organic matter. Energy added as fat tended to decrease crude fiber and NFE digestion.

OBJECTIVES

The main objective of this experiment was to study the effect of energy concentration of a fattening ration on nitrogen metabolism of steers. Also, the effect on the digestibility of the various feed constituents was studied.

EXPERIMENTAL PROCEDURE

Six yearling Angus steers were fed three fattening rations of different energy concentration in a series of three metabolism trials lasting from May 17 to July 31, 1963. The experimental design consisted of two randomly selected 3 x 3 latin squares. The steers were kept in false bottom metabolism stalls which are modifications of the stall described by Nelson _et_ _al_. (1954). Each trial consisted of a 10-day preliminary period followed by a 10-day collection period. In some cases only a 7-day collection was possible because swollen and tender legs made it necessary to remove steers from the metabolism stalls. The steers were tamed and allowed to adjust to the metabolism stalls several weeks before the first trial was started. At the end of trials 1 and 2 the steers were placed for approximately one week in box stalls bedded with moist sawdust.

The fattening rations were composed of shelled yellow corn, corn cobs, cottonseed meal, 10% grass hay, minerals and vitamins. A vitamin A and D premix was added to supply 30,000 and 3750 I.U. per steer per day, respectively. Ration compositions are presented in Table 1.

Table 1. Composition of the Rations

Ration Energy level	D-1 Low	D-2 Medium	D-3 High
Percent composition			
Grass hay	10.0	10.0	10.0
Corn cobs	38.0	24.9	11.5
Shelled corn	30.1	45.1	60.3
Cottonseed meal	20.1	18.2	16.3
Defluorinated rock phosphate	0.6	0.5	0.5
Ground limestone	0.7	0.8	0.9
Trace mineralized salt	0.5	0.5	0.5
Vitamin A[a]	+	+	+
Vitamin D[b]	+	+	+
Percent chemical composition			
Dry matter	90.44	90.35	89.99
Crude protein	12.18	12.51	12.29
Ether extract	2.18	2.62	2.96
Crude fiber	20.77	16.24	10.75
Nitrogen free extract	51.50	55.02	60.16
Organic matter	86.58	86.50	86.15
Ash	3.86	3.84	3.84
Kcal. gross energy/gm.	4.022	3.999	3.942

[a] 227,000 I. U. per 100 lb. of feed

[b] 28,375 I. U. per 100 lb. of feed

The shelled corn and corn cobs were varied to provide three energy levels of approximately 62, 67 and 72% calculated total digestible nutrients (TDN) on an as-fed basis. An attempt was made to equalize crude protein (12.5%), calcium and phosphorus contents. Trace mineralized salt was included in all rations at the 0.5% level. In order to ensure uniformity of the mixed feeds among trials a sufficient amount of shelled corn, corn cobs and grass hay for the three trials were individually ground in a hammer mill through a 3/4 inch screen, and the total amount of a given feed was mixed prior to the beginning of the experiment. The rations for individual trials were mixed just before the particular trial started.

Each steer received 6000 gm. of ration daily during each trial, one-half of which was fed at 7:00 A.M. and one-half at 5:00 P.M. Water was available at all times except during the feeding period which usually lasted 2-hours for each feeding. At the beginning and end of each trial the steers were weighed individually after an overnight shrink from feed and water.

The feces were collected in metal pans, picked up several times each day and placed in tightly covered metal cans. A metal funnel, placed under a metal grid on the floor of the metabolism stall, directed the urine into plastic jugs, where it was collected. The feces were weighed once daily and a 5% sample taken. The urine was diluted to a definite minimum weight once daily and a 1% sample taken. Feces were preserved with thymol and sufficient sulfuric acid (1 to 1 with water by weight) was added to the urine samples to maintain a slightly acid pH. The feces and urine samples were kept under refrigeration until analyzed. Rations were sampled at each feeding during the preliminary and collection periods.

Feeds and feces were analyzed for crude fiber by the method of Whitehouse et al. (1945). Urine was analyzed for nitrogen, and feeds and feces were analyzed for dry matter, crude protein, ether extract and ash according to the methods of the A.O.A.C. (1955). Gross energy of feeds, feces and urine were determined in a Parr adiabatic oxygen bomb calorimeter. The urine was prepared for energy determination by drying in a forced air oven at less than 90° C. The energy lost upon drying was corrected for by the method of Swift and French (1954).

Methane production was calculated using the formula of Swift et al. (1948). Metabolic fecal nitrogen and endogenous urinary nitrogen were calculated using the formulae developed by Swanson and Herman (1943). The value of 0.53 gm. nitrogen per 100 grams of dry matter ingested was used to calculate metabolic fecal nitrogen. To calculate endogenous nitrogen the following formula was used: $N = .712\ X^{.42}$. N refers to grams of endogenous nitrogen and X to body weight in kg. Biological value was calculated using the Thomas-Mitchell formula:

Biological value =

$$\frac{\text{N intake} - (\text{fecal N} - \text{metabolic fecal N}) - (\text{urinary N} - \text{endogenous N})}{\text{N intake} - (\text{fecal N} - \text{metabolic fecal N})} \times 100$$

N refers to grams of nitrogen.

The data were statistically analyzed by the analysis of variance method of Steel and Torrie (1960).

RESULTS AND DISCUSSION

During trial 1 feed intake of one steer fed ration D-2 was very low. The steer was not used during this trial, but was replaced by a similar steer for trials 2 and 3. Therefore, there are only five observations for each item measured for ration D-2. The missing value was replaced for statistical analysis by the method of Steel and Torrie (1960).

Energy utilization data are presented in Table 2. A statistical summary is presented in Appendix Table 1. There was a definite linear increase in the energy available to the steers as indicated by the digestible energy data. Digestible energy of the low, medium and high energy rations increased linearly ($P < .01$) from 1133, to 1164 and 1222 kcal. per lb. of feed, respectively. Data for metabolizable energy and TDN showed similar linear changes as the digestible energy data.

The actual TDN values were approximately 58, 60 and 63% for the low, medium and high energy rations, respectively. The calculated values based on chemical analysis of the experimental feeds, and digestion coefficients from Morrison (1959) were 62, 67 and 72%, respectively. There is a large discrepancy between calculated and observed values, and it increases with increasing energy concentration. There is no easy explanation for this discrepancy, but it needs further study.

Table 2. Digestible and Metabolizable Energy and TDN Content of the Rations

Ration Energy level	D-1 Low	D-2 Medium	D-3 High
Animals per treatment	6	5	6
Digestible energy kcal./lb. of feed	1133	1164	1222
Metabolizable energy kcal./lb. of feed	936	978	1032
TDN	57.85	59.97	63.35

Nitrogen intake, excretion and utilization data are presented in Table 3, and a statistical summary appears in Appendix Table 2.

When digestible energy concentrations were 1133, 1164 and 1222 kcal. per lb. of feed, nitrogen retention, expressed as grams per day, was 14.76, 18.27 and 16,27, respectively. The medium energy ration tended to support the highest nitrogen retention. There was a quadratic effect ($P < .10$) indicating that maximum nitrogen retention was obtained with the medium energy ration. Nitrogen retention expressed as

Table 3. Effect of Energy Intakes on Nitrogen Retention and Utilization

Ration Energy level	D-1 Low	D-2 Medium	D-3 High
Animals per treatment	6	5	6
Nitrogen intake, gm./day	116.80	120.50	118.20
Nitrogen excretion, gm./day			
Fecal	43.03	43.53	43.42
Urinary	59.00	56.68	58.51
Total	102.03	102.21	101.93
Nitrogen retention, gm./day	14.76	18.27	16.26
Nitrogen retention, % of intake	12.64	15.18	13.76
Metabolic fecal nitrogen, gm./day	28.76	28.71	28.62
Endogenous urinary nitrogen, gm./day	7.66	7.62	7.62
True digested nitrogen, gm./day	102.36	105.66	103.23
Absorbed nitrogen utilized, gm./day	51.18	54.60	52.50
Biological value, %	50.06	51.63	50.84

percent of intake followed the same trends. Nitrogen intakes of steers fed the low, medium and high energy rations were 116.8, 120.0 and 118.2 gm. per day, respectively. Therefore, the small increase in nitrogen retention may possibly be due to the small increase in nitrogen intake when the medium energy ration was fed. Thus, it is questionable that differences in energy intake had an effect on nitrogen retention. Matsushima _et_ _al_. (1957) reported evidence showing that when fattening ration energy concentrations of 58.5, 65.0 and 71.5% TDN were compared, energy had no effect on nitrogen retention. The data presented by Fontenot _et_ _al_. (1955) show that nitrogen retention was increased when a high roughage wintering ration containing approximately 10% protein was supplemented with 700 gm. cerelose. Further cerelose additions were not effective. Nitrogen retention was not significantly changed when a 12% protein ration was supplemented with cerelose. In the present experiment, possibly the energy and/or protein level was too high for increases in energy intake to cause sparing of nitrogen.

True digested nitrogen of the low, medium and high energy rations was 102.36, 105.66 and 103.23 gm. per day, respectively. The quadratic effect was significant ($P < .05$). Probably these small differences are due to differences in nitrogen intake.

Biological values of protein for the rations containing 1133, 1164 and 1222 kcal. digestible energy per lb. of feed were 50.00, 51.63 and 50.84%, respectively. These values showed a quadratic effect ($P < .05$), indicating that the highest value was obtained at the medium energy level.

These results are not in agreement with those of Williams <u>et al</u>. (1953) who found that starch supplement to 10 and 13% protein sheep rations had no effect on biological value. Fontenot <u>et al</u>. (1955) showed a large increase in biological value resulted when a high fiber steer wintering ration containing 12% protein was supplemented with 700 gm. cerelose. When the cerelose level was increased further to 1050 gm. biological value was increased further, but to a lesser degree.

Total fecal nitrogen excretion was 43.0, 43.5 and 43.4 gm. per day for the low, medium and high energy rations, respectively. These values are not significantly different. Mitchell (1924) has shown with rats that the amount of crude fiber passing through the digestive tract has an influence on metabolic fecal nitrogen. In the present experiment the low, medium and high energy rations contained crude fiber levels of 20.77, 16.24 and 10.75%, respectively, and crude fiber excretion amounted to 551, 508 and 409 gm. per day, respectively. Thus, there were large differences in the amount of crude fiber passing through the digestive tracts of the steers, but no difference in fecal nitrogen excretion. This indicates that metabolic fecal nitrogen may not be related to crude fiber intake or excretion in cattle, at least within the limits of the trials presented here.

The apparent digestion coefficients are shown in Table 4 and a statistical summary is shown in Appendix Table 3.

Table 4. Average Coefficients of Apparent Digestibility

Ration Energy level	D-1 Low	D-2 Medium	D-3 High
Animals per treatment	6	5	6
Apparent digestibility, %			
Crude protein	63.08	63.86	63.17
Ether extract	77.71	79.57	79.84
Crude fiber	55.78	47.96	36.46
Nitrogen-free extract	67.44	71.86	77.05
Dry matter	63.58	65.83	69.47
Organic matter	64.20	66.09	70.11
Energy	62.09	64.18	68.02

Apparent digestion coefficients for crude protein were 63.08, 63.86 and 63.17 for the low, medium and high energy rations, respectively. They were not significantly different. This substantiates the postulation of Fontenot et al. (1955) that their observed decrease in apparent digestibility of crude protein, from increasing energy intake, was due to an increase in metabolic fecal nitrogen, resulting from an increased dry matter intake.

Increased ration energy concentration resulted in a linear decrease ($P < .01$) in crude fiber digestibility from 55.78 to 47.96 and 36.46%, respectively. This agrees with the findings of Mitchell et al. (1940), Swift et al. (1947), Fontenot et al. (1955) and Chappell and Fontenot (1963). Mitchell et al. (1940) have suggested that the decrease in crude fiber digestion may be that readily-available carbohydrate is more readily fermented by rumen microorganisms than is cellulose.

Digestibility of NFE increased linearly with increasd ration energy concentration. The values were 67.44, 71.86 and 77.05%, for the low, medium and high energy rations, respectively. This is in agreement with Wicke and Weiske (1896), Hamilton (1942), Swift et al. (1947), Fontenot et al. (1955), Woods et al. (1956) and Robinson (1958). According to Annison and Lewis (1959) starch is much more susceptible to ruminal degradation than cellulose and there is a rapid increase in the number of microorganisms able to utilize the readily-available carbohydrates when starch and sugar feeding is increased. They postulated that the competition for essential nutrients is won by the microorganisms attacking the readily-available carbohydrates.

Dry matter digestibility increased in a linear manner ($P < .01$) with increased energy intake. The values were 63.58, 65.83 and 69.47% for the low, medium and high energy rations, respectively. Dowe et al. (1955) using steers and bulls found that as the concentrate portion of a corn-alfalfa ration increased, dry matter digestibility tended to increase. Fontenot <u>et al</u>. (1955) reported that when a steer wintering ration was supplemented with cerelose (which increased dry matter intake) there was little difference in dry matter digestibility. It appears that in the present experiment there was a greater increase in the quantity of NFE digested than the decrease in the quantity of crude fiber digested; therefore, an increase in the digestibility of dry matter resulted.

SUMMARY

Three digestion and nitrogen balance trials were conducted with six Angus yearling steers to study nitrogen metabolism and digestibility by steers fed fattening rations containing three energy concentrations. The three rations contained approximately 12.5% crude protein. The energy concentration was varied by changing the proportions of shelled corn and corn cobs. Equal amounts of the rations were fed. The determined digestible energy levels were 1133, 1164, and 1222 kcal. per lb. of feed for the low, medium and high energy rations, respectively. This represented a linear ($P < .01$) effect. Metabolizable energy and TDN values followed the same pattern.

Increasing digestible energy concentration from 1133, to 1164 or 1222 kcal. per lb. of feed had no significant effect on nitrogen retention expressed as grams per day or as percent of intake. Biological value was highest for the medium energy level and the quadratic effect was significant ($P < .05$).

The apparent digestibilities of crude protein and ether extract were not significantly influenced by energy concentration. Digestibility of dry matter, organic matter and NFE increased ($P < .01$) and digestibility of crude fiber decreased ($P < .01$) with each increase in energy concentration.

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APPENDIX

Table 1. Analysis of Variance for Digestible and Metabolizable Energy and TDN

Source	Degrees of freedom	Dig. energy kcal/lb. feed	Metab. energy kcal./lb. feed	TDN %
		m.s.	m. s.	m.s.
Animals	4	4520*	3859*	5.56
Trials	2	2986	1933	2.16
Latin squares	1	9568*	7938*	29.75**
Treatment	2	12074**	14832**	45.75**
Linear	(1)	24031**	27648**	90.70**
Quadratic	(1)	117	16	.35
Error	7	856	730	1.60
Total	16			

*P < .05
**P < .01

Table 2. Analysis of Variance for Nitrogen Retention and Utilization

Sounce	Degrees of Freedom	Excretion		N retention		True digested N	Absorbed N Utilized	Biol. Value
		Fecal gm.	Urin. gm.	gm.	%	gm.	gm.	%
		m.s.	m.s.	m.s.	m.s.	m.s.	m.s.	m.s.
Animals	4	20.03**	49.85**	11.72	7.44	30.68*	11.19*	25.41
Trials	2	17.63*	83.84**	38.80	29.73	34.52*	36.92**	51.73
Latin squares	1	2.86	73.04**	103.39*	73.89*	2.60	103.97**	102.67
Treatment	2	.38	1.76	29.47	15.95	16.92	28.55**	14.27[a]
Linear	(1)	.45	.74	6.82	3.74	2.30	5.25	6.78
Quadratic	(1)	.31	2.78	52.10[a]	28.16[a]	31.53*	51.84**	21.75*
Error	7	1.85	1.33	10.25	6.19	5.23	1.46	3.59
Total	16							

a P < .10
* P < .05
** P < .01

Table 3. Analysis of Variance for Apparent Digestion Coefficients

Source	Degrees of Freedom	Percent Apparent Digestibility						
		Dry Matter	Crude Protein	Ether Extract	Crude fiber	NFE	Organic Matter	Energy
		m.s.	m.s.	m.s.	m.s.	m.s.	m.s.	m.s.
Animals	4	7.27**	15.33**	29.31	23.32	5.33	8.16*	12.41*
Trials	2	5.80**	20.21**	121.52**	63.25	3.98	6.14	9.07
Latin squares	1	59.07**	1.51	.20	241.63*	28.68*	47.34**	27.97*
Treatment	2	52.26**	.78	6.99	585.19**	138.91**	53.34	53.19**
Linear	(1)	104.02**	.03	13.65	1117.08**	277.15**	104.73**	105.32**
Quadratic	(1)	.50	1.53	.32	53.29		1.98	1.05
Error	7	.33	1.75	7.90	19.86		1.69	2.55
Total	16							

a P < .10
* P < .05
** P < .01

Table 4. Average Daily Nitrogen Balance and Biological Value of Protein

Trial No.	Steer No.	Nitrogen intake	Excretion		Nitrogen retention		Meta. fecal N	Endo. urin. N	True dig. N	Absorbed N	Biol. Value
			Fecal N	Urin. N							
		gm.	gm.	gm.	gm.	%	gm.	gm.	gm.	gm.	%
							Ration D-1				
1	41	112.80	42.87	53.68	16.25	14.41	28.87	7.48	98.80	52.60	53.24
1	61	112.80	46.59	50.71	15.50	13.74	28.87	7.65	95.07	52.02	54.71
2	64	117.60	43.42	67.08	7.10	6.04	28.85	7.42	103.03	43.37	42.09
2	86	117.60	45.96	54.19	17.45	14.84	28.85	7.65	100.49	53.95	53.69
3	3	120.00	39.20	63.90	16.90	14.08	28.56	7.71	109.36	53.17	48.59
3	34	120.00	40.15	64.48	15.37	12.81	28.56	8.05	108.41	51.98	47.95
	Av.	116.80	43.03	59.00	14.76	12.64	28.76	7.66	102.36	51.18	50.00
							Ration D-2				
1	64	121.20	41.42	57.72	22.06	18.20	28.85	7.53	108.63	58.44	53.80
2	3	119.40	43.62	64.30	11.48	9.61	28.85	7.60	104.63	47.93	45.81
2	41	119.40	43.84	58.76	16.80	14.07	28.85	7.65	104.41	53.30	51.05
3	61	121.20	45.52	60.71	14.97	12.35	28.49	7.58	104.17	51.04	49.00
3	86	121.20	43.25	51.91	26.04	21.49	28.49	7.75	106.44	62.28	58.51
	Av.	120.50	43.53	58.68	18.27	15.18	28.71	7.62	105.66	54.60	51.63
							Ration D-3				
1	3	117.60	43.74	60.46	13.40	11.39	28.81	7.49	102.67	49.70	48.41
1	86	117.60	46.71	48.27	22.62	19.23	28.81	7.18	99.70	58.61	58.79
2	34	120.00	40.69	61.70	17.61	14.68	28.61	7.69	107.92	43.91	49.95
2	61	120.00	49.39	57.57	13.04	10.87	28.61	7.81	99.22	49.46	49.85
3	41	117.00	39.44	61.06	16.50	14.10	28.44	7.78	106.00	52.72	49.74
3	64	117.00	40.54	62.01	14.45	12.35	28.44	7.74	104.90	50.63	48.27
	Av.	118.20	43.42	58.51	16.27	13.76	28.62	7.62	103.23	52.50	50.84

Table 5. Apparent Digestion Coefficients and TDN

Trial No.	Steer No.	Percent Apparent Digestibility							% TDN
		Dry Matter	Crude protein	Ether extract	Crude fiber	NFE	Organic matter	Energy	
					Ration D-1				
1	41	65.57	69.94	75.19	58.10	69.94	66.13	63.34	59.57
1	61	61.29	58.55	69.63	55.98	65.60	61.92	59.36	56.41
2	86	63.69	60.92	76.32	54.01	68.34	64.12	61.22	57.86
2	64	59.04	63.13	81.48	46.71	62.90	59.60	58.19	54.06
3	63	64.67	67.36	79.40	57.25	68.33	65.74	64.53	58.69
3	34	67.24	66.56	83.93	62.51	69.53	67.72	65.95	60.51
	Av.	63.58	63.08	77.71	55.78	67.44	64.20	62.09	57.85
					Ration D-2				
1	64	66.46	65.74	77.21	48.88	72.30	65.28	64.82	60.81
2	3	64.46	63.33	79.33	46.42	70.75	65.18	62.56	59.05
2	41	68.43	63.19	83.43	56.38	73.57	68.99	66.69	62.53
3	86	65.83	64.45	74.04	48.30	71.81	66.54	63.70	59.48
3	61	63.96	62.61	83.86	39.80	70.88	64.44	63.14	58.00
	Av.	65.83	63.86	79.57	47.96	71.86	66.09	64.18	59.97
					Ration D-3				
1	3	69.44	62.81	70.67	37.07	77.78	70.13	69.86	63.39
1	86	68.94	60.25	72.63	44.36	75.78	69.12	66.54	62.81
2	61	64.40	58.51	86.61	24.31	72.39	65.16	62.27	59.54
2	344	72.05	65.83	83.35	36.40	79.61	72.78	70.60	65.81
3	41	72.44	66.30	83.50	40.08	80.04	73.22	70.81	65.56
3	64	69.56	64.34	82.29	36.56	76.71	70.27	68.06	62.98
	Av.	69.47	63.17	79.84	36.46	77.05	70.11	68.02	63.35

Table 6. Metabolizable and Digestible Energy

Trial	Steer	Intake	Excretion			Dig. Energy		Meta. Energy	
			Fecal	Urin.	Methane	Total	Per lb. Feed	Total	Per lb. feed
		kcal.	kcal.	kcal.	kcal.	kcal.	kcal.	kcal.	kcal.
					Ration D-1				
1	41	24,054	8796	959	1800	15,236	1152	12,499	945
1	61	24,054	9775	816	1712	14,278	1079	11,751	888
2	86	24,114	9351	870	1731	14,763	1116	12,162	919
2	64	24,114	10,081	871	1592	14,032	1061	11,570	875
3	3	24,234	8597	932	1725	15,638	1182	12,980	981
3	34	24,234	8251	899	1779	15,982	1208	13,305	1006
	Av.	24,134	9142	891	1723	14,988	1133	12,378	936
					Ration D-2				
1	64	24,042	8457	761	1783	15,584	1178	13,041	986
2	3	24,006	8987	690	1728	15,018	1135	12,601	952
2	41	24,006	7997	645	1832	16,010	1210	13,532	1023
3	86	23,940	8691	672	1742	15,250	1153	12,835	970
3	61	23,940	8824	746	1684	15,116	1143	12,686	959
	Av.	23,987	8591	703	1754	15,396	1164	12,989	978
					Ration D-3				
1	3	23,916	7208	685	1878	16,708	1263	14,145	1069
1	86	23,916	8003	711	1866	15,914	1203	13,336	1007
2	61	23,760	8964	602	1715	14,795	1118	12,479	943
2	34	23,760	6985	592	1895	16,775	1268	14,288	1080
3	41	23,652	6903	633	1914	16,748	1266	14,202	1073
3	64	23,652	7554	800	1837	16,098	1217	13,461	1017
	Av.	23,776	7603	671	1851	16,173	1222	13,652	1032

Table 7. Average Daily Intake of the Various Feed Constituents

Trial No.	Steer No.	Dry matter	Crude protein	Ether extract	Crude fiber	NFE	Organic Matter	Gross Energy
		gm.	gm.	gm.	gm.	gm.	gm.	kcal.
					Ration D-1			
1	41	5446.8	703.2	128.4	1260.0	3130.8	5222.4	24,054
1	61	5446.8	703.2	128.4	1260.0	3130.8	5222.4	24,054
2	86	5443.8	735.0	134.4	1228.2	3115.8	5213.4	24,114
2	64	5443.8	735.0	134.4	1228.2	3115.8	5213.4	24,114
3	3	5389.2	750.6	129.0	1251.0	3023.4	5148.6	24,234
3	34	5389.2	750.6	129.0	1251.0	3023.4	5148.6	24,234
	Av.	5426.6	729.6	130.6	1246.4	3090.0	5194.8	24,134
					Ration D-2			
1	64	5442.6	756.0	150.6	955.2	3351.6	5213.4	24,042
2	3	5444.4	744.6	162.0	1038.6	3259.2	5215.2	24,006
2	41	5444.4	744.6	162.0	1038.6	3259.2	5215.2	24,006
3	86	5376.0	760.8	158.4	930.0	3293.4	5142.6	23,940
3	61	5376.0	760.8	158.4	930.0	3293.4	5142.6	23,940
	Av.	5416.7	753.4	158.3	978.5	3291.4	5185.8	23,987
					Ration D-3			
1	3	5434.8	735.0	174.6	677.4	3621.6	5210.4	23,916
1	86	5434.8	735.0	174.6	677.4	3621.6	5210.4	23,916
2	61	5398.2	745.0	190.8	618.6	3610.8	5165.4	23,760
2	34	5398.2	745.0	190.8	618.6	3610.8	5165.4	23,760
3	41	5365.8	731.4	166.8	639.0	3596.4	5133.6	23,652
3	64	5365.8	731.4	166.8	639.0	3596.4	5133.6	23,652
	Av.	5399.6	737.1	177.4	645.0	3609.6	5169.8	23,776

Table 8. Daily Average Fecal Excretion of the Various Feed Constituents

Trial No.	Steer No.	Dry Matter	Crude protein	Ether extract	Crude fiber	NFE	Organic Matter	Gross energy
		gm.	gm.	gm.	gm.	gm.	gm.	kcal.
Ration D-1								
1	41	1875.1	267.6	31.9	527.9	941.2	1768.6	8796
1	61	2108.4	291.5	39.0	554.6	1077.1	1988.5	9775
2	86	1976.5	287.3	31.8	564.8	986.5	1870.4	9351
2	64	2229.7	271.0	24.9	654.5	1155.9	2106.2	10,081
3	3	1904.1	245.0	26.6	534.8	957.5	1763.8	8597
3	34	1765.7	251.0	20.7	469.1	921.2	1662.0	8251
	Av.	1976.6	268.9	29.2	551.0	1006.6	1859.9	9142
Ration D-2								
1	64	1825.4	259.0	34.3	488.3	928.3	1709.9	8457
2	3	1934.9	273.1	33.5	556.5	953.2	1816.2	8987
2	41	1718.8	274.1	28.5	453.1	861.4	1617.1	7997
3	86	1836.9	270.4	41.1	480.8	928.4	1720.7	8691
3	61	1937.7	284.5	25.6	650.0	959.0	1828.9	8824
	Av.	1850.7	272.2	32.6	507.7	926.1	1738.6	8591
Ration D-3								
1	3	1660.9	273.4	51.2	426.3	804.2	1556.4	7208
1	86	1688.1	292.1	47.8	376.9	877.2	1577.9	8003
2	61	1918.0	309.0	25.5	468.2	996.8	1799.6	8964
2	34	1509.0	254.6	33.7	393.4	736.3	1405.9	6985
3	41	1479.1	246.5	27.5	382.9	717.8	1374.7	6903
3	64	1633.2	253.5	29.5	405.4	837.6	1526.0	7554
	Av.	1631.6	271.5	35.9	408.9	828.3	1540.1	7603

Influence of Energy Concentration of Fattening Ratios on Nitrogen Utilization by Steers

by

Paul Alfred Stone

(ABSTRACT)

Six Angus steers were used in a series of three metabolism trials to study the effect of energy concentration on nitrogen metabolism and digestibility. The experimental design consisted of two randomly selected 3 x 3 latin squares. Three fattening rations were fed which contained 1133, 1164 and 1222 kcal. digestible energy per lb. feed and 12.18, 12.51 and 12.29% crude protein, respectively. The rations were composed of 10% grass hay, shelled corn, corn cobs and cottonseed meal. An attempt was made to equalize calcium and phosphorus contents. Vitamins A and D were added at the rate of 30,000 I.U. and 3750 I.U. per steer per day, respectively. Energy concentration was varied by changing the proportions of shelled corn and corn cobs. Digestible and metabolizable energy and TDN were all significantly increased with each increase in energy concentration. Digestible energy concentration of feed had no significant effect on nitrogen retention. Biological value was higher for the medium energy ration than for the low

or high energy rations. The quadratic effect was significant ($P < .05$). The apparent digestibilities of crude protein and ether extract were not influenced by energy concentration. Digestibility of dry matter, organic matter and NFE significantly increased and digestibility of crude fiber significantly decreased with each increase in energy concentration.