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I am submitting herewith a thesis written by Robert Duane Plymale entitled "Digestibility and Nitrogen Utilization of Three Beef Cattle Rations Containing Corn Silage Ensiled with Limestone and Varying Levels of Urea." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Husbandry.

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DIGESTIBILITY AND NITROGEN UTILIZATION OF THREE BEEF CATTLE RATIONS
CONTAINING CORN SILAGE ENSILED WITH LIMESTONE
AND VARYING LEVELS OF UREA

A Thesis
Presented to
the Graduate Council of
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Master of Science

by
Robert Duane Plymale

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ABSTRACT

The purpose of this experiment was to compare digestibility and nitrogen utilization of three beef cattle rations containing one of three levels of urea in limestone corn silage. The experiment was designed to determine if adaptation to urea nitrogen utilization occurs when these rations are fed, and if diethylstilbestrol has an effect on the rate of this adaptation.

Two digestion and nitrogen metabolism trials were conducted separately. The experimental silage treatments were as follows:

Treatment 1--0.5 percent urea silage: corn green chop plus 5 kilograms of urea (281% crude protein) and 5 kilograms ground limestone per metric ton.

Treatment 2--0.75 percent urea silage: corn green chop plus 7.5 kilograms of urea (281% crude protein) and 5 kilograms ground limestone per metric ton.

Treatment 3--1.0 percent urea silage: corn green chop plus 10 kilograms of urea (281% crude protein) and 5 kilograms ground limestone per metric ton.

In both trials, there were four steers per treatment and each steer was offered a constant amount of concentrate mixture (corn and cottonseed meal) together with approximately 80 percent of the amount of urea corn silage which was consumed by the animal with the lowest feed intake toward the end of the preliminary period. The three rations were calculated to supply the recommended crude protein requirements. As the

nitrogen content in the urea silages increased, the proportion of cottonseed meal in the concentrate mixture was reduced to make the three rations approximately isonitrogenous. The first two steers of each treatment group were implanted with 24 mg. of diethylstilbestrol. During the period between the two trials, the experimental steers were continued on their respective rations. The second trial was conducted the same as the first.

The results from this study were as follows:

1. The digestion coefficients of dry matter and energy were slightly higher for the 0.5 percent urea ration but no significant differences were observed among treatments in both trials.

2. Digestion coefficients of crude protein were significantly higher ($P < .05$) for the 1.0 percent ration in the first trial, and higher in the second trial but not significantly so. Crude protein digestibility between the 0.75 and 0.5 percent urea silage rations for both trials was not significantly different. The higher apparent crude protein digestibility of the 1.0 percent silage ration may have been caused by the higher crude protein equivalency in that ration.

3. Estimated total digestible nutrient values in the 0.5 percent urea silage ration were significantly higher ($P < .05$) than in the 0.75 and 1.0 percent silage rations in both trials. There were no significant differences in TDN values between the 0.75 and 1.0 percent urea silage ration in both trials. The higher estimated TDN values of the 0.5 percent silage ration was probably not related to its lower urea content but to the decreased dry matter intake of that ration.

4. In both trials, absorbed nitrogen retained data indicated that the 1.0 percent urea silage ration was utilized significantly better ($P < .05$) than the 0.5 percent urea silage ration. The general trend in both trials was an increase in retention of absorbed nitrogen with increased urea levels in the ration. This increase of retention of absorbed nitrogen with increased urea levels in the rations was probably not related to the amount of urea in the rations.

5. In both trials, net protein utilization was significantly higher in the 1.0 percent urea silage ration and these values generally followed the same trend as absorbed nitrogen retained values.

6. The data from both trials indicated that no adaptation response for nitrogen utilization occurred in rations where urea supplied 30 percent or less of the crude protein equivalency.

7. Since there was no adaptation response, diethylstilbestrol had no effect upon shortening the adaptation period. However, those steers implanted with diethylstilbestrol showed improved weight gains.

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CHAPTER I

INTRODUCTION

Increasing the efficiency of beef production in the Southeast could greatly increase the feeding enterprises in this section and provide additional industry. Urea-limestone corn silage with the addition of readily digestible carbohydrates such as shelled or crushed corn shows promise of being an acceptable growing-finishing ration for beef cattle.

Feeding urea-limestone corn silage has received considerable attention in the southeastern United States within the past few years. This ration has been shown to be economically advantageous for producing beef cattle gains. Since corn silage is generally low in calcium, the addition of ground limestone at the time of ensiling tends to correct this deficiency and to improve fermentation.

Urea has been used for a number of years as a protein supplement for replacing the more expensive organic supplements such as cottonseed meal or soybean meal. However, the optimum level of urea to be added to corn silage for feeding beef cattle has not been definitely determined. Cost of gains in feeding enterprises could be reduced if the level of urea could be increased.

The major objective of this experiment was to compare digestibility and nitrogen (N) utilization of three beef cattle rations containing varying levels of urea in corn silage. The secondary

objective was to determine if adaptation to nitrogen utilization occurs when these rations are fed and if diethylstilbestrol (DES) has an effect on the rate of this adaption.

CHAPTER II

REVIEW OF LITERATURE

I. HISTORY

Urea was synthesized from inorganic substances by Wohler in 1828 (Stangel, 1967). As early as 1891, Zuntz suggested that microorganisms might be able to utilize urea, a non-protein nitrogen (NPN) compound, to produce body protein. Commercial production of urea was not started in Germany until 1920, and from 1924 to 1936 urea was imported to the United States from Germany. In the late 1930's the United States started commercial production of urea from carbon dioxide and ammonia, the method used being essentially the same as the German synthesis, except for a few alterations that increased yields (Merz et al., 1943).

Research involving urea for the feeding of livestock in the United States was initiated by Hart et al. (1939). They used urea to demonstrate that calves made satisfactory gains by utilizing the nitrogen from urea. Weber and Hughes (1940), Harris et al. (1943), Baker et al. (1949) and Ross et al. (1949) reported that nitrogen in urea could replace part of the more expensive organic protein supplements with equal utilization.

In cattle rations, urea was first mixed together with grains. This was the most accepted practice for a number of years because of the relatively inexpensive grain and labor costs. Beeson and Perry (1951) indicated that urea fed with concentrates was a satisfactory protein

supplement in wintering rations for beef cattle. Beeson and Perry (1952) incorporated small amounts of urea into the original Purdue formula "Purdue Supplement A" which proved to be a satisfactory ration for "balancing the nutritional deficiencies of roughages for beef cattle." This was substantiated by Burroughs et al. (1952) who added urea to concentrate mixtures which were then used with roughages in fattening rations for beef cattle.

Corn silages are low in protein but adequate in energy, and when fed with protein supplements have proven very economical for feeding beef cattle (Morrison, 1956). Bentley et al. (1955) attempted to ✓ fatten beef cattle by adding urea to corn silage so that the protein content would be adequate. Their data indicated that, for fattening purposes, a corn silage ration with 1 percent urea was equal to an untreated silage which was supplemented with soybean meal. Goodrich ✓ and Meiske (1966) found that beef cattle fed corn silage rations with urea added when ensiled, performed better than beef cattle fed equivalent untreated corn silage plus a corn-urea ration supplement. Corrick and ✓ Hobbs (1968) have indicated that corn silages with urea levels up to 1.0 percent supplemented with ground shelled corn showed promise of being acceptable growing-finishing rations for beef heifers.

II. UREA METABOLISM

Hydrolysis Reaction

In the rumen, urea is broken down very rapidly by an enzymatic hydrolysis reaction into carbon dioxide and ammonia. The problem

associated with urea feeding is not with digestibility but with efficiency of utilization. When very high levels of urea are fed, ammonia is produced so rapidly by hydrolysis that only limited amounts are utilized by the rumen microorganisms. Bloomfield et al. (1960) reported ✓ that the release of ammonia by urea hydrolysis occurred four times faster than microorganisms were able to utilize the ammonia. At present, various researchers are studying different methods of slowing down urea hydrolysis.

Utilization of Urea

Ammonia present in the rumen may be utilized by two pathways.

- ✓ Pearson and Smith (1943) demonstrated that the nitrogen from urea was utilized by microorganisms to produce amino acids for the microbial
- ✓ protein. The rumen contains many strains of microorganisms which are capable of utilizing the nitrogen from non-protein nitrogen sources (Purser and Buechler, 1966). Black et al. (1952) reported that microorganisms digested by the host animal have almost the same biological value as the essential amino acids needed by the rat. Johnson et al. (1944) demonstrated that dried rumen bacterial samples fed to rats had yielded 82 percent digestibility and 66 percent biological value. The rumen protozoa samples yielded 86 percent digestibility and 68 percent biological value. McNaught et al. (1954) later demonstrated that the higher nutritive value of protozoa reported in the literature was due to the higher digestibility. Their work also indicated that the utilization of protozoa as an additional source of protein is advantageous to the host animal.

Loosli et al. (1949) demonstrated that ruminants fed diets where urea was the only source of nitrogen were able to synthesize those amino acids which are considered essential for the rat. Although amino acid synthesis does occur at high levels, a deficiency of specific amino acids may exist when urea is fed (Bergen et al., 1968). Ellis et al. (1955) reported that rumen microbial protein yielded an amino acid distribution that was relatively constant but inadequate in tryptophan. This resulted in experiments where the supplementation of amino acids such as methionine, tryptophan and lysine to high-urea diets proved beneficial (Gallup et al., 1952; Gossett et al., 1962; McLaren et al., 1965a).

✓ The second pathway for utilization of the nitrogen from NPN is absorption of ammonia through the rumen wall. This was first demonstrated by McDonald (1948). Lewis et al. (1957) reported an increase of portal blood ammonia as a linear function of rumen ammonia content. McDonald (1948) demonstrated that not only is ammonia absorbed through the rumen wall but small amounts are also absorbed from other parts of the digestive tract such as the omasum, small intestine and caecum. The rate of ammonia absorption in the rumen is influenced by the concentration gradient and pH (Hogan, 1961; Bloomfield et al., 1963). Lewis et al. (1957) demonstrated that blood ammonia enters the liver and is converted back to urea for excretion. However, a small amount of ammonia may be found in other systems of the body such as gastric juices and saliva (Hirose et al., 1960). Schmidt-Nielson et al., (1957, 1958) related the importance of this pathway. They implied

that the recycling of ammonia plays an important part in the nitrogen economy of the ruminant's system.

Urea Toxicity

When ammonia levels are extremely high in the circulatory system, urea toxicity may exist because of the inability of the liver to convert the ammonia to urea. Dinning et al. (1948) stated that urea toxicity includes such symptoms as dyspnea, excessive salivation, and tetany. Bloat and death may occur as rapidly as 1.2 to 7.0 hours following the first visual symptoms. Hart et al. (1939) indicated that the liver and kidney may show signs of pathological conditions. Lewis (1961) reported that urea toxicity is a complex problem that involves a disturbance of the acid-base balance of the body. Visek (1968) emphasized the problems associated with pH and diffusion of NH_3 across tissue barriers and has given equations for the calculation of the percentage of total ammonia which may exist in ionic form. Since ✓ overfeeding of urea may cause toxic effects, feeders are concerned about the safe levels of urea to feed for maximum utilization and optimum economic gains.

Adaptation

Data from Smith et al. (1960), Barth et al. (1961), and McLaren et al. (1965a) suggested that an adaptation period might influence utilization of urea. McLaren et al. (1956) demonstrated by multiple regression analysis that nitrogen utilization was enhanced by the length of time of urea feeding. Bell et al. (1957) reported that

diethylstilbestrol did not effect digestibility of N but did increase retention. McLaren et al. (1959, 1960) reported that diethylstilbestrol shortens the adaption period for nitrogen utilization, however, the mechanism of diethylstilbestrol influence is not fully understood.

III. FACTORS EFFECTING UREA UTILIZATION

Energy Requirements of Rumen Microorganisms

The ratio of nitrogen to readily available carbohydrates in the rumen is very important for optimum NPN utilization. Rumen microbes must be furnished readily available carbohydrates for optimum utilization of the urea (Wegner et al., 1940; Arais et al., 1951; Belasco, 1956; Reis and Reed, 1959). McLaren et al. (1965b) reported that nitrogen utilization by lambs increased 2 percent with each addition of 100 kcal. of readily fermentable carbohydrates to a urea ration.

Minerals Needed for Microbial Metabolism and Growth

There are a number of minerals which are very important for efficient microbial metabolism and growth. Among these minerals is calcium. Corn silage is considered too low in this element and the supplementation of calcium in a corn silage ration may increase urea utilization (Essig, 1968). Mohler et al. (1962) reported that urea-limestone treated corn silage contained more carotene than non-treated corn silage. The urea-limestone treated corn silage retained a greener color, was more palatable, and feed consumption was increased by 13 percent as compared to non-treated corn silage. Owen et al. (1966) reported conflicting

IV. UREA SILAGE FEEDING

Dairy Cattle

Early reports by Wise et al. (1944) indicated that feeding urea (in aqueous solution) treated silage to dairy cows did not improve milk production when compared to non-treated silage. Woodward and Sheperd (1944) reported that feeding corn silage treated with 0.5 percent urea reduced feed intake but did not affect milk production. However, no indication was given to indicate whether these early researchers used isenitrogenous rations or if nitrogen was deficient. Hillman et al. (1966) suggested that silage treated with urea should contain a minimum of 30 percent dry matter so that the silage may contain more protein on a dry matter basis. These studies revealed that samples of corn silage which contained 30 percent dry matter averaged 2.5 percentage points more protein than samples which contained less than 30 percent dry matter.

In summary, it has not been fully determined which level of urea gives optimum benefits for milk production. However, urea-treated corn silage has been proven to be a very inexpensive ration for feeding dairy cattle, and it has been proven to be adequate for maintaining sufficient milk production.

Sheep

Bentley et al. (1955) conducted digestion studies with wether lambs to determine the digestibility of the crude protein equivalency in corn-urea silage with urea (0.85%) being added at the time of

ensiling, and corn silage plus soybean oil meal and corn silage with a ground corn-urea supplement. Their results indicated that the nitrogen digestibility in the three isonitrogenous rations was essentially the same.

Beef Cattle ✓

Reports in the literature indicate that urea added up to 0.6 percent as a supplement to rations of silage or silage plus cereal grains or molasses provides a satisfactory growing-finishing ration (Ross et al., 1949; Beeson and Perry, 1952; Van Arsdell et al., 1953; Pope et al., 1959).

Bentley et al. (1955) conducted a fattening trial with seven steers per ration, replicated three times and fed for 112 days. The nitrogen in the urea corn silage rations was approximately equal to that in soybean meal supplemented rations, and the gains on the urea corn silage compared favorably with that of regular corn silage plus soybean oil meal. These data indicated that for fattening purposes, a corn silage ration with 1.0 percent urea and ground corn is equal to an untreated silage which was supplemented with soybean oil meal and ground corn.

In contrast, Goodrich and Meiske (1966) found that beef cattle ✓ fed a corn silage ration with urea, added when ensiled, performed better than beef cattle fed equivalent untreated corn silage plus a corn-urea ration supplement. Corrick and Hobbs (1968) have indicated that corn silage rations containing levels of urea up to 1.0 percent (added when ensiled) show promise of being an acceptable growing-finishing ration.

Their work indicated that there were no statistical differences between cattle gains on the three urea silage rations and no significant differences of carcass data were observed.

In general, the common protein supplements such as cottonseed meal or soybean meal have produced better rates of gain and efficiencies of food conversion than urea when compared to an equal energy and nitrogen basis but this has not often been significantly higher.

In summary, research has demonstrated that urea added to silage or silage plus cereal grains provides a satisfactory growing-finishing ration for beef cattle. The optimum level of urea (added at time of ✓✓ ensiling) for maximum nitrogen utilization has not been determined because there seem to be many factors which affect nitrogen utilization such as the amount of readily available energy, amount of dry matter in the corn silage, and available minerals.

CHAPTER III

EXPERIMENTAL PROCEDURE

In this study in vivo methods were used to determine the apparent digestibility and nitrogen utilization of limestone corn silage rations containing one of three levels of urea. Two identical digestion and nitrogen metabolism trials were conducted in the animal husbandry laboratory facilities at the University of Tennessee. The first and second trials were conducted during December, 1967, and March, 1968, respectively. Both trials were companion studies of a feeding trial conducted by Corrick and Hobbs (1968) at the University of Tennessee Animal Husbandry Experimental Farm. The two trials were conducted approximately at the beginning and at the completion of the feeding trial, respectively.

I. EXPERIMENTAL SILAGES

The experimental corn silages were obtained from the University of Tennessee Animal Husbandry Experimental Farm. At the time of ensiling one of three levels of urea with a constant level of limestone were added to the green chop before it was loaded into the respective silos. The experimental silage treatments were as follows:

Treatment 1--0.5 percent urea silage: corn green chop plus 5 kilograms of urea (281% crude protein) and 5 kilograms ground limestone per metric ton (referred to hereafter as a 0.5 percent urea silage).

Treatment 2--0.75 percent urea silage: corn green chop plus 7.5 kilograms of urea (281% crude protein) and 5 kilograms ground limestone per metric ton (referred to hereafter as a 0.75 percent urea silage).

Treatment 3--1.0 percent urea silage: corn green chop plus 10 kilograms of urea (281% crude protein) and 5 kilograms ground limestone per metric ton (referred to hereafter as a 1.0 percent urea silage).

In the first trial, the 0.75 percent and the 1.0 percent urea silages had sporadic mold formation. In addition, ammonia odor could be detected in the silage containing 0.75 percent urea. The silage containing 0.5 percent urea had no detectable ammonia odor or mold formation in trials one and two. In the second trial, the silage containing 0.75 and 1.0 percent urea were of better quality.

II. EXPERIMENTAL RATIONS

In both trials, each steer was offered a constant amount of total concentrates (2.72 kg./day) and approximately 80 percent of the urea corn silage consumed daily at the end of the preliminary period (4.54 and 5.90 kg./day, respectively). The three rations were calculated to supply the recommended crude protein requirements (N.R.C., 1963). As the nitrogen content in the urea silages increased, the proportion of cottonseed meal in the concentrate mixture decreased to make the three rations approximately isonitrogenous. The daily consumption and nutrient composition of all ration constituents are presented in Table I.

INTAKE AND NUTRIENT COMPOSITION OF EXPERIMENTAL RATIONS USED IN TRIAL I AND TRIAL II

^aCrude protein equivalent = (N x 6.25).
^bAs-fed basis.
^cDry matter basis.

III. EXPERIMENTAL ANIMALS

Twelve weanling Hereford steers from the University of Tennessee-Atomic Energy Commission Agricultural Research Laboratory with an average body weight of 272 kilograms were chosen for the experiment according to uniformity of weight, conformation and condition. Three steers in each treatment had been creep fed and one was not creep fed while nursing their dams on pasture. When the steers arrived at the Animal Husbandry Experimental Farm, they were placed on urea (0.5 percent), limestone (0.5 percent), corn silage ration for approximately three weeks, until the initiation of the preliminary period of the first digestion and nitrogen metabolism trial.

IV. DIGESTION AND NITROGEN METABOLISM STUDIES

Experimental Design

Two digestion and nitrogen (N) metabolism trials were conducted. The first trial consisted of three treatments with four steers per treatment. The first two steers of each treatment group were implanted with diethylstilbestrol. During the period between the two trials the experimental steers were continued on their respective rations at U.T. Animal Husbandry Experimental Farm. The second trial was conducted the same as the first.

Conduction of Trials

The steers were randomly placed in metabolism crates (Hobbs et al., 1950) and fed their respective rations for a preliminary period of ten

days. The purpose of this preliminary period was to allow the steers to become adjusted to their respective rations and the new environment, and to measure the maximum feed consumption. In both trials the twelve steers were fed equal portions of their daily rations at 7:00 a.m. and 4:30 p.m. During the collection period individual refusals were collected, weighed and stored each morning. Daily rectal body temperatures indicated that all steers were apparently healthy.

Two days prior to the seven-day collection period of the first trial, two steers within each treatment group were subcutaneously implanted with 24 mg. of diethylstilbestrol in the left ear. The two remaining steers within each treatment were not implanted. Accounting for feed intake was started two days prior to the collection of feces and urine.

Collection of Excreta

Fecal collection boxes were lined with plastic sheets and one was placed behind each steer. Total feces output was collected once daily for seven days. Each day a 5 percent aliquot sample of the feces of each steer was taken, composited and stored under refrigeration at 7°C in a plastic jar. A small amount of thymol was added to each jar to prevent mold formation.

At the start of the collection period, urine collection bottles were placed under the funnels of the metabolism crates. To prevent the volatilization of ammonia, 25 ml. of six normal hydrochloric acid was added to each collection vessel. Urine was collected once daily

and diluted with tap water to a constant volume of 4000 ml. Five percent of the diluted urine was composited in storage jars that contained 10 ml. of six normal hydrochloric acid. Urine samples were then stored in a refrigerator at 7°C until the laboratory analyses could be performed.

Laboratory Analyses and Calculations

Shortly after each trial, two 500 gm. sub-samples of each ration constituent, feed refusal and fecal sample were dried for three days at 65°C, allowed to air-equilibrate for one week and ground in a Wiley Mill using a medium mesh screen of 2mm. diameter.

Protein and dry matter analyses were performed according to the A.O.A.C. (1965) methods and gross energy was determined according to Parr (1960) oxygen bomb calorimeter procedures. Digestion coefficients of dry matter, crude protein and energy were then calculated. Digestible energy (DE) was obtained by multiplying the digestion coefficients of energy by the gross energy content of the ration and estimated total digestible nutrients (ETDN) was calculated from digestible energy using the equation reported by Barth et al. (1959).

Absorbed nitrogen retained (Anderson et al., 1959) was calculated by the Thomas-Mitchell method, and endogenous urinary nitrogen and metabolic fecal nitrogen were calculated from Swanson and Herman (1943) data. Net protein utilization (NPU) was derived by multiplying apparent protein digestibility times absorbed nitrogen retained (Forbes and Yoke, 1955) and net protein value (NPV) was derived by multiplying NPU times the percent of protein content in the ration.

Statistical Analyses

Differences between mean values with respect to various digestion and nitrogen utilization variables were tested by an analysis of variance. Estimation of missing values was accomplished with methods outlined by Steel and Torrie (1960). Duncan's (1955) new multiple-range test was used for mean separation of digestion coefficients and nitrogen utilization data when significant differences were detected by analysis of variance. Duncan's (1955) test was applied to the data from each trial as well as to the pooled data from both trials.

CHAPTER IV

RESULTS AND DISCUSSION

I. DIGESTIBILITY OF RATIONS IN TRIALS I AND II

Digestibility and nitrogen utilization data from the first and second trial appear in Tables II and III, respectively. In both trials, the digestion coefficients of dry matter and energy were slightly but non-significantly higher in the 0.5 percent urea silage ration. These results are in agreement with the work of Reddy et al. (1961) ✓ who reported that dry matter and energy digestion coefficients were not statistically different when various levels of urea furnished up to 36 percent of the total nitrogen intake, and similar to the results of Klosterman et al. (1964) who reported only small differences in ✓ digestibility between urea or soybean meal supplemented high-fiber rations.

The crude protein digestion coefficient of the 1.0 percent urea silage ration was significantly greater ($P < .05$) than those of the 0.75 and 0.5 percent urea silage rations in the first trial. In the second trial, the crude protein digestion coefficient was also higher in the 1.0 percent urea treated silage, but these differences were not statistically significant. The higher apparent crude protein digestibility in the 1.0 percent silage ration in the first trial may be caused by one of two factors. The percentage of crude protein equivalency in ✓ the 1.0 percent urea ration was higher than in the other two rations and Holter and Reid (1959) and Ryley (1967) reported that apparent crude

TABLE II

EFFECT OF VARYING UREA LEVELS IN CORN-SILAGE RATIONS ON DIGESTIBILITY
AND NITROGEN UTILIZATION IN BEEF CATTLE (TRIAL I)

Observations	Ration		
	Urea 0.5%	Urea 0.75%	Urea 1.0%
Number of steers	4	4	4
Average weight of steers, kg.	262.0	258.0	264.0
Dry matter intake, kg./day	3.9	4.2	4.2
Crude protein, % ^a	13.0	13.9	15.3
Digestion coefficients:			
Dry matter, %	74.4 ^f	72.4 ^f	73.1 ^f
Energy, %	72.7 ^f	70.6 ^f	71.5 ^f
Crude protein (N x 6.25), %	63.1 ^f	62.6 ^f	67.5 ^g
Digestible energy, kcal./gm. ^a	3.3 ^f	3.2 ^f	3.2 ^f
Estimated TDN, % ^{a,b}	73.0 ^f	70.0 ^g	70.5 ^g
Nitrogen intake, gm./day	78.5	82.0	85.5
Fecal nitrogen, gm./day	29.0	31.0	28.0
Metabolic fecal nitrogen, gm./day	11.5	12.2	11.0
Urinary nitrogen, gm./day	30.5	22.2	24.0
Endogenous urinary nitrogen, gm./day	7.5	7.5	7.5
Absorbed nitrogen retained, % ^c	62.4 ^f	76.7 ^g	75.5 ^g
Net protein utilization, % ^d	39.2 ^f	47.9 ^g	50.9 ^g
Net protein value, % ^e	5.1 ^f	6.6 ^g	7.8 ^h

^aCalculated on a dry-matter basis.

^bEstimated TDN was calculated using the equation reported by Barth et al. (1959).

^cAbsorbed nitrogen retained (Anderson et al., 1959) was calculated by the Thomas-Mitchell method.

^dNet protein utilization was derived by multiplying apparent protein digestibility and absorbed nitrogen retained (Forbes and Yost, 1955).

^eNet protein value was derived by multiplying net protein utilization and percent of protein content in the ration.

^{f,g,h}Means in the same row followed by the same letter(s) are not significantly different ($P > .05$)--those followed by different letters are significantly different ($P < .05$).

nitrogen equivalency, should not have been expected.

The increase in absorbed nitrogen retention with increasing urea levels can probably be explained by the somewhat higher percentage of crude protein equivalency in the higher urea rations, because the data of Smith et al. (1960) showed that absorbed nitrogen retention increased as the crude protein equivalency in the rations increased. ✓

Net Protein Utilization

The method used to measure how much of the ingested crude protein equivalency was retained by the body was determined by net protein utilization values (NPU) which were derived by multiplying apparent protein digestibility by the absorbed nitrogen retained. These values indicated that the 1.0 percent urea silage ration was utilized with significantly higher efficiency ($P < .05$) than the 0.5 percent level. In the first trial, this rate of utilization decreased as the level of urea in the corn silage decreased. Differences in NPU between the two higher urea rations were not statistically significant from one another. In the second trial, the two rations with lower urea levels were not significantly different from one another for NPU. Since the crude protein digestibilities of the rations were relatively constant, the NPU values generally follow the same trend as absorbed nitrogen retained.

III. ADAPTATION

Since there were no significant differences in the retention of absorbed nitrogen between trials I and II, adaptation to urea feeding

TABLE IV
 AVERAGE DAILY GAINS OF EXPERIMENTAL STEERS ON AN
 EIGHTY-FOUR DAY FEEDING PERIOD

Ration	No Diethylstilbestrol kg./day	Diethylstilbestrol kg./day	Increase kg./day
Number of steers	6	6	---
Urea 0.5%	0.39	0.59	0.20
Urea 0.75%	0.55	0.83	0.28
Urea 1.0%	0.35	0.51	0.16
Overall mean	0.43	0.64	0.21

CHAPTER V

SUMMARY

The purpose of this experiment was to compare digestibility and nitrogen utilization of three beef cattle rations containing one of three levels of urea in limestone corn silage. The experiment was designed to determine if adaptation to urea nitrogen utilization occurs when these rations are fed, and if diethylstilbestrol has an effect on the rate of this adaptation.

Two digestion and nitrogen metabolism trials were conducted separately. The experimental silage treatments were as follows:

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Treatment 3--1.0 percent urea silage: corn green chop plus 10 kilograms of urea (281% crude protein) and 5 kilograms ground limestone per metric ton.

In both trials, there were four steers per treatment and each steer was offered a constant amount of concentrate mixture (corn and cottonseed meal) together with approximately 80 percent of the amount of urea corn silage which was consumed by the animal with the lowest

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APPENDIX

TABLE V
DIGESTIBILITY AND NITROGEN METABOLISM OBSERVATIONS
FROM INDIVIDUAL STEERS IN TRIAL I

Steer number	Digestion coefficient of			Digestible energy (kcal./gm.)	Absorbed nitrogen retained %	Net protein utilization %	Net protein value %	Estimated total digestible nutrients %
	Crude protein %	Energy %	Dry matter %					
1	57.9	67.7	69.6	3.1	65.6	38.0	4.9	68.1
2	68.9	77.0	78.6	3.5	61.0	42.1	5.4	77.0
3	58.0	69.2	71.2	3.2	66.1	38.3	5.0	70.1
4	68.0	76.6	78.0	3.5	57.0	38.4	5.0	76.6
5	65.5	71.1	72.6	3.2	66.7	43.6	6.1	70.5
6	59.0	69.9	71.8	3.2	76.9	45.4	6.3	69.5
7	67.3	74.1	76.1	3.3	81.0	54.5	7.6	73.3
8	58.7	67.2	69.1	3.0	82.1	48.1	6.7	66.8
9	69.4	75.8	77.1	3.4	64.2	44.5	6.8	74.7
10	67.2	68.6	70.3	3.1	83.5	56.2	8.6	67.7
11	68.0	71.4	73.2	3.2	81.3	55.3	8.5	70.6
12	65.4	70.0	71.8	3.1	73.0	47.7	7.3	69.1

TABLE VI

DIGESTIBILITY AND NITROGEN METABOLISM OBSERVATIONS
FROM INDIVIDUAL STEERS IN TRIAL II

Steer number	Digestion Coefficient of			Digestible energy (kcal./gm.)	Absorbed nitrogen retained %	Net protein utilization %	Net protein value %	Estimated total digestible nutrients %
	Crude protein %	Energy %	Dry matter %					
1	67.5	75.4	76.6	3.4	50.7	34.2	4.7	75.7
2	71.4	76.9	77.5	3.5	77.6	55.4	7.7	77.1
3	72.2	78.1	79.0	3.6	60.0	43.3	6.0	78.2
4	67.8	73.1	74.6	3.3	66.2	44.9	6.2	73.5
5	63.8	68.4	69.6	3.1	61.4	39.2	5.5	68.1
6	69.8	74.3	75.7	3.4	53.5	37.3	5.2	73.8
7	68.7	74.2	75.5	3.4	68.1	46.8	6.6	73.9
8	66.0	71.2	72.6	3.2	---	---	---	70.9
9	72.6	73.5	75.1	3.3	79.8	57.9	8.5	72.2
10	71.9	72.2	74.1	3.2	74.7	53.7	7.9	71.2
11	72.0	73.4	75.2	3.3	85.3	61.4	9.0	72.3
12	69.7	72.3	74.1	3.2	69.9	48.7	7.2	71.3

TABLE VII
MEAN SQUARES OF DIGESTIBILITY AND NITROGEN
UTILIZATION OBSERVATIONS

Source	Degrees of freedom	Digestion coefficient of Crude protein	Energy	Dry matter	Digestible energy	Absorbed nitrogen retained	Net protein utilization	Net protein value	Estimated total digestible nutrients
Treatment	2	45.64*	36.90	12.28	0.06	366.44*	276.17*	11.78**	33.65*
Trials	1	152.76**	24.81	63.67	0.06	41.97	9.21	0.30	24.40
DES	<u>1</u>	<u>7.39</u>	—	<u>0.04</u>	—	<u>120.22</u>	<u>24.10</u>	<u>0.47</u>	<u>0.04</u>
Residual	19	218.55	8.85	2.48	0.0179	82.77	40.36	0.83	7.94

*Significantly different ($P < .05$).

**Significantly different ($P < .01$).

VITA

Robert Duane Plymale was born in Huntington, West Virginia on November 11, 1943. He was educated in the West Virginia school system where he graduated from Vinson High School in May 1961. After two years of work, he entered Brigham Young University located in Provo, Utah. In May 1967 he received his Bachelor of Science degree with a major in Animal Science and a minor in Chemistry. In September, 1967, he entered the Graduate School at the University of Tennessee, holding a teaching assistantship. In December, 1968, he received his Master of Science degree in Animal Husbandry with Beef Nutrition being his field of special interest. While at Graduate School, he also held various church positions.

He plans to work in Agricultural Extension Service and to continue in raising registered Morgan horses.