UTILIZATION OF UREA BY CATTLE FED LOW QUALITY ROUGHAGE DIETS

by 45

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B. S., Kansas State University, 1953

A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1969

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INTRODUCTION

With increased demand for protein for human consumption, substitute products containing non protein nitrogen (NPN) are being included and fed to ruminant animals in increasing amounts. In general, protein constitutes the most expensive portion of the animal ration.

In 1891, Zuntz, a German scientist, suggested NPN might replace protein nitrogen in the rations of ruminants. It was not until 1937, some 46 years later, that conclusive evidence showed that urea nitrogen could be used to replace some protein in ruminant rations. Successful feeding of urea to ruminant animals has best been demonstrated in finishing rations. Conversely, the value of urea containing supplements fed to ruminants, kept under range conditions and/or fed low quality roughages, has not been as clear cut.

The ruminant animal, because of the anatomy of the stomach and associated microorganisms (flora and fauna) is able to utilize urea and other non protein nitrogen sources and convert them into amino acids. The billions of bacteria and protozoa have the capability of converting cullulose into soluble products which then can be utilized by the host animal, principally cattle, sheep, and goats and also synthesize certain vitamins.

The feeding of non protein nitrogen to ruminants in substitution for protein and the utilization of dietary carbohydrate sources not in direct competition for human food becomes paramount as world population expands. The successful utilization of non protein nitrogen sources fed with forages and residual carbohydrates which are presently being discarded as waste or disposed of at added cost need to be implemented into ruminant rations.

If ruminant animals are to continue as a link in the human food chain, full advantage must be taken to utilize those inherent physiological and biochemical capabilities they possess.

Still unanswered are many problems regarding the utilization of urea in ruminant rations where the quantity of concentrate feed offered as a supplement to mature, dry, unpalatable and low nutritive value forages is at a low level.

The purpose of this report is to study the use of urea in the utilization of low quality roughages, both dry standing feed and cash crop residues fed to beef cattle under varied environmental conditions.

THE RUMINANT ANIMAL

Protein Digestion and Metabolism

Chemically, proteins are among the most complex of all organic substances. All proteins are composed mainly of five elements--nitrogen, carbon, hydrogen, oxygen and sulfur. The most significant of these is nitrogen. When these elements are grouped together in various proportions the resulting compounds are called amino acids.

The proteins in livestock feedstuffs are not necessarily identical with those that comprise the proteins of the animal's body. In order to assimilate these feed proteins into amino acids the animal must break them down by metabolic means.

After ruminant animals ingest protein-containing feeds, enzymes secreted in the rumen, true stomach and intestine cause breakdown of the proteins to their constituent amino acids, free amino groups or ammonia.

Ruminants, because of microorganisms that are maintained in the rumen, can synthesize microbial protein from ammonia in the presence of adequate supplies of energy. The microbial population of the rumen can be divided into the microfauna, consisting mainly of ciliated protozoa, and the microflora which comprise the bacteria. In the rumen of mature animals, the total counts of protozoa and bacteria average about $0.5 - 2x10^6$ and 10^{10} per gram of rumen contents, respectively (Eadie, 1962).

Amino acids that are digested and absorbed are synthesized into proteins needed for maintenance of the body production. If excess protein above the animal's needs is fed, it is deaminized and the non-nitrogenous residue is utilized as a source of energy. This deaminization occurs primarily in the liver. Nitrogenous products are eliminated primarily through urine as urea, uric acid, creatine, and ammonium salts.

A small amount of the non protein nitrogen is secreted back into the digestive tract as urea in the saliva. Many of the common feedstuffs fed to livestock contain some NPN. Oil meals contain about 0.25 percent of their total nitrogen as urea while oats may contain 4.5 percent. Forage plants, especially young plants may contain 15 percent of their total nitrogen as NPN, while mature plants usually contain less than 5 percent of their nitrogen in this form. Both sources of urea, the urea in the saliva, and the naturally occurring urea in feedstuffs can be utilized by the rumen bacteria to manufacture microbial protein in the presence of adequate energy. This indicates that certain feeds contain non protein nitrogen and that non protein nitrogen is not a foreign substance in ruminant rations.

Urea--A Protein Replacement

In 1891 Nathan Zuntz, a German scientist, suggested that NPN could possibly replace protein in the rations of ruminant animals. It was not until almost sixty years later that the use of urea in feed mixes began in the United States (Hall, 1961).

Chemically the compound carbamide, more frequently called urea, was recognized as a substitute for protein which could be fed to ruminant animals. Fed as a replacement for protein, urea contains no protein but serves as a source of ammonia, which is an end product of the breakdown of urea in the rumen. Part of the NH_3 produced in the rumen is used by the bacteria for synthesis of cell constituents; part is absorbed through the ruminal wall of cattle into the portal blood stream, and part passes out of the rumen into the lower portions of the gut.

Urea, an organic compound, contains 42 or 45 percent nitrogen and is equivalent to a 262-281 percent protein feed. One pound of urea has the potential when combined with certain energy feeds, to provide about 2.62 - 2.81 lbs. of crude protein. Pure urea has the protein equivalent of 292 percent but added ingredients which prevent caking while in storage lower the protein to the feed grade equivalent of 262-281 percent.

Economically, a cost reduction may result where urea is fed as a protein supplement. Using the protein equivalent of 281 percent, 13.5

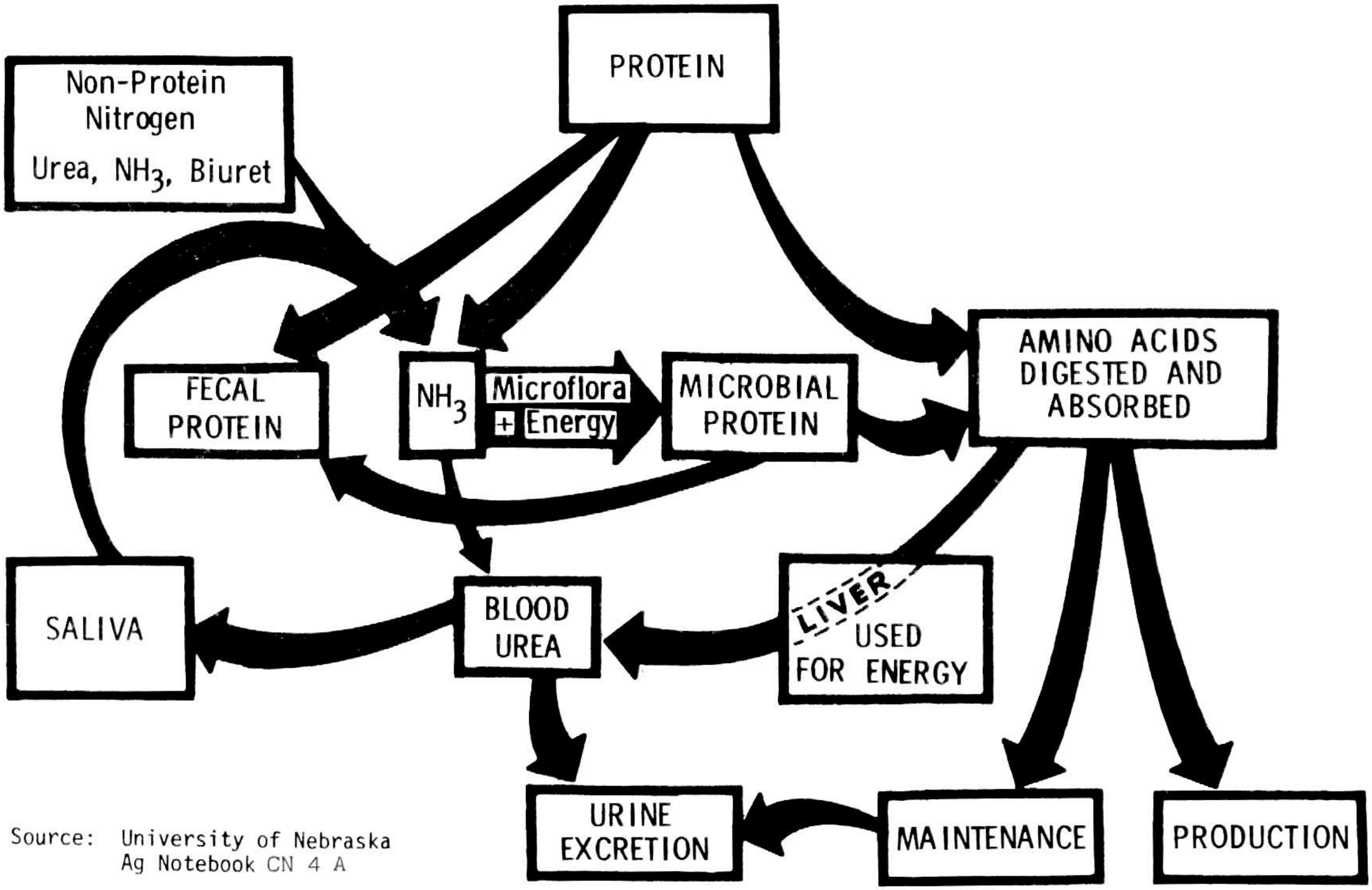
pounds of urea and 86.5 pounds of corn or similar cereal grain are equal in protein and energy value to 100 pounds of 44 percent protein soybean meal or similar oil meal protein supplement.

Utilization of Urea

The utilization of urea and other non protein nitrogen compounds is made possible by rumen microorganisms, the bacteria and protozoa. The generally accepted sequence of events in urea catalysis and subsequent synthesis are as follows: (a) microorganism urease in the rumen hydrolyzes urea to ammonia and carbon dioxide, (b) the ammonia nitrogen is combined with alpha-keto acids to synthesize amino acids, (c) amino acids are converted to microbial protein, and (d) the microbial protein is digested to amino acids further down in the digestive tract and there absorbed into the blood stream. Ruminal ammonia may also be absorbed through the rumen wall into the portal blood stream. Absorbed ammonia either donates its amine group for the synthesis of essential amino acids or is changed again into urea, part of which may be recycled back into the rumen by way of the saliva. Figure 1 illustrates the mechanism of utilization of nitrogen in the rumen.

The rate at which NH_3 (ammonia) passes through the ruminal wall depends on the concentration of urea being fed. When this is high, the rate of absorption may be greater than the liver can convert to urea. Ammonia then spills over into the bloodstream and when it reaches a certain level there, signs of toxicity appear (Lewis _et al_., 1957). The absorption of NH_3 is also influenced by the pH of the rumen ingesta

RUMINANT PROTEIN DIGESTION AND METABOLISM



Source: University of Nebraska
Ag Notebook CN 4 A

Fig. 1

(Coombe *et al.*, 1960). Part of the beneficial effect of feeding readily available carbohydrates with urea and other NPN compounds may be due to the fact that acids produced by their fermentation prevent a rise in the rumen pH, and thereby reduce the rate at which NH_3 leaves the rumen.

The NH_3 which passes out of the rumen is of little benefit to the animal other than that portion returned in the saliva.

One of the major problems in the efficient utilization of urea is the rapid release of ammonia. Bloomfield *et al.* (1960) indicated that urea hydrolysis occurred four times faster than uptake of the liberated ammonia and thereby resulted in an eventual loss of nitrogen available for microbial protein synthesis. If the rate of release were slower, ruminal ammonia could be converted more efficiently into microbial protein.

FACTORS AFFECTING UREA UTILIZATION

Carbohydrate Source

Adequate amounts of available carbohydrates are necessary for the synthesis of protein to take place when non protein nitrogen is fed. Adding urea to high starch rations appears to make the most efficient utilization of urea. Pearson and Smith (1943) showed the amount of synthesis depended to some extent upon the starch concentration or the type of carbohydrate added, being greatest with starch, galactose, and maltose with dextrin, glucose, glycerol and lactic acid having little effect.

Carbohydrates more complex than starch, such as cellulose, do not appear to be efficient sources of energy for protein synthesis from urea, probably because energy is not sufficiently available when needed by microorganisms. In spite of the overwhelming evidence in favor of starch, molasses has been employed more than any other carbohydrate in the co-feeding of urea (Bell et al., 1953). The reason for this choice is that molasses can serve a dual purpose, namely as a source of energy for the microorganisms and, secondly, it ensures a fairly slow intake because of its sticky syrupiness. For these reasons it is not surprising to find that urea is most efficiently utilized in finishing rations and least efficiently used as a protein replacement fed to cattle on winter range or fed other low quality roughages.

Arias et al. (1951), working with an artificial rumen, showed that six different sources of energy--starch, glucose, cane molasses, sucrose, cellulose, and ground corn cobs--all aided in the production of bacterial protein from urea. It was observed that small amounts of readily available carbohydrates aided cellulose digestion, which in turn increased urea utilization, whereas large amounts inhibited cellulose digestion.

Conrad et al. (1950) showed that certain microorganisms must be present in the rumen for the maximum utilization of cellulose. Rumen samples of cattle starved for 48 hours showed a decreased ability to ferment sugar and digest cellulose.

Burroughs et al. (1950) showed that many feeds influence rumen microorganisms in the digestion of cellulose. Dried distillers' solubles, soybean oil meal, and linseed oil meal seemed to be most helpful. Cane molasses, corn, wheat bran and cottonseed meal were next best.

In feeding, rations high in readily available energy encourage rapid bacterial multiplication in the rumen and this in turn results in more rapid assimilation of urea nitrogen into microbial protein.

Minerals and Vitamins

A ration may need supplemental minerals when a part of the protein has been replaced with urea or other NPN sources. This is not due to an increased need for these nutrients but it is possible that the content of these nutrients will be lowered due to the removal of a part of the protein supplement. Most of the high protein oil meals are high in phosphorus and relatively high in trace minerals.

Although sulfur, phosphorus, and an unknown number of mineral elements are required for ruminal synthesis of protein from non protein nitrogen, sulfur requirements have been given the most thorough study. Thomas _et al_. (1951a) found that methionine has been shown to be superior to either inorganic sulfate or elemental sulfur as a stimulatory substance in urea rations.

It has been shown that sulfur in the sulfate form is used by the rumen organisms of the cow to synthesize sulfur-containing amino acids. With rations low in sulfur, the addition of sodium sulfate may improve production and nitrogen retention in cattle (Jones and Haag, 1946).

Brown _et al_. (1960) added sodium sulfate and the alpha hydroxy analogue of methionine to urea supplemented rations for dairy heifers. They found the average gain for the control group was 72.4 pounds, while that for the group getting sulfur ranged from 84.6 to 97.7 pounds in a 90-day feeding trial.

Loosli and Harris (1945) showed that the addition of methionine to rations supplemented with urea increased nitrogen retention by lambs.

Albert et al. (1956) found that the addition of 0.2% elemental sulfur to certain modified urea supplements in silage wintering rations containing 0.12% total sulfur improved lamb gains.

Rations containing urea require sulfur supplementation only where a sulfur deficiency occurs in the co-fed feeds. It is probable that there is no significant difference between inorganic and organic forms of sulfur as supplements, and that where supplementation is necessary it should be effected by the cheapest available substance (Brown et al., 1960).

Burroughs et al. (1951) showed by artificial rumen technique that rumen microorganisms have varying requirements for sodium, potassium, calcium, magnesium, phosphorus, sulfur and chlorine.

Substances necessary for cellulose digestion were found in autoclaved water extracts of cow manure and in good quality roughages. These substances were found to be absent in poor quality roughages. Burroughs et al. (1949) concluded that the decrease in roughage digestion observed in the presence of corn starch could be explained on the basis of the mineral requirements of rumen bacteria. Poor quality roughage did not supply sufficient inorganic nutrients to support the starch-digesting and roughage-digesting organisms simultaneously, and since the former grew rapidly, the latter were depressed.

Several experiments conducted by Gallup et al. (1951) at Oklahoma were carried out to determine whether urea, when used as a substitute for protein in ruminant rations, affected the utilization of carotene and vitamin A. Blood plasma determinations made periodically on lambs to determine the amounts of vitamin A stored in the liver showed the lambs fed the rations containing cottonseed meal stored slightly more vitamin A than those fed the soybean meal rations. Partial replacement of either of these protein supplements by urea did not affect the efficiency of utilization of vitamin A. The vitamin content of the ration is not known to affect the utilization of urea except as it may affect the bacterial activity of the rumen and the general well being of the animal. Therefore, the vitamin content of the ration should be about the same whether or not urea is fed.

Tests conducted at the Oklahoma Experiment Station by Nelson et al. (1961a) indicated that the addition of trace minerals or dehydrated alfalfa meal to supplements containing urea did improve weight gains of steer calves.

Level of Dietary Protein

It is still unknown whether or not a small amount of preformed protein or amino acids is essential for utilization of NH_3 by ruminal bacteria. It does seem possible that some source of amino acids is needed, since several important species of ruminal bacteria require these for growth (Bryant, 1961), and many of the organisms which can utilize NH_3 as sole source of nitrogen require branched chain volatile fatty acids, which are normally derived from amino acids in the rumen. Only a certain number can grow in the absence of both amino acids and volatile fatty acids (Bryant, 1963). Whether these alone can maintain the normal functions of the rumen is questionable.

It has frequently been found that if the protein content of the feed is too high, NPN supplements are utilized poorly or not at all. This is explained on the basis that the protein alone provides more than sufficient NH_3 for the requirements of the bacteria.

Work done by Wegner et al. (1941) indicated that when the protein level in the concentrate mixture was above 18 percent, any added urea was poorly converted into protein. In like manner, the rate of conversion of urea nitrogen to protein in the rumen decreased as the protein level of the rumen ingesta became greater than 12 percent. Apparently at high levels of protein intake, even in the presence of a fermentable carbohydrate, the proteins themselves share or become prominent sources of nitrogen for the developing flora of the rumen.

Hamilton et al. (1948) found that the nitrogen of a ration providing 16.2% protein equivalent of which urea supplied 63% of the supplemental protein was not as efficiently utilized as that of a ration containing 11.4% protein of which urea provided 46%. These workers concluded that urea was a satisfactory source of nitrogen for growing lambs in most ordinary feeds, provided that the protein equivalent of the ration did not exceed 12%.

Rations that are low in readily available protein also favor urea utilization. This does not necessarily mean that urea should be added only to rations extremely low in protein, but indicates that rations approaching the necessary protein content will benefit little by adding urea.

Frequency of Feeding Urea

The importance of feeding a urea diet more frequently was demonstrated by Campbell et al. (1963a). Feeding a grain ration containing urea six times daily rather than twice daily resulted in growth and feed efficiencies similar to those obtained with animals fed a protein-supplemented diet. Feeding small quantities of urea at frequent intervals helped attain more comparable overall rates of urea hydrolysis and utilization of ammonia nitrogen resulting in a significantly higher rate of gain and improved feed conversion.

Briggs et al. (1947) also observed better utilization of urea when the same amount was fed twice daily rather than when fed once on alternate days.

Bloomfield et al. (1961) fed urea containing diets twice daily and sixteen times a day to sheep and concluded that the frequent feeding of urea resulted in increased utilization as measured by nitrogen balance and blood urea levels.

In effect, there is no optimum level of urea that will give satisfactory responses to benefits under all conditions. Generally accepted guidelines according to Campbell et al. (1963b) are: not more than one-third of the protein equivalent in the total ration or more than 1% urea in the ration dry matter.

Age of the Animal

The extent of development of the rumen and the bacterial population are related to the age of the animal. This undoubtedly influences the animal's ability to utilize urea. The usual period for the development of an effective flora in the rumen is from 6 to 12 weeks of age. The nature of the diet fed has a great influence on the development of a functional rumen (Flatt et al., 1958; Tamate et al., 1959). Normal mature-type rumen fermentation results in the synthesis of large quantities of B-complex vitamins (Conrad and Hibbs, 1954) as well as the formation of amino acids and good quality protein from ordinary sources (Loosli et al., 1949a).

An experiment by Loosli and McCay (1943) conducted at Cornell showed that 2-month-old calves fed a diet containing only 4.4% protein were unable to grow. When urea was added to the diet to give a calculated protein content of 16.2% (N x 6.25) calves increased in body weight and height at fairly satisfactory rates. The calves fed the basal diet were in negative nitrogen balance while those receiving the added urea were in positive nitrogen balance, retaining 24 to 36% of the dietary nitrogen. The apparent digestibility of the dry matter and carbohydrates of the basal diet was 57 to 63% while the dry matter and carbohydrates of the urea diet were 74 to 84% digested. It is interesting that calves as young as 2 months of age are able to make fair gains in weight when urea constitutes about three-fourths of the dietary nitrogen.

Lassiter et al. (1960) showed that calves can utilize urea to a small extent as early as 3 weeks of age.

Experiments in which urea provided from 40 to 70 percent of the nitrogen for dairy calves 4 months of age or older showed that body weight was gained at a rate of 82 to 88% of those calves fed rations supplemented with an equivalent amount of nitrogen from cottonseed meal, casein, peanut oil meal, soybean oil meal or tuna fishmeal (Reid, 1953a). Cereal grains and other high starch feeds composed one-third or more of the rations. Similar responses have been obtained with beef calves. In a few experiments, growing cattle fed urea gained as well as others fed common protein supplements, but from the great mass of data available, it must be concluded that urea is somewhat inferior to conventional protein supplements for growth.

Experiments in wintering beef cattle on dry native grass supplemented with 2 to 3 pounds of a pelleted urea feed gave inconsistent results. The small amount of readily available carbohydrate in such rations and the practice of feeding the supplements on alternate days as compared to twice daily, produced conditions unfavorable for most efficient utilization of urea nitrogen. Yearling and 2-year-old cattle were wintered more successfully than heifer calves under these conditions; in fact, the older cattle made gains similar to those of cattle fed an equivalent amount of protein supplied as oil meal (Gallup et al., 1953a).

METHODS OF FEEDING UREA

Purified Diets

Since protein will continue to be the nutrient most limiting in human diets, it may be economically unfeasible to feed large quantities of protein supplements to ruminants. Since many of the forages and waste product feedstuffs are very low in protein in comparison to the cereal grains, research is directed to the feasibility of feeding more than one-third of the protein equivalent in the total ration in the form of NPN.

Loosli et al. (1949b) and Thomas et al. (1951b) were able to maintain sheep in positive nitrogen balance for over 300 days on a purified ration containing urea, cellulose, cornstarch, glucose, lard, minerals, and vitamins, and to show the presence of all the essential amino acids in the rumen. As a result, purified diets have been formulated so that it is now possible to maintain ruminants on diets containing only NPN as a protein source for extended periods of time with reasonable performance.

Growing lambs fed purified diets containing urea as compared to isolated soy protein or casein on an ad libitum basis indicated that growth and feed efficiency were about 70% as good with an NPN source as with a protein source (Oltjen et al., 1962a; Matrone et al., 1965).

Further work by Oltjen et al. (1962b) indicated that reproduction was possible by cattle fed diets containing urea as the sole source of nitrogen. Gains and feed efficiency by the purified diet fed heifers were about 75% that of the heifers fed the natural diet. Bulls creep-fed the urea purified diet started at 14 days of age and weaned onto this diet at 84 days of age have later proven to be fertile.

Use of Energy Urea Combinations (Starea)

Because wintering rations of beef cattle lack available carbohydrates, it has been difficult to use urea effectively in such rations as a protein supplement. As a result, a urea product for ruminants called Starea, a starch urea product, was recently developed at Kansas State University by Bartley et al. (1968) in cooperation with the W. R. Grace Chemical Co. Starea was produced by mixing finely ground grains (corn, sorghum, barley, etc.) or other economical starch sources with a non protein nitrogen source. The material is processed by passing it through a cooker-extruder under moisture, temperature, and pressure conditions that cause the starch to gelatinize. Advantages of the process claimed are: slowing down urea hydrolysis in the rumen, increased synthesis of rumen microbial protein, reduction in urea toxicity, increased palatability, and a minimization of segregating urea in protein supplements.

To determine if Starea might be utilized as a protein supplement, 74 Hereford heifers were divided into two similar groups and wintered on native hay and fed a protein supplement of soybean oil meal, corn and molasses or a mixture of Starea (34% protein) and molasses. Both groups of heifers were implanted with 15 mg. of diethylstilbestrol pellets and were fed 1.5 lbs. of sorghum grain and 2 lbs. of the protein supplement daily. Native hay was available free choice. After 84 days on test, the Starea fed heifers made an average daily gain of 0.98 lbs. whereas the soybean oil meal fed heifers averaged 0.96 lbs. per day. No significant difference was observed between the two groups. Apparently, Starea served as a protein supplement under conditions usually considered unfavorable for urea utilization. Feeding the starch-controlled urea product to cattle lowered free ammonia in the rumen more than did feeding urea and unprocessed grain. The lowered ammonia concentration suggested nitrogen conservation because microbial protein synthesis increased when Starea was fed and the synthesized protein apparently was available to the host.

Restricting Urea Intake

Feeding urea in composite blocks restricts consumption and reduces toxicity risks since cattle must lick a solid block and intake at any one time is small. The inclusion of a high percentage of salt insures a slow intake of urea. The composite blocks generally contain phosphorus.

Altona et al. (1960), in South Africa, reported on the success obtained on summer grazing with a salt block containing 30% of the supplemental protein from urea fed to yearling steers. Urea increased consumption of a salt lick from 3 oz. to 6 oz. per head per day, while on test 40 days. At the beginning of the test the steers consumed very little of the block containing urea but as they became accustomed to the taste they ate more than the intended 3 ounces per head daily. The steers receiving the urea-molasses salt block gained more pounds per head than the steers receiving the salt block alone.

Richardson et al. (1958) studied the value of self feeding a mixture of blackstrap molasses, urea, phosphric acid and water as the protein supplement of beef cattle. Heifer calves were divided into three lots of 10 animals each. Animals in all lots received all of the sorghum silage they would clean up each day. The remainder of the ration was as follows:

Lot 1 - Free choice mixture, 77 percent blackstrap molasses, 3 percent phosphoric acid, 10 percent urea, and 10 percent water.

Lot 2 - Free choice mixture same as Lot 1 plus .5 pound soybean oil meal, and 1.5 pounds sorghum grain.

Lot 3 - Control, 1 pound soybean oil meal and 2 pounds sorghum grain.

Salt, steamed bonemeal, and limestone were fed free choice to all lots.

Results of the wintering phase of this test indicated no toxic symptoms were observed from self-feeding the urea, phosphoric acid, water and molasses mixture. Satisfactory gains were obtained on the silage and molasses mixture; however, the rate of gain was increased by adding soybean oil meal and grain to the ration.

Smith et al. (1957) studied feed intake and performance of steer calves wintered on bluestem pasture comparing self fed urea-molasses with molasses and soybean meal. The rations fed were as follows: (1) dry bluestem pasture, molasses and soybean meal, and (2) dry bluestem pasture and a urea-molasses mixture self fed containing 10 percent urea. Calves getting soybean meal gained 99 pounds per head while the self-fed urea-molasses steers gained 12 pounds per head. It was concluded from this study that apparently some additional source of protein other than that found in dry bluestem pasture and urea was necessary for calves.

PROBLEMS OF TOXICITY

Cattle, like all mammals, rid themselves of ammonia, the toxic end product of nitrogen metabolism, by synthesizing urea in the liver. The net reaction may be represented by the following equation:

$$2NH_3 + CO_2 \qquad (NH_2)_2CO + H_2O$$

Although endogenous urea is normally harmless and excreted in the urine, its introduction into the alimentary tract can cause poisoning.

Toxicity produced by drenching steers with solutions of urea, by forced feeding, and by withholding feed for 24 to 48 hours before offering urea feeds, has been reported from a few laboratories. Gallup et al. (1953b) could not produce chronic toxicity by feeding 500-pound steers as much as 1 pound of urea per day. The urea was fed in increasing amounts in a ration of 4 pounds of prairie hay, 3 pounds of corn, 6 pounds of molasses, and minerals over a period of 125 days. Acute toxicity was produced by withholding feed for 48 hours and then offering a mixture of corn, molasses, and urea in such amounts (2 to 3 pounds) that the animals consumed approximately 20 grams of urea per 100 pounds of body weight. Staggering, prostration, convulsions, and bloating were common symptoms. Blood ammonia values were elevated and the animals either died within a few hours or completely recovered.

It is almost impossible to compute the safety limits for any particular animal's urea dosage since the toxic dose depends not simply on species and body size, but on nutritional state, rate of feeding, and character of the whole ration. Reid (1953b) stated that cattle will rarely ingest a toxic quantity of urea because of its unpalatability, but nevertheless urea should not constitute more than 2% of the ration on a dry weight basis.

Warren (1962) and Coombe et al. (1963) pointed out that ammonia was most toxic in conditions of high pH. Yoshida and Nakumura (1963) also stated that ammonia absorption from the rumen into the blood was enhanced by a high rumen pH in the goat.

Many commercial urea-containing feeds are essentially urea molasses mixtures in either a solid or liquid form. Starch or sugars probably prevent urea intoxication, acting as a diluent and a source of acids, which match the ammonia produced and prevent rises in rumen pH (McNaught and Smith, 1947).

The major difficulty concerning the use of urea-containing protein supplements when poor quality roughages are fed concerns the rapid hydrolysis of urea and the danger of toxicity if an animal consumes too much of the feed within a short time. Whitehair et al. (1955) summarized those factors which increase the susceptibility of cattle and sheep to urea toxicity:

1. Animals which have never consumed urea appear to be the most susceptible.

2. Animals which have previously been consuming only low nitrogen roughages and are in a semi-starved condition will consume urea containing feed rapidly.

3. Individual animals within a herd which are aggressive and consume their feed rapidly are most susceptible.

4. Animals which have had previous access to urea will consume the diet slowly and will not consume enough urea to cause toxicity.

In general the amount of urea necessary to produce toxicity is approximately 20 grams per 100 pounds of body weight.

ROUGHAGE FEEDING EXPERIMENTS

Silage and Urea

Adding urea to a crop at the time of ensiling has the following advantages: (1) masks the undesirable taste of urea; (2) allows a more even intake of urea over the whole day and minimizes high levels of ammonia; and (3) takes advantage of automated silage systems.

The proper amount of urea suggested per ton of green chopped forage is 0.5-1.0% or 10 to 20 lbs. A combination of urea and ground limestone has been used. The addition of 0.5% urea would increase crude protein content by about 1.3% on an as fed basis or 4.5% on a dry matter basis (Hughes et al., 1967). The purpose of adding limestone was to aid the fermentation process. The activity of the anaerobes decreases as the pH goes below 4.5 and the silage keeping quality is lowered if the pH is above 4.8 (Langston et al., 1958).

It appears that urea should not be used as the primary source of nitrogen for supplementing corn silage (Tolman and Woods, 1967). Based on their results with Nebraska feeding trials, one-third and possibly two-thirds of the supplemental protein can come from urea. The remainder of the protein in the supplement should come from other natural protein sources.

Davis et al. (1944) observed that dairy cattle ate sorghum silage treated with 0.5% urea as well as untreated silage. At 1.5% urea, silage intakes were greatly depressed and there was complete refusal of silage treated with 2.5% urea.

Jordan *et al.* (1965), at Minnesota, showed that all-in-one (complete) rations based on corn silage can be quite satisfactory for wintering calves. Each trial compared four silage-protein treatments. The treatments were as follows:

Lot 1. Regular corn silage, ground shelled corn, and soybean meal fed as separate feeds.

Lot 2. Corn silage to which 1% urea and 4% molasses had been added at ensiling time, plus ground shelled corn at time of feeding.

Lot 3. Corn silage to which had been added at the time of ensiling 0.7% urea and 28.6% ground shelled corn.

Lot 4. Corn silage to which 4.8% soybean meal and 23.8% ground shelled corn added.

The following table shows the results of this trial.

Table 1. All-in-one silages for wintering calves (147 days).

Treatment	Corn silage	Corn silage urea molasses	Corn silage urea ground corn	Corn silage soybean meal ground corn
Lot No.	1	2	3	4
Initial wt. lbs.	447.6	447.5	447.8	447.8
Gain lbs.	216.7	206.5	240.7	243.1
Av. daily gain in lbs.	1.46	1.40	1.60	1.62
Daily feed lbs. of silage	14.03	14.03	19.65	19.65
Feed per 100 lb. gain of silage	961.0	1002.1	1228.1	1213.0
Total feed	1481.7	1512.0	1351.9	1336.3
Feed costs per 100 lb. gain	$14.73	$15.75	$12.67	$13.30

The addition of urea and molasses to the silage in Lot 2 provided slightly less protein equivalent and slightly more energy and produced weight gains comparable to the cattle in Lot 1. Neither urea nor soybean meal as an additive at time of ensiling had an advantage as is indicated from the similar weight gains in Lots 3 and 4. The lowest feed costs per 100 lb. of gain were obtained with the all-in-one silage which urea and ground corn were added (Lot 3). Previous studies at the Minnesota station in 1963 and 1964 indicated that all-in-one corn silage rations, supplemented with urea, urea and corn, or soybean meal and corn, produced satisfactory and efficient gains.

Essig (1968) summarized twenty-six different experiments for average daily gains of cattle fed silage treated with different levels of urea and limestone. In some comparisons protein supplements were added to the control silage at the time of feeding and then compared with the urea treated silage. Treating the corn material at the time of ensiling with urea or a combination of urea and limestone appeared to produce a silage that was utilized about 5% more efficiently than the non-treated silage.

Collins and Hogg (1965) measured the influence of additional source of protein on average daily gain. A three year summary indicated there was no benefit from adding additional nitrogen either in the form of urea supplement or cottonseed meal to silage which contained 0.5% urea at the time of ensiling.

Bentley <u>et al</u>. (1955), using lambs in metabolism trials, indicated that the apparent digestibility of the dry matter and non protein nitrogen in urea-corn silage and corn compared favorably with that obtained for corn silage supplemented with corn and soybean meal or corn and urea. Cellulose digestibility appeared to be slightly lower for the urea-corn silage.

Richardson *et al.* (1967) designed a trial which compared soybean oil meal and urea in wintering and finishing rations of steer calves. In the wintering phase of this trial, the steers were fed sorghum silage, 2 lbs. of average quality alfalfa hay, and either none, 3 or 6 lbs. of added sorghum grain. The amount of protein derived from urea was 39 percent. In this wintering phase, the calves receiving the urea supplement without added grain gained significantly less ($P < .05$) than other lots. When 3 or 6 pounds of grain was added per head daily to urea supplemented calves, gains were significantly greater than by calves on soybean meal without grain but not greater than by calves fed silage, grain, and soybean meal. It was indicated that urea was partially utilized with as little as 3 pounds of grain per head daily but added grain improved gains.

In summary, there appeared to be no difference in the average daily gain of cattle fed urea-treated silage or those fed silage supplemented with adequate protein. Cellulose digestibility appeared to be slightly lower for the urea-corn silage.

A slight increase in feed efficiency and daily gain has resulted in favor of the animals fed urea-treated silage versus silage without added protein.

The benefits of adding 0.5% urea to silages at the time of ensiling appear to be related to economics, since urea offers an opportunity for reducing costs without sacrificing any appreciable daily weight gains or losses.

The addition of 3 to 6 pounds of grain per head daily to a urea-ensilage diet improved gains significantly, when compared to calves fed soybean meal without grain. These gains were not greater by calves fed silage, grain, and soybean meal.

Dry Grass and Urea

In most cases it is necessary that range grasses be supplemented for cattle. These deficiencies are in general: protein, phosphorus and carotene (vitamin A). In addition, energy is usually needed to insure high reproductive performance in the case of cows and heifers.

Many years ago cottonseed cake was the standard supplement used by ranchers. Not only did it provide protein but it was an excellent source of phosphorus as well. In recent years, most cattlemen buy supplemental commercial protein to feed cattle on dry grass. The most popular is a 20% protein supplement usually containing some urea, fortified with phosphorus, and vitamin A and usually fed at the rate of 1 or 2 lbs. per day. Feeding of urea as a substitute for vegetable protein helps lower the cost of supplemental feed.

The protein and energy requirements of range cattle are dependent upon their age and the stage of their production. Mature cows have lower protein requirement and can eat more than a calf; therefore, it is more likely that they will come closer to getting their required protein from range forage.

Range grasses in mid-winter are high in crude fiber and low in readily available carbohydrates. Adequate amounts of available carbohydrates are required for the synthesis of protein from non protein nitrogen. Carbohydrates more complex than starch, such as cellulose, do not appear to be efficient sources of energy for protein synthesis from urea, because energy is not sufficiently available when needed by microorganisms.

Based on 16 trials involving 879 cattle, Nelson and Waller (1962) concluded that urea-containing supplements were not efficiently utilized by beef cattle wintered on dry bluestem range grasses. In these trials urea furnished one-third to one-half of the nitrogen contained in the supplement. The urea-containing diets were improved by the addition of trace minerals but animal performance was never as good as that of animals fed cottonseed meal.

Results of these 16 trials indicated that the urea to carbohydrate ratio was too narrow for good urea utilization and that supplements containing lower levels of crude protein and more starch or sugar were indicated. Table 2 shows the results of the 16 trials conducted at the Oklahoma Experiment Station.

For three successive years, Gallup et al. (1952) wintered yearling heifers on dry grass and protein supplements for periods of 100 to 148 days. One group of heifers was fed a cottonseed meal supplement and a corresponding group was fed a pelleted supplement containing 25 percent of the nitrogen from urea. Both supplements contained equal amounts of protein and these were fed every other day in amounts equivalent to 2.45

Table 2. Winter weight gains of cattle grazing native range.

	1 lb. 40% protein (no urea)	1 lb. 40% protein (1/3 of protein from urea)	1 lb. 40% protein (1/2 of protein from urea)	1 lb. 40% protein (1/3 of protein from urea plus trace minerals)
	lbs.	lbs.	lbs.	lbs.
Heifer calves (152 day gains)	- 5	-	-33	-
Steer calves (3 yr.)	27	-14	-	4
Steer calves (6 yr.)	34	6	-	-
Yearlings (2 yr.)	-19	-79	-	38
Winter gains	-331	-	-371	-
Calf weaning wt.	405	-	381	-

pounds per head daily. The average of the three trials showed a gain of 34 lbs. for the cottonseed meal fed heifers and 42 lbs. gain where the urea supplied 25% of the protein in the pellet.

In other trials, heifer calves were wintered on dry grass with cottonseed meal and urea pellets. The urea supplied 25% of the protein in the pellet. In still another test, two-year-old steers were wintered on native range grass and pellets for three successive trials. Results of these wintering trials indicate that steers and heifers fed the urea pellets wintered as well as those fed cottonseed meal. The level of protein supplement fed in these trials was quite high especially with yearling heifers and two-year-old steers, and it is possible that the natural protein in the urea pellets may have approached the minimum requirements of the cattle.

Nelson _et al_. (1961b) initiated tests for the purpose of determining if urea can be efficiently utilized by cattle wintered on dry range grass when it is added to a mixture of corn and cottonseed meal to produce a pellet containing 40 percent protein, with one-third of the nitrogen furnished by urea. In addition to free access to dry native grass, the calves were fed an average of two pounds per head daily of the following pelleted protein supplements with the following results:

		130 day gain in lbs.
Lot 1.	26% protein supplement	34
Lot 2.	40% protein supplement containing urea	30
Lot 3.	40% protein supplement	50
Lot 4.	26% protein combination supplement containing soybean oil meal, linseed meal, and cottonseed meal	56
Lot 5.	40% protein supplement containing urea	46
Lot 6.	40% protein combination supplement containing soybean oil meal, linseed meal and cottonseed meal	77

Gains were greater when the combination supplements were fed. Urea was not efficiently utilized by cattle wintered on dry range grass.

Ely and Duitsman (1968) studied the efficiency of urea and cottonseed meal utilization by wintering nursing cows on grass. Three lots of twenty cows each were placed on pasture. All cows had suckling two-month-old calves at their side. The cows were fed one of the following rations, once daily: (1) 3.2 pounds of a urea-sorghum grain pellet; (2) 3.7 pounds of cottonseed meal plus a sorghum grain pellet, or (3) 1.9 pounds of cottonseed meal pellet without grain. The urea-sorghum grain pellet contained 5.6% urea (which supplied 35% of the protein), 84% sorghum grain, 7% wet molasses, dicalcium phosphate and vitamin A. In addition to the supplemental protein, four pounds per head daily of poor quality alfalfa hay was fed.

All cows lost body weight during the 141 day trial. The sorghum grain-urea fed cows lost 75.7 lbs.; the CSM-sorghum grain fed group lost 79.5 lbs.; and the CSM and no grain group lost 88 lbs. Although weight losses were evidenced, they were not considered significant differences. It was concluded from these preliminary results that urea plus sorghum grain in a pellet may be fed efficiently to cows grazing dry mature grass in winter and nursing suckling calves.

In summary, any advantage from using urea in supplements comes through a reduction in the cost of the supplements being fed. In feeding trials under range conditions where dry native grass is deficient in protein, urea has not been found to be a satisfactory substitute for true protein under present supplementation methods. This is attributed to the lack of readily available carbohydrates, primarily starch. Cellulose, in the form of dry grass, does not appear to be an efficient source of energy for protein synthesis of urea because energy is not readily available when needed by the rumen microorganisms.

The addition of grain to urea supplemented diets fed to cattle on dry winter range grass has given some favorable but not conclusive responses. The questionable part of adding grain is how much to add and still be practical. If more than 4 pounds of a high energy grain is required (as stated by some researchers) to utilize urea on winter range, it would seem more practical to feed an all plant protein supplement.

Mature beef animals, more so than younger cattle, would seem to possess a greater ability to utilize urea, due in part to a more extensive developed rumen and resulting microorganism populations.

Hay and Urea

The feeding of hay and protein supplements is much like that of grazing dry native grass and feeding protein with the exception that the hay fed most frequently contains a higher percentage of crude protein and phosphorus. Hay is also lower in fiber content and contains other nutrients not in dry range grasses.

Nelson *et al.* (1957) compared cottonseed meal, cottonseed meal plus urea and urea plus trace minerals for heifer calves on a prairie hay diet.

Replicated lots of cattle were fed three different pelleted rations plus prairie hay. Rations fed were as follows:

Lots 1 and 2. 40% protein supplement, containing primarily cottonseed meal.

Lots 3 and 4. 40% protein supplement containing urea. Contained cottonseed meal, ground yellow corn, 5 percent urea (furnished one-third of the nitrogen in the pellet).

Lots 5 and 6. Same as lots 3 and 4 plus trace minerals.

In addition to the feeding of equal amounts of prairie hay daily, a mixture of 2 parts of salt and 1 part steamed bone meal, were fed free choice. Weight data for the replicated lots are summarized in Table 3. The heifers did not perform as well where urea was fed. The addition of trace minerals to a pellet containing urea and fed as a supplement with prairie hay apparently increased the utilization of urea only slightly, if at all.

To improve the utilization of urea fed with prairie hay, Smith *et al.* (1965) conducted a trial where the following trace minerals were fed: cobalt, iodine, copper and zinc. Urea or soybean oil meal and limited sorghum grain was fed with the hay.

Prairie hay and rolled sorghum grain were the base feeds in all of the rations. Lots 1 and 2 were fed prairie hay, 5 pounds of grain sorghum with and without added trace minerals. Lots 3 and 4 were fed prairie hay, .15 lbs. of urea and 4.85 lbs. of grain sorghum with and without added trace minerals. Lots 5 and 6 received a ration of prairie hay, 1 lb. of soybean oil meal, 4.0 lbs. of ground sorghum grain with and without added trace minerals. The amounts are in pounds per steer daily.

Table 3. Urea in protein supplements for wintering heifer calves fed prairie hay.

	Cottonseed meal supplement		Urea supplement		Urea supplement with added trace minerals	
	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6
Average weight per head (lbs.)						
Initial	448	448	448	448	448	439
Final	540	552	529	529	537	522
Gain	92	104	81	81	89	83
Daily gain	0.69	0.78	0.61	0.61	0.67	0.62

Lots 1 and 2 gained .76 lbs. without trace minerals and .88 lbs. with added trace minerals. Lots 3 and 4 fed urea had weight gains of 1.28 lbs. with no added trace minerals and 1.14 lbs. gain with added trace minerals. Lots 5 and 6 gained 1.66 lbs. without added trace minerals and 1.67 lbs. with added trace minerals. This trial shows that urea is utilized in a prairie hay and limited sorghum grain diet but less efficiently than soybean oil meal. The added trace minerals to the rations seemed to have little measurable effect on the steers.

Work by Bohman _et al._ (1954) indicated urea was not a good supplement for poor quality roughage diets. Animals receiving soybean oil meal rations, with corn or molasses, gained significantly more than the urea supplemented animals. Adequate synthesis of protein from urea did not occur in the urea rations.

Raleigh and Wallace (1963) studied the level of protein supplenent to feed with a meadow hay diet to determine what amount of urea could be used to replace the protein in a supplement. The hay fed in this trial to steers contained 5.5% crude protein on a dry matter basis. Urea, cottonseed meal and a mixture of urea and cottonseed meal were used to establish the desired levels of crude protein--6, 9 and 12 percent.

Urea and cottonseed meal, when used, were supplied in amounts so that 50% of the nitrogen came from urea and 50% from cottonseed meal. Salt and monosodium phosphate were mixed in equal parts and made up one percent of the diet. The hay was finely chopped, mixed along with the other ingredients and pelleted. Table 4 gives the daily gain of the animals fed at various levels of protein.

Two of the steers died and a third was removed from this experiment. A total of three steers died as a result of feeding the 12% crude protein diet containing urea. The differences in gains between the 6 and 9 percent protein level groups were highly significant ($P < .01$). The steers receiving an all CSM supplement gained more than those receiving urea alone or in combination with CSM at the 9 and 12 percent protein level.

The lesser response from steers receiving urea may have been partially due to the lack of available energy. Practically no additional energy was provided when urea made up the entire supplement.

In this trial, steers were hand-fed having access to their feed for approximately 8 hours a day. Ruminants make better use of urea when self fed rather than hand fed.

These data indicate that urea alone does not appear to be a suitable nitrogen supplement source to be fed with roughage, but urea in combination

Table 4. Daily gain of the animals at various levels of protein.

Diet	Crude protein %			
	5.5%	6.0%	9.0%	12%
Daily gain in lbs.				
Hay alone	0.27	-	-	-
Hay + urea	-	0.39	1.23	(died)
Hay + CSM	-	0.26	1.62	1.83
Hay + urea + CSM	-	0.41	1.35	1.51
Average	0.27	0.35	1.40	1.67

with cottonseed meal, while possibly not as good as cottonseed meal alone, was a satisfactory supplement.

In summary, cattle fed hay diets containing protein supplemented with urea, utilized the urea only partially. The feeding of urea and hay alone at a 12% protein level caused the death of three steers in the Oregon trial, indicating that urea should not replace more than 30-35% of the protein in the supplement.

The addition and feeding of limited grain indicated that urea utilization is improved but to a lesser degree than soybean meal and added grain. Trace mineral feeding had no beneficial effects when fed with hay diets containing urea or not containing urea.

The feeding of urea supplemented protein can result in lowered animal performance, especially in the feeding of roughages, but it can also produce economical gains. Levels of urea performance are increased with the addition of grain to the diet. The use of self-fed protein supplements for cattle have received widespread popularity in some areas with the development of protein blocks and liquid supplements.

Pasturing of Cornstalks Plus Urea

A cornstalk grazing trial with 800-pound heifers was initiated by Ewing et al. (1961) in which self fed protein blocks and a liquid protein supplement containing urea were compared. Dry cornstalks and missed ears supplied the entire grain and roughage diet for the two groups of cattle. The protein blocks of 32% crude protein contained: 43% soybean meal, 31% cottonseed meal, 10% molasses, 10% salt, 5% dicalcium phosphate and 1% trace mineral-vitamin A premix, and the liquid supplement of 30% crude protein contained: 70% molasses, 10% urea, 10% water, 3% phosphoric acid, 6% ethanol and 1% trace mineral-vitamin A premix.

The protein block self fed heifers gained 88 pounds during the 48-day pasturing period and the liquid-urea fed heifers gained 87 pounds during the same period. Weights gained were almost identical, indicating that urea was evidently utilized by the heifers. The liquid-urea self-fed group of heifers consumed 2 1/2 pounds of additional supplement per head daily compared to the protein block fed heifers. This increased consumption was three times the cost of the protein blocks making the per pound of gain costly. The stalk fields contained an abundance of corn which provided an adequate energy supply.

Summarizing the results of this trial, daily weight gains of 1 1/2 pounds are possible where heifers are pastured on cornstalk fields containing ample dropped ears and are supplemented with either urea containing liquid supplements or natural protein blocks. Urea was evidently utilized by the cattle grazing the stalkfields as evidenced from the similarity of gains made by both groups. Cost of gains made by the liquid-urea self fed heifers was greater compared to the protein block fed heifers.

Corn Cobs and Urea

Culbertson et al. (1949) showed that yearling steers gained 1 1/2 pounds per head per day fed a liberal ration of corn cobs supplemented with protein containing urea. As much as 14 pounds of corn cobs were consumed per head per steer daily. Results of this Iowa trial are summarized in Table 5.

Table 5. Iowa results feeding large amounts of corn cobs to yearling steers.

Feedstuffs (lbs.)	Corn cob rations		
	No. 1	No. 2	No. 3
Corn cobs fed per day	12.8	14.0	11.9
Alfalfa hay	2.5	2.5	2.5
Shelled corn	2.5	-	2.0
Molasses	-	2.5	2.5
Linseed meal	2.5	2.5	1.3
Urea	.2	.2	.35
Minerals and trace elements	.1	.1	.1
Average daily gains	1.55	1.62	1.64
Cost per lb. of gain (¢)	15.3	13.7	13.4

The level of urea fed varied from 1% to 1.7% of the total ration. Urea was evidently utilized in all three corn cob-urea supplemented rations. The protein fed in all rations would tend to indicate that adequate protein was already available without adding urea to it. Increasing the amount of urea fed in ration 3 reduced the cost per pound of gain compared to rations 1 and 2.

Corn cob rations must include, in addition to protein, (1) a readily available source of energy, molasses and/or cereal grain, (2) minerals, (3) vitamin A, and (4) unknown constituents generally found in good quality plant protein.

Ewing *et al.* (1962) conducted two trials in which corn cobs and urea supplements were fed in a beef cow wintering ration. A moderate (8.5 pounds of TDN daily) or a high (10 pounds of TDN daily) level of energy was fed to replicated lots of beef cows. This energy content was regulated by the quantity of corn silage fed.

In the first trial, the cows fed a moderate level of energy ration supplemented with soybean meal gained 105 lbs. while cows fed the high energy ration supplemented with soybean meal gained 153 lbs. The Modified Iowa Economy supplement, containing 10% urea in the supplement, was compared to soybean meal for efficiency of gains and reproduction. The Iowa supplement containing urea was formulated as follows: molasses (20%), urea (10%), dehydrated cob meal (57%), dicalcium phosphate (1 1/4%), monosodium phosphate (3.1%), ground limestone (3 3/4%), salt (2%), trace mineral mix (2 1/2%), and vitamin A premix (.67%). Cows fed silage and corn cobs supplemented with .14 lbs. of urea per head per day gained

99 lbs. fed the moderate energy ration, and 96 lbs. fed the high energy ration. All weight gains are based on 102 day feeding trial. Soybean meal-corn cob fed cows had heavier birth weight calves as compared with the urea supplemented cows but the results were not significant.

The second trial was conducted in a similar manner with the exception that the energy levels fed to replicated lots were reduced to 7.2 and 9.0 pounds of TDN per head daily for the moderate and high levels, respectively. In this second trial the moderate level fed cows gained 77 lbs. for the 102-day period and the high level fed cows gained 71 lbs. The cows fed the urea at the moderate level of TDN gained 55 lbs. while the high level urea fed cows gained 81 lbs. Calf birth weights were almost identical for both groups, averaging 71 lbs.

These results suggest the feasibility of using urea-containing supplements in beef cow wintering rations. It also appears that a 10 percent level of urea in the supplement is appropriate for both moderate and high energy rations in which ground corn cobs make up as much as 35 percent of the total dry matter.

Beeson and Perry (1951) conducted an experiment in which 1/3, 1/2 and 2/3 of the soybean meal protein was replaced with urea and fed with a corn cob ration to steers. Fourteen steers weighing 650 lbs. were divided into lots and fed the following experimental rations:

Lot 1. Purdue Supplement A - soybean oil meal, molasses feed, bonemeal, salt and vitamin A.

Lot 2. 1/3 of protein from urea, soybean oil meal, molasses feed, bonemeal, salt and vitamin A.

Lot 3. 1/2 of protein from urea plus above feedstuffs.

Lot 4. 2/3 of protein from urea plus above feedstuffs.

The steers were fed all the ground corn cobs they would eat daily. The experimental rations were then poured over the cobs. Table 6 gives the results of these trials and the rations fed.

Table 6. Wintering steers on corn cobs (175 days).

Lot No.		Daily feed (lb.)	Feed per lb. gain (lb.)	Gain per steer (lb.)	Daily gain (lb.)
1	Corn cobs	15.13	11.8	224	1.28
	Supplement	3.49	2.7		
2	Corn cobs	14.49	11.6		
	1/3 protein from urea	4.28	3.4	219	1.25
3	Corn cobs	14.63	12.8	200	1.14
	1/2 protein from urea	4.66	4.1		
4	Corn cobs	14.60	12.5	204	1.17
	2/3 protein from urea	4.96	4.3		

Summarizing the feeding results of corn-cob-urea investigations, it can be assumed that urea may be used to supply 1/3 to 2/3 of the supplemental protein for growing calves when additional energy is supplied to compensate for the energy of protein supplement replaced by urea. More feed per lb. of gain was needed as urea was increased. Additional energy was needed to compensate for that of the protein supplement replaced by urea. Cows too can be wintered on a free choice corn cob diet supplemented with urea provided that a source of energy either in the form of cereal grain, molasses or grain contained in silage. Any of these sources are satisfactory energy feeds.

Stalklage and Urea

Designed for feeding minimal amounts of costly protein by making use of urea as a substitute in the protein fed, Burroughs et al. (1952) compared the feeding of three supplements namely, Purdue Supplement A (containing soybean meal), Iowa I (urea replaces 1/4 of protein), and Iowa II (urea replaces 1/2 of the protein). Three lots of 8 steers averaging 750 pounds were fed a daily ration of 10 pounds of cornstalks, 2 pounds of hay, plus corn and supplement. The daily ration fed and and pounds per head per day gained were as follows:

Lot 1. Purdue A plus 4.5 lbs. of corn - gained 1.73 lbs.

Lot 2. Iowa I (1/4 urea) plus 6.9 lbs. of corn - gained 1.65 lbs.

Lot 3. Iowa II (1/2 urea) plus 5.9 lbs. of corn - gained 1.61 lbs.

There were no significant differences in gains made on different supplements; however, the Purdue A supplement fed cattle gained slightly faster than the urea fed cattle. Feed required per 100 lbs. gain was as follows: Purdue A (1198 lbs.), Iowa I (1244 lbs.), and Iowa II (1273 lbs.). Although feed requirements were greater compared with Purdue A, the cost per pound of gain was cheaper where Iowa I and II urea containing supplements were fed.

Using cornstalk silage supplemented with protein of which approximately 1/3 of the protein was provided by urea, Burroughs et al. (1955)

found that beef heifers not only made satisfactory gains but did it economically. In this trial, no attempt was made to compare feeding trials with an all protein ration only to attempt weight gains of 1.25 to 1.50 lbs. per head per day.

Three lots of heifers each weighing approximately 400 lbs. were full fed a diet of cornstalk silage and four and a half pounds of a urea-protein corn supplemental mixture per head per day for 140 days. The cattle of the three lots gained an average of 1.25 pounds at an economical feed cost. Although a control lot fed protein was absent, it must be assumed that urea was utilized as the gains were satisfactory.

Since 1963, Albert et al. (1967) studied methods of supplementing cornstalk forages for wintering beef cows. The National Research Council recommends 7.5 percent crude protein in wintering rations for mature beef cows. In this trial either urea or biuret was added to formulate a 11 percent crude protein ration. Approximately 25 pounds of either urea or biuret were added per ton of forage. The lot of 10 cows fed urea treated stalklage for the 50-day period gained 11.2 lbs. and consumed 39 lbs. per head per day while the biuret treated silage fed cattle gained 10 lbs. and consumed 46 pounds of stalklage per day.

Perry et al. (1958) compared the value of Purdue Supplement A (32% crude protein) with a high urea supplement (58% protein) fed on an equivalent protein and energy basis for cattle wintered on cornstalk silage. In order to make the supplementation equivalent in protein and energy, it was necessary to feed 1.5 lbs. of the high urea supplement plus 1.5 lb. of corn--a total of 3.0 lb.--to be equivalent to 3.0 lb. of Supplement A. Purdue A contains soybean meal and dehydrated alfalfa meal in the main.

The four lots of steers averaging 561 pounds were fed as follows:

Lot 1. Cornstalk silage ad libitum plus 1.5 lb. high urea supplement, 1.5 lb. ground shelled corn and minerals free choice.

Lot 2. Cornstalk silage ad libitum plus 3.0 lb. Purdue A and minerals free choice.

Results of the 133-day feeding trial and the rations fed are shown in Table 7.

Table 7. Comparison of Purdue Supplement A with a high urea supplement on cattle wintered on cornstalk silage.

	Lot 1 Cornstalk silage + high urea supp.	Lot 2 Cornstalk silage + Purdue Supp. A
Gain per steer (lb.)	65.0	89.0
Average daily gain (lb.)	.55	.75
Silage fed per 100 lbs. gain (lbs.)	5787	4154
Cost per lb. of gain (¢)	32.5	26.4

These results indicate that cattle fed a high urea supplement (58%) gained significantly less than steers fed a 32% Purdue Supplement A and it required more feed per pound of gain.

In summary, feeding cornstalk silage to cattle has been shown to be an economical method of increasing weight gains especially where urea has been fed as a part of the supplemental protein. Gains of 1.25 to 1.50 lbs. per head per day can be anticipated in a wintering feeding program. Not more than 1/3 of the protein should consist of urea.

Adding grain to the diet, seemingly improves the weight gains of cornstalk silage urea supplemented cattle.

Beef cows fed urea supplemented cornstalk silage increased their weight but more important they apparently utilized urea satisfactorily.

SUMMARY

Fundamentally, the economy in feeding ruminants is based upon taking full advantage of the rumen function, with particular emphasis on the digestion of roughages and the synthesis of high quality proteins from low quality protein such as urea, a non protein nitrogen substance.

Utilization of non protein nitrogen is made possible by the bacteria in the rumen of cattle and sheep. Frequently referred to as "bacteria synthesis of protein", this process involves urea being broken down into ammonia and the ammonia being combined with carbohydrate fragments to form protein in the bacterial cells.

Part of the ammonia, NH_3, produced in the rumen is used by the bacteria for synthesis of cell constituents; part is absorbed through the ruminal wall into the portal blood stream, and part passes out of the rumen into portions of the lower gut.

The ability of ruminal bacteria to utilize NH_3 depends upon the readily-available carbohydrate contained in molasses and cereal grains; a relatively low level of natural protein supplemented in the diet, and minerals. When glucose or starch are added to the diet, the uptake of NH_3 by the bacteria is much more rapid than when roughage alone is present.

Feed grade urea may contain 42 or 45 percent nitrogen and furnishes 2.62-2.81 pounds of protein equivalent (6.25 x .42). Urea itself contains no protein only nitrogen. Urea is the most common of the non protein compounds used in ruminant feeding. Urea has limited use in rations low in protein and high in roughages because of the small amount that may be added and not exceed more than one-third of the protein coming from urea.

Based on sixteen trials with 879 cattle, Oklahoma researchers concluded that urea-containing supplements were not effectively used by beef cattle wintered on dry bluestem pasture, where urea provided 1/3 to 1/2 of the nitrogen in the supplement. This poor utilization of urea has been attributed to the lack of readily available carbohydrates such as starch. Carbohydrates more complex than starch, such as cellulose, do not appear to be efficient sources of energy for the protein synthesis from urea.

In wintering trials with weanling calves pastured on dry bluestem range, a urea molasses mixture was found to be unsatisfactory as the sole source of supplemental nitrogen. The addition of trace minerals has improved urea utilization in some cases.

Feeding trials with steers and heifers have indicated that urea was utilized in a prairie hay and limited sorghum grain diet but less efficiently than to soybean meal. Urea alone does not appear to be a suitable nitrogen supplement source to be fed with hay, but urea fed in combination with cottonseed meal, while not as good as cottonseed meal alone, was a satisfactory supplement. The addition of trace minerals to a hay and urea pellet seemed to have little measurable effect on steer gains.

Gains of 1 1/2 pounds per head per day have been obtained in feedlot trials when properly supplemented urea-corn cob diets are fed to yearling steers. Cows fed soybean meal-corn cob diets had heavier calves at birth than urea supplemented cows but the results were not significantly different where urea supplements were fed. The higher levels of energy produced greater gains with cows.

Heifers full fed cornstalk silage supplemented with 4 1/2 pounds of a urea-corn mixture per head per day gained 1.25 pounds. Yearlings fed the same ration gained 1.75 pounds. An average of 22 lbs. of cornstalk silage was consumed per head per day in making these gains. Again, it was shown that urea should not replace more than one-third of the protein in the concentrate part of the ration where cornstalk silage was the main roughage fed. A depression in efficiency of gain from feeding excessive amounts of urea was demonstrated.

Yearling cattle self fed a liquid molasses-urea supplement, while grazing cornstalk fields gained as well as those self fed free choice protein blocks without urea. Dropped ears of corn provided a readily available energy source for urea utilization.

Results of trials in Kansas with silage-urea fed cattle indicated that urea was partially utilized with as little as three pounds of grain per head per day but added grain improved gains. Urea should not be used as the primary source of nitrogen for supplementing corn silage when no additional grain is fed. The optimum level of urea for a corn silage ration was indicated as not more than 1/3 of the supplemental protein needed in a ration based upon rate of gain and feed required per unit of gain.

In conclusion, the true value of urea in ruminant feeding has not yet been completely assessed. The challenge is to develop an efficient, absolutely safe, high-level urea supplement at reasonable cost to supplement poor quality roughages for maintenance and production feeding of ruminants.

ACKNOWLEDGMENTS

The writer of this report wishes to express his sincere appreciation to his major advisor, Dr. Ed F. Smith, Professor in Animal Science and Industry, for his assistance, guidance and counseling.

Appreciation is also expressed to Wendell Moyer and Herman Westmeyer, Livestock Extension Specialists, for their interest, encouragement, and suggestions in the writing of this report.

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UTILIZATION OF UREA BY CATTLE FED LOW QUALITY ROUGHAGE DIETS

by

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AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1969

The ruminant uses as raw material a high proportion of coarse fibrous plants not suited to the diet of other animals. It employs fermentation in breaking down the structural parts of the plants to liberate and concentrate the more valuable nutrients contained therein adding to these nutrients growth factors not originally present.

The most common source of non protein nitrogen (NPN) used in ruminant rations is urea. Many other products have been used experimentally and commercially, but most of them do not compare favorably to urea because of greater toxicity, higher cost or lower palatability.

Many studies have shown that urea-containing rations are best utilized by ruminants when they are well mixed to avoid toxicity and contain large amounts of readily available carbohydrates and/or self fed.

Urea contains no protein, only nitrogen. Feed grade urea contains 42 or 45 percent nitrogen and furnishes 2.62 or 2.81 pounds of protein equivalent (42 x 6.25). Through a process of microorganism activity in the rumen, ammonia is released and along with carbon fragments, provided by carbohydrates, microbial protein is produced. The microbial protein is then utilized by the host ruminant. Carbohydrates more complex than starch, such as cellulose, do not appear to be efficient sources of energy for the protein synthesis from urea.

In diets containing ample starch, urea can safely replace a quarter or a third of the dietary protein required in the ration. Low levels of available protein favor urea utilization whereas the presence of large amounts of highly soluble and easily hydrolyzable protein in the diet depresses urea utilization.

Tests have indicated that urea is apparently not efficiently utilized by cattle wintering on dry range grass when it is added to a mixture of corn and cottonseed meal to produce a pellet containing 40 percent protein with one-third of the nitrogen furnished from urea. The addition of trace minerals or dehydrated alfalfa meal to the pellet improved urea utilization.

Satisfactory gains, 1 1/2 pounds per day per head, have resulted where properly supplemented urea-corn cob diets were fed to yearling cattle. Cows apparently are capable of utilizing urea with corn cobs but not as efficiently as with soybean meal.

Cornstalk silage supplemented with urea (not more than 1/3 of the protein equivalent in the supplement from urea) plus added grain resulted in gains of 1.25 lbs. for heifers and 1.75 lbs. for yearlings. More urea than this has reduced gains.

Pasturing of cornstalk fields by cattle supplemented with a liquid molasses 10 percent urea mixture self fed has proven successful but costly, because of the excessive consumption of the supplement.

Results of Kansas trials with silage-urea fed cattle indicated that urea was partially utilized with as little as three pounds of grain per head per day with not more than 1/3 of the supplemental protein coming from urea.

Urea has a limited use in rations low in protein and high in roughage because of the small amount that may be added and still not exceed more than one-third of the protein equivalent in the supplement.

A starch urea combination product (Starea) recently developed to overcome the problem of inefficient conversion of urea-nitrogen to protein, toxicity and palatability suggests new horizons for use of urea with low quality roughages.