LEVEL OF ENERGY FOR THE EFFICIENT UTILIZATION OF UREA

by

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B. Sc. (Hons), University of Ibadan, 1965

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Husbandry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1967

Approved by:

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INTRODUCTION

Work with non-protein nitrogen in ruminant rations was started in the latter half of the last century. Weiske, Schrodt and Dangel (1879), as a result of nitrogen balance studies with sheep, showed that asparagine could be used to maintain nitrogen equilibrium in sheep. It was known that carbohydrates and fats must be present in the ration to provide principally energy and protein to replace the tissues which are constantly broken down. The latter fact gave rise to the concept of nitrogen equilibrium. For a long time there was controversy among research workers as to whether non-protein nitrogen compounds could replace partly or wholly the protein portion of an animal's ration. The independent works of Hagemann and Zuntz (1891) gave some indications that ruminants convert non-protein nitrogen to protein nitrogen, the conversion being mediated through the microorganisms of the rumen. Although Voltz advanced the idea in 1919 that urea could be used to replace protein in the ruminant's ration, direct evidence for the conversion of urea nitrogen to protein nitrogen was not obtained until many years later when more refined research techniques were developed.

The interest developed by animal nutritionists in the use of non-protein nitrogen as a substitute for part of the protein in ruminant rations may be explained in a number of ways. From a nutritional point of view, protein is the most likely nutrient to be deficient under the conventional methods of feeding. From an economic standpoint, protein is the most expensive of all the nutrients, and coupled with this is the fact that competition for protein between man and farm animals is becoming more and more acute as the world population increases at a tremendous rate. In regions of the world where protein shortage is very critical, feeding urea to ruminants would be of the greatest nutritional and economic advantage. As Jennings (1952) pointed out, in addition to its use as a protein substitute, urea can be considered an extender of the feed supply. Urea would permit greater utilization of such feeds as corn cobs, straw and stover. Urea can thus increase the total quantity of animal products available for human food.

The experimental work carried out on urea was concerned with its value for growth, lactation, meat and wool production. Though the literature indicates variations in the results obtained, it can be seen that under certain feeding conditions urea has definite value as a replacement for protein in the ruminant ration. A lot of the variations obtained may be accounted for by the fact that the nitrogen level fed was above the requirement of the animal. Also, many of the earlier workers did not seem to fully realize the need for readily available carbohydrates, other nutrients like sulfur, age of animal, frequency of feeding, etc. are important factors in the efficient utilization of non-protein nitrogen by the rumen microorganisms.

The purpose of this study was to determine the level of energy, as grain, required for the efficient utilization of urea.

LITERATURE REVIEW

Research on the utilization of non-protein nitrogen by ruminants has been based on the fact that non-protein nitrogen is converted to ammonia by urease in the rumen. The ammonia is then utilized for the synthesis of microbial protein. In the true stomach and the small intestine, the microbial protein is broken down to amino acids and absorbed. This has been proven beyond any doubt, the evidence being based on nitrogen balance studies, growth, milk production, body composition, and decreased rumen ammonia followed by an increase in rumen protein. The most conclusive evidence, however, came from Watson's studies with urea labeled with isotope N^{15} in 1949.

Urea in Sheep Rations

Nitrogen Balance Studies. In nitrogen balance studies with sheep weighing 50 to 80 pounds, Harris and Mitchell (1941) showed that nitrogen equilibrium (for maintenance) and nitrogen retention (for growth) could be produced by feeding sufficient amounts of urea. The data obtained are summarized in Table 1.

Table 1. The value of urea in the synthesis of protein in the rumen of sheep.

Ration	Protein percent	Urea percent	Percent N as urea N	N stored per day (g.)
Basal	5.35	----	----	----
2	8	0.93	34	1.42
3	11	1.88	50	2.35
4	15	3.16	62	2.60

Loosli et al. (1949) working with sheep showed that the ten "essential" amino acids are synthesized in ruminants fed urea as the only dietary source of nitrogen. Coombe and Tribe (1963) carried out three experiments with sheep to investigate the effect of urea, added to a diet of straw plus molasses, on roughage intake and digestion and on the nitrogen status of the animal. Urea added to straw and molasses at the level of 3 percent of the amount of straw increased the ad libitum food intake, rate of cellulose digestion in the rumen, and the rate of passage of food through the gut. The highest level of intake, rate of cellulose digestion, and rate of passage occurred with 8-16 g urea per sheep per day. The authors also found that under the feeding conditions of their experiments, once a sufficient amount of urea had been added to the diet to bring the animal into a small positive nitrogen balance, additional dietary nitrogen supplied as urea was practically all excreted in the urine. So it was concluded that under these feeding conditions, the primary function of a urea supplement is to enable the animal to maintain nitrogen equilibrium rather than to store significant amounts of nitrogen in the body.

Gallup, Pope and Whitehair (1952) studied the value of supplemental nitrogen added as urea to different basal rations containing about 7 percent protein in a series of digestion and nitrogen balance trials with sheep. The data given in Table 2 were obtained.

The results indicated that the addition of urea to basal rations containing either cottonseed meal, soybean oil meal or corn gluten meal to form rations containing about 7 percent crude protein resulted in about the same amounts of nitrogen being retained by lambs. Without the urea supplementation, however, the amounts of nitrogen retained were lower.

Table 2. The value of supplemental nitrogen added as urea to different basal rations containing about 7 percent protein.

	Cotton-seed meal (basal)	C.S.M. basal + urea	SBOM (basal)	SBOM basal + urea	Corn gluten meal (basal)	C.G.M. basal + urea
No. of lambs	8	7	6	6	7	7
Av. wt. lamb (lb.)	67	68	69	69	67	69
N retained (g)	7.73	10.67	7.73	10.68	7.72	10.62

As a result of their nitrogen balance studies with Rambouillet sheep, Harris, Work and Henke (1943) concluded that nitrogen equilibrium or nitrogen retention could be produced by feeding sufficient amounts of non-protein nitrogen. They showed that nitrogen equilibrium may be maintained on 202 mg. urea nitrogen per kg. of body weight daily. The authors noted considerable variation in the conversion of urea at the same level of intake.

Hamilton, Robinson and Johnson (1948) used growing lambs as experimental animals to compare the utilization of the nitrogen of urea with that of some feed proteins. They obtained the following results from nitrogen balance studies: the nitrogen in a ration containing 16.2 percent protein equivalent, 63 percent of which was from urea, was less efficiently utilized than that in a ration containing 11.4 percent protein equivalent, 46 percent of which came from urea. The workers also found that the nitrogen of urea was as well utilized as was the same amount of nitrogen from feeds like dried skimmed milk, casein and gluten feed, provided that the protein equivalent in the ration does not exceed 12 percent and at least 16 percent of the total nitrogen in the ration is in the form of pre-formed protein.

Feeding Trials With Sheep. Pope and his associates (1952) working with urea and cottonseed meal as supplements for lamb-fattening rations, fed urea at the levels of 10.03 and 12.15 g. of urea nitrogen per lamb daily. The lambs were 4 months old and had an average weight of about 56 pounds. The feeding period covered 99 days.

Table 3. Comparison of urea and cottonseed meal as protein supplements for lamb-fattening rations.

	Basal	Urea	Urea	CSM
No. of lambs	12	12	11	12
Av. daily ration, lb.				
Corn	1.58	1.56	1.54	1.56
Cottonseed meal	0.125	0.125	0.125	0.29
Dried beet pulp	0.17	0.17	0.17	0.17
Prairie hay	0.87	0.87	0.88	0.87
Urea N (g.)	---	12.15	10.03	---
Av. daily gain, lb.	0.37	0.37	0.37	0.40

Data in Table 3 shows that addition of urea to the basal ration made no significant difference in average daily gain. This indicates that the basal ration supplied all the nitrogen requirements of the animals.

Watson et al. (1949) used sheep to study the nutritive value of urea as a protein supplement. The control animals received the required TDN but only 1/2 to 1/3 of the maintenance requirement for protein. The sheep were given an average basal ration of 25 percent oat straw, 42 percent turnip, 5 percent apple pomace, 2 percent flax bolls, 6 percent oat hulls, 6 percent corn meal, 10 percent corn starch and 4 percent corn oil. Practically no growth was made in 40 weeks while the animals fed urea made an average gain of 0.18 pound per head daily.

One of the most conclusive evidences in support of synthesis of protein from non-protein nitrogen sources in the rumen was the results of work by Watson and his associates (1949). In their work, low-nitrogen diets supplemented with N^{15} labeled urea were fed to sheep for 4 days, after which time the sheep were sacrificed and quantities of N^{15} in the protein and non-protein fractions of the kidneys, liver and blood were measured. Since the quantity of N^{15} in these body proteins exceeded that found in the body proteins of similar sheep not fed urea, it was concluded that urea nitrogen was utilized in the formation of body proteins by ruminants.

Williams, Morrison and Klosterman (1946) carried out feeding experiments with Western lambs to determine the value of 0.00441 lb. added sodium sulfate. The rations consisted of 0.062 lb. urea, 0.3 lb. cane molasses, 3.5 pounds of corn silage and 1.06 pounds corn with and without added sodium sulfate. The lot which received sodium sulfate gained 0.273 pounds daily while the lot without sodium sulfate gained 0.257 pounds daily. This difference may be important considering the small amount of urea given to the animals.

Starks and his associates (1952) studied the effect of elemental sulfur on the utilization of urea nitrogen by growing lambs on a purified diet. The ration contained 0.062 percent sulfur, 41.4 percent starch, 24.5 percent cellulose, 10.0 percent wood flock, 10.0 percent wheat straw, 5 percent mineral mixture, 3.0 percent corn oil, 2 percent gelatin, 0.1 percent choline and vitamins A, D, E, thiamine and riboflavin. A second ration was the basal ration plus 3 grams of elemental sulfur per pound of feed (0.705

percent sulfur). The feeding trial was conducted for 90 days. Nitrogen balance and sulfur balance were obtained at three periods throughout the trial. The lambs receiving sulfur retained more of the dietary nitrogen than did the lambs receiving the basal ration. The following symptoms were observed in the sulfur deficient lambs: poor appetite, loss of wool, cloudy eyes, profuse salivation, weakness and death.

The results of the last two experiments suggest that sulfur is required for urea utilization but only a small amount is needed for the synthesis of the sulfur-containing amino acids.

Urea in Cattle Rations

Growing Cattle. Loosli and McCay (1943) investigated the utilization of urea by young calves. Calves just removed from milk feeding were used in this study. The basal ration was composed of 20 percent yellow corn, 30 percent chopped timothy hay, 37 percent corn starch, 10 percent cane molasses, 2 percent bone meal and 1 percent salt. The basal ration contained 4.4 percent protein and the urea ration 16.2 percent protein. The 2 calves on the basal ration failed to grow and were in negative nitrogen balance, losing 4.7 and 9.5 g. of N daily during the 10 day test period. In contrast, the calves fed urea were in positive nitrogen balance, retaining 11 and 17.9 g. N daily.

Lassiter et al. (1958) carried out a series of studies to investigate the effect of high level urea feeding, with and without sulfur supplementation, on the growth and metabolism of growing dairy heifers. Three levels of urea, 3.0, 5.0 and 7.0 percent of the grain ration, were fed. Without sulfur supplementation the level of urea in the ration did not significantly affect nitrogen retention or the blood serum levels of urea nitrogen. With sulfur supplementation, the blood serum levels of non-protein nitrogen increased and the levels of serum proteins decreased as the intake of urea increased above 3 percent. The authors pointed out the possibility of a sulfur deficiency in a ration containing 5.0 and 7.0 percent urea. It should be noted, however, that seldom do we feed 5.0 percent or higher levels of urea. Sulfur supplementation improved the utilization of rations containing more than 3.0 percent urea.

Colovos et al. (1963) investigated the role played by urea in the utilization of fiber by young dairy heifers. Two types of concentrate mixtures, a low-fiber and a high-fiber, which contained 4 levels of urea, were fed together with field-cured hay. The levels of urea were 0, 0.5, 1.0 and 2.0 percent of the concentrate mixture. The results of the experiment showed that without urea the low-fiber rations were generally superior to the high-fiber rations in digestible energy and total digestible nutrients. But when the level of urea in the concentrate mixture was increased to 2.0 percent, the high-fiber ration was comparable in nutritive value to the low-fiber ration. The authors attributed this effect of urea to a decrease in the heat increment of the ration as the level of urea in the ration was increased.

<u>Lactating Cattle</u>. Archibald (1943) worked with 4 Holstein cows to investigate the effect of urea feeding on milk production. Roughages used were of fair quality hay from mixed grasses. Corn silage, dried beet pulp, molasses and concentrates were used. Urea provided 42.7 percent of the nitrogen in the concentrate. There were no significant differences observed between the length of the lactation and the dry period. Reproductive

performances were comparable. Blood urea values of 2 cows not fed urea averaged 25.7 and 19.4 mg. percent while the blood urea values of the two cows fed urea averaged 25.5 and 20.7 mg. percent at the same time. In the milk of cows fed urea, the urea values averaged 25.9 and 26.1 mg. percent while the urea levels in the milk of cows not fed urea averaged 25.9 and 26.3 mg. percent.

Owen, Smith and Wright (1943), in milk production studies, worked with 7 Ayrshire cows of average milk yield in a series of tests. The maintenance ration provided 5.5 pounds of starch equivalent, 0.5 pounds protein equivalent per 1,000 pounds live weight. The nitrogen balance data obtained showed that the urea fed to the experimental animals was partially retained by all the animals. The milk urea level closely approximated that of the blood and never exceeded 28 mg./100 ml., an amount that would have no deleterious effect on the milk consumer.

Rupel et al. (1943) compared the values of urea and linseed meal for milk production by Holstein cows. The basal concentrate mix of yellow corn, oats and bone meal contained 10 percent protein and the supplemented concentrates contained 18 percent protein. Corn silage and timothy hay comprised the roughages. The weights of calves born by cows on the two rations (urea and linseed meal) were comparable, which may indicate equality of the two rations. The milk produced was normal in composition and flavor. The urea level in the milk of cows fed the urea ration ran from 0.011 to 0.015 percent, which is normal. The blood urea level for the basal group averaged 14.5 mg. percent, for one urea lot 16.9; and for the second 18.8, and for the linseed meal group 19.3. Blood protein levels were comparable. Thus, the only way these values can be explained is to assume that the non-protein nitrogen in the ration was converted to protein. The same workers (Rupel et al., 1943) found that there was greater milk production when urea was used with yellow corn than when corn molasses was the only source of readily available energy.

As a result of work with Holstein cows under Hawaiian conditions, Willett, Henke and Maruyana (1946) came to the conclusion that the dairy cow is able to utilize urea nitrogen in the production of milk, but not so efficiently as nitrogen entirely derived from plant sources.

From the results of work done on urea, it appears that no constant value can be assigned to the protein replacement value of urea in dairy cattle rations, probably because of the numerous factors that appear to control its utilization. Since urea has no energy value for animals, the literature indicates that for every 1.0 pounds of urea fed about 10 pounds of concentrate should be fed along with it for maintenance and for milk production in a lactating cow. This amount should raise the protein equivalent of cereal-grain concentrates for dairy cows from about 9 percent to about 18 percent.

Finishing Cattle. Bell et al. (1951), in a series of digestion and nitrogen balance trials with steers, investigated the value of urea as a source of nitrogen in rations containing different carbohydrate feeds. The carbohydrate feeds used in formulating the different rations were ground yellow corn, dehydrated sweet potatoes, cracked nuts, rolled barley, and cane molasses. Each of these feeds was combined with prairie hay and a sufficient amount of protein supplement to provide basal rations having 8 percent protein. Urea improved nitrogen retention when added to each ration, a greater improvement being made when it was added to the corn ration than when it was added to the cane molasses ration. The authors concluded that urea could be useful as a nitrogen supplement in rations adequately supplied with carbohydrates from widely different sources.

In their study, Briggs et al. (1947) used yearling shorthorn steers which averaged 500 pounds in weight to determine the nutritional value of urea during the finishing phase of a feeding trial. The basal ration consisted of corn, wheat, oats and prairie hay. The level of urea fed was 0.37 pounds per head daily. The workers obtained an average daily weight gain of 1.62 pounds with cattle fed urea, whereas similar animals gained 2.03 pounds on the basal diet supplemented with cottonseed meal. The authors explained their results by stating that with rations containing urea, there was reduced feed consumption due to the unpalatability of urea.

In vitro and In vivo Studies With Cattle. Pearson and Smith (1943) used in vitro techniques to determine the efficiency of various types of carbohydrate as energy sources for the utilization of urea by ruminants. To 1,500 ml. of rumen liquor from a fistulated steer were added 0.65 g. urea, 4.5 g. K_2HPO_4, 0.1 g. $FeSO_4$, and 7.5 g. starch. The pH was maintained between 7 and 7.3. The urea was found to be rapidly converted to ammonia and in 3 hours protein was synthesized at the rate of 9 mg./100 g. rumen liquor at the expense of ammonia. It was calculated that a cow with a 75 kg. rumen capacity would convert 54 g. of non-protein nitrogen to 337 g. of protein in one day. Adequate energy sources were found to be necessary for the efficient conversion of urea to protein. Starch was found to have the greatest beneficial effect. Galactose, sucrose, maltose, lactose, glucose and dextrin were all found to be positive contributors while glycerol and lactic acid promoted hydrolysis. In this study, ammonium bicarbonate and ammonium sulfate were compared with urea. Ammonium bicarbonate was found to be about equal to urea but the sulfate was not. This could not be explained. These workers also went further to determine that the optimum amount of urea N/100 g. of rumen liquor was about 75 to 100 mg. The authors, however, cautioned that results of in vitro experiments must sometimes be taken with reservation because long incubations are subject to question in interpreting the happenings in the rumen.

Another in vitro study was carried out by Smith and Baker (1944) in search of some correlation between protein synthesis and microbial activities in the rumen. Rumen liquor from a fistulated steer was incubated with and without added carbohydrates. The synthesis which resulted was estimated by isolating the synthesized material as an amorphous powder which consisted mainly of bacteria. Synthesis of protein was found to be accompanied by the synthesis of a starch-like polysaccharide and by an increase in the iodophile population of the medium. The greater portion of the synthesis was attributed to the masses of iodophile bacteria which are abundant in the rumen. Protozoa do not appear to contribute to the synthesis. Analytical figures for the sediment containing the synthesized material are 0.5 percent moisture, 36.3 percent protein, 46.6 percent polysaccharide, 9.5 percent lipoid matter and 6.2 percent ash. The authors think that these values are typical for feeding stuffs like linseed cake.

Wegner and his associates (1940) studied the in vitro conversion of inorganic nitrogen to protein by microorganisms from the cow's rumen. In a synthetic medium, the influence of sugars on the utilization of inorganic nitrogen was studied. Corn molasses, dextrose and starch, but not cellulose, stimulated the disappearance of inorganic nitrogen. Urea and ammonium bicarbonate gave similar results. Recovery of bacterial cell nitrogen indicated conversion into protein. Using the cow's ration as medium, the addition of casein decreased the conversion of ammonium bicarbonate into bacterial protein. This may be attributed to the high solubility of casein. Other very soluble proteins too would be expected to have similar effects on the conversion of non-protein nitrogen to protein by the rumen microorganisms.

Arias et al. (1951) carried out in vitro studies in order to study the influence of different amounts and sources of energy upon the in vitro utilization of urea by rumen microorganisms. Six different sources of energy, dextrose, cane molasses, sucrose, starch, cellulose and ground corn cobs each at three levels were studied in in vitro fermentation flasks with respect to their influence upon rumen microorganisms in converting urea N into bacterial protein. Each source of energy, whether a readily available carbohydrate or a complex carbohydrate, such as cellulose, aided urea utilization provided that the carbohydrate underwent digestion. It was observed that small amounts of readily available carbohydrate aided cellulose digestion, which in turn increased urea utilization, whereas large amounts of readily available carbohydrate inhibited cellulose digestion. The results of these workers may be explained by the fact that presence of large amounts of readily available carbohydrate does not call for the breaking down of cellulose since the microorganisms can obtain most of their energy requirements without having to break down cellulose. On the other hand, small amounts of readily available carbohydrate provide just the initial amount of energy to trigger microbial action on cellulose and thereafter further energy requirements are met by the broken-down cellulose.

The results of experiments conducted in vitro by McNaught and Smith (1947) suggested that the nature of the protein in a ration affects the efficiency with which non-protein nitrogen is converted to protein. The workers pointed out the possibility that when the ration contains insoluble protein, the amount of ammonia formed from the protein may be small, a situation that favors a more efficient utilization of urea. This prediction was confirmed by the work of McDonald (1952) who showed that large amounts of ammonia are formed from casein and gelatin which are very soluble and readily hydrolyzable proteins, but that the addition of zein, an insoluble protein that hydrolyzes with difficulty, caused no change in the ammonia content of the rumen liquor.

In an in vivo study with dairy cows, Belasco (1956) found that the utilization of urea was greater with starch than with cellulose, xylan or pectin. Total volatile fatty acid production was greatest with starch, followed by dextrose, and then cellulose. The worker also found that high amounts of dextrose inhibited cellulose digestion while a 1:1 ratio of starch:cellulose increased cellulose digestion.

Wegner et al. (1941) carried out an in vivo study with a fistulated dairy heifer in order to observe the chemical changes in rumen ingesta with and without added urea. The basal ration consisted of 6 pounds timothy hay, 3 pounds ground corn, 3 pounds ground oats and 18 pounds corn silage. The crude protein level in the basal ration was 8.45 percent. The level of urea in the supplemented ration was 1.0 percent. This ration contained 11.3 percent protein. The data obtained in this study showed that urea was hydrolyzed within an hour after feeding and the liberated ammonia had disappeared within 4 to 6 hours after feeding. By using a lower protein basal of 15 pounds corn silage and 3.0 pounds starch, additional tests were carried out, urea being added at a 5 percent level. Crude protein level in the rumen was boosted to over 12 percent. This indicated that the higher the protein level in the ration, the less urea is utilized for protein synthesis by rumen microorganisms.

Pearson and Smith (1943), working with fistulated steers, studied the synthesis and breakdown of protein in the rumen ingesta. Tests with added amino acids showed that glycine, alanine, lysine, tyrosine, and particularly arginine promoted protein synthesis in single tests without added urea. With added urea, leucine promoted protein synthesis while asparagine promoted the hydrolysis of protein instead of synthesis. Fresh uncoagulated egg white, freshly prepared casein and gelatin all reduced protein synthesis markedly and protein hydrolysis predominated. It should be noted that the last three named substances are all very soluble proteins. The authors interpreted their results to mean that the nitrogen required by rumen microorganisms is in the form of ammonia and that more complex nitrogenous compounds such as amino acids are not required.

Mills and his associates (1944) investigated the utilization of urea for the growth of heifer calves with corn molasses or cane molasses as the only readily available carbohydrate in the ration. They used a 1,000 pound fistulated Holstein heifer. Feeds were studied by sampling twice weekly at 1, 3 and 6 hours after feeding the animal in the morning. Ammonia, urea nitrogen and total nitrogen were determined. It was found that without added urea in rations, the level of ammonia N in the rumen changed only slightly when either timothy hay alone, or the hay plus starch, or the hay plus molasses were fed. The ammonia N values were between 0.008 and 0.041

percent on a dry basis in all three cases. With added urea and/or casein, ammonia N values with all the three rations were between 0.14 and 0.22 percent on a dry basis at 1 to 3 hours after feeding. These values, however, dropped to levels of from 0.014 to 0.094 percent 6 hours after feeding. Protein synthesis was shown on the urea-molasses feed by the rumen protein increasing from 7.7 to 9.28 percent on a dry basis. With starch-urea ration, the rumen protein level was 10.9 percent and the addition of casein did not alter this level. So it was concluded that starch is better than molasses for stimulating protein synthesis from urea. The authors recommended that rations should contain 3 to 5 percent of an insoluble fermentable carbohydrate to aid in the use of urea.

The Quality of Protein Synthesized From Urea

The quality of a protein may be measured in terms of the response obtained when the protein is fed to animals. The degree of response may be referred to as the biological value of the protein. Thus, the biological value may be defined as the extent to which protein synthesized from urea may be used for growth, lactation, meat and wool production. The level of urea in the ration to provide for either of the above-mentioned factors must not be toxic.

Johnson et al. (1944) did much good work to determine the mechanism of non-protein nitrogen utilization by ruminants. Growing lambs were fed rations containing urea. Protozoa and bacteria were each separated from rumen contents. The dried protozoal fraction contained 54.75 percent crude protein, had a true digestibility of 86.2 percent and a biological value of 68 percent. Determinations were carried out with rats. The dried bacterial fraction, which was not satisfactorily isolated, contained 44.5 percent crude protein, while the bacterial fraction obtained by culture on synthetic media contained 58.81 percent crude protein which also had a digestibility of 82.4 percent and a biological value of 66.0 percent. Bacterial and protozoal counts in the rumen contents made at one hour intervals for 24 hours following feeding showed the greatest number of bacteria and the smallest number of protozoa one hour after feeding. At succeeding intervals, the number of bacteria decreased and that of the protozoa increased regularly for 16 hours. One hour after feeding, 6,500,000 bacteria and 450,000 protozoa per c.c. of rumen fluid were observed, but 16 hours later the number of bacteria had fallen to 500,000 and that of protozoa had risen to 840,000 per c.c. A yeast-like organism was also observed to be present in the rumen content in very large numbers. This work supports the hypothesis that in ruminants most of the dietary nitrogen is first broken down and then synthesized into bacterial proteins, some of which is utilized by the protozoa for growth, and finally both the protozoal and the remaining bacterial protein are digested and absorbed. So the authors concluded that up to the maximum amount of nitrogen capable of utilization by the rumen microorganism, all dietary nitrogen would have a biological value characterized by the mixed population of microorganisms reaching the abomasum and the duodenum. They further added that any nitrogen consumed above the requirement of the rumen microorganisms should exhibit a biological value approximating, probably somewhat less than, that of a non-ruminant of similar requirements since the excess nitrogen would pass through the rumen and reticulum unaffected. In the abomasum and the intestines, the excess nitrogen would undergo digestion just as it would in a monogastric animal.

Harris, Work and Henke (1943) carried out studies with steers to investigate the utilization of urea and soybean oil meal nitrogen. They found that the digestion coefficient for both urea nitrogen and soybean oil meal nitrogen were each 94, after correcting for metabolic nitrogen in feces. The biological value of urea nitrogen was 34 and that of soybean oil meal nitrogen was 60 percent, when fed at protein equivalent levels of 12 and 14 percent. The authors commented that the wide range of biological values obtained for urea may be the result of differences in the nature and amounts of basal rations to which urea has been added. Generally, literature indicates that at nitrogen equilibrium or thereabout, the biological value of protein formed from urea is somewhat lower than that of protein formed from the conventional protein supplement.

Urea Toxicity

In any discussion on urea utilization, urea toxicity constitutes an important aspect, for according to the literature, it is the single most important factor that limits the amount of urea to be added to a ration.

After conducting a preliminary experiment with a male calf, Hart et al. (1939) used four heifers to study urea nitrogen utilization by ruminants. The basal ration consisted of 20.0 percent yellow corn, 42.5 percent ground timothy hay, 24.0 percent starch, 10.0 percent corn molasses, 2.0 bone meal, 1.0 percent salt and 0.5 percent cod liver oil. The levels of urea fed are given in Table 4.

The animals had an average weight of 270 pounds at the start of the experiment and an average weight of 600 pounds at the end of the experiment. For a substandard ration, the gains were considered normal. Estrus was also normal. Diuresis was, however, noted in heifers 3 and 4. All the experimental animals were slaughtered. Cuts from rib, shoulder, leg and the liver were analyzed. Protein percentages were normal with no excessive NPN.

Table 4. Utilization of urea by growing heifer calves.

Heifer	Percent protein in ration	Percent urea added	Percent N from urea	Blood urea N after 8 mo. mg./100 ml.
1	5.38	---	--	14.1
2	9.49	1.4	43	10.6
3	13.70	2.8	61	13.2
4	17.64	4.3	70	16.4

Histological examination of the kidneys showed slight congestion in all the animals fed urea and there was a definite evidence of damage in heifers 3 and 4, that is those on 2.8 and 4.3 percent urea. So the authors concluded that for feeding, the levels of 2.8 and 4.3 percent urea are too high.

Work et al. (1943) observed the tolerance of Hereford cattle for urea. The cattle were fed for 244 days. The basal ration consisted of molasses, strip cane and cottonseed meal. Levels of 0.88, 0.97, 1.91 and 2.29 percent urea were tested. At the end of the experiment, all the animals were sacrificed. Gross examination of all the animals showed normal organs. Portions of the liver and kidneys were examined microscopically and they were found normal. Therefore, under the conditions of this experiment, 2.29 percent urea could be tolerated by the Hereford cattle.

Whitehair and his associates (1955) conducted experiments to determine the general conditions under which acute and chronic urea toxicity might occur in cattle. Steers were fasted for 48 hours and then fed various amounts of urea, according to body weight, in a molasses-corn mixture. The symptoms of urea toxicity were as follows: from 30 minutes to one hour after feeding, the cattle showed uneasiness, staggering and kicking at the flank. They usually went down during this period. While down they exhibited severe convulsions and bloating. Blood ammonia increased to abnormally high levels. No specific tissue changes were noted on post-mortem examinations. The rumen contents had a strong ammonia odor. The amount of urea in the feed necessary to produce these acute symptoms were in excess of 20 g. per 100 pounds of body weight. This amount was fed in about 2.5 pounds molasses-corn mixture. The authors have termed the above-mentioned symptoms as those of acute urea toxicity.

The same workers (Whitehair, et al., 1955) conducted a test with 8 steers in order to study the symptoms of chronic urea toxicity. The test lasted for 125 days. The 8 steers were divided into three lots of 2, 2, and 4. Lot 1 (2 steers) received a daily ration of 4 pounds prairie hay, 3 pounds corn, 6 pounds molasses, 0.2 pound bone meal and salt free choice. Lot 2 (2 steers) had a ration which was the same as the one fed to Lot 1 except that 1.0 pound of cottonseed meal was added and molasses decreased to 5.3 pounds. Lot 3 (4 steers) was given the same ration that was given to Lot 1 but also received 1.0 pound of urea in addition.

At the end of the experiment, the animals were sacrificed. Neither gross nor microscopic alterations were found in the various tissues of the body. Blood urea N was higher in the animals fed urea than in those not fed urea. According to the authors, unusual conditions that may predispose cattle to disturbances due to consumption of urea in feed are: (1) starved and fasted cattle will consume large amounts of feed containing urea in a short time; (2) rapid consumption of feeds containing urea by animals having "hoggish" appetites; (3) animals not previously fed feeds which contain urea; (4) feeds containing urea improperly mixed or in amounts greater than recommended; and (5) high-roughage rations tend to cause poorer utilization of urea than rations high in concentrates.

The literature generally indicates that the amounts of urea which would normally be used in practice are less than the apparent toxic level. Also, since urea is quite unpalatable, it does appear that there should be no need for great concern in its use provided that the recommended level is used and the substance is uniformly mixed in the feed.

EXPERIMENTAL PROCEDURE

The experiment was conducted to determine the amount of grain in a ration necessary for the efficient utilization of urea. The test consisted of a wintering and a finishing phase. The wintering phase started on December 17, 1965, and ended on April 8, 1966. The finishing phase then followed until October 13 of the same year.

Seventy yearling Hereford steers averaging 520.5 pounds were used in this experiment. All the animals were in good condition at the beginning of the experiment. The steers were randomly allotted to five lots of 14 animals each. The experimental animals were fed twice daily, at 6:30 in the morning and at 4 in the afternoon. During the wintering phase of the test, silage, protein supplement and milo were fed in the morning while hay was fed in the afternoon. In the fattening phase, the protein supplement and part of the grain were fed in the morning, and the remaining part of the grain and the hay were fed in the afternoon. As a result of the death of two steers from lot one near the end of the finishing phase, the amount of feed fed to that lot was accordingly adjusted. The steers remained in the feedlot where their performance was observed throughout the test period.

A comparison of five rations was made in this study. Three of the rations contained urea while the remaining two contained soybean meal. Soybean meal represented the source of natural protein while the urea supplement consisted of 14 percent urea and 86 percent ground sorghum grain. The rations compared were urea only, urea plus 3 pounds of grain, urea plus 6 pounds of grain, soybean meal only and soybean meal plus 3 pounds of grain. During the wintering phase, all the animals were fed sorghum silage ad libitum plus two pounds of alfalfa hay and 70 mg. of aureomycin per head daily. In addition, the animals in lots 1 and 3 received one pound of soybean meal per head daily while the animals in lots 2, 4 and 5 received one pound of urea supplement per head daily. During the finishing phase, two pounds of prairie hay per head daily replaced the sorghum silage which was fed in the wintering phase. In addition to the aureomycin, 10 mg. of stilbestrol per head per day was also fed during the finishing phase. In the finishing phase, all the animals were fed as much sorghum grain as they could consume. The urea supplements were well mixed with the feed. All the animals had ready access to water and salt at all times.

The steers were weighed at the start of the experiment and every 4 weeks thereafter until the end of the experiment. Chemical analyses were run on the feeds used. The analysis was run twice, each being in duplicate so that the final figures obtained represent averages of 4 samples. These figures were compared with those of Morrison in his book of Feeds and Feeding. The methods employed in chemical analysis were those of the AOAC though slightly modified. The data obtained are given in Table 5.

Table 5. Chemical analyses of feedstuffs used. Percentages are expressed on dry basis.

	Dry matter	Crude protein	Crude fiber	Ether extract	Nitrogen free extract	Ash
Alfalfa hay	91.3	16.9	28.2	1.7	35.5	9.0
Prairie hay	92.5	5.7	29.2	2.6	47.2	7.8
Sorghum silage	37.5	3.4	8.5	1.1	19.8	2.7
Soybean meal	90.8	50.0	2.4	1.2	30.3	6.9
Urea supplement	89.5	50.2	2.3	2.7	31.9	2.4
Sorghum grain	89.8	9.8	2.6	3.1	71.6	2.7

At the end of the experiment all the animals were slaughtered and left in the cooler for 24 hours after which carcass traits were obtained.

The average daily gains during the wintering, finishing and wintering and finishing phases were computed. The carcass traits were assigned the usual numerical value. Analysis of variance on the three sets of average daily gains and the various carcass traits were run with the help of the computer. Fisher's Least Significant Difference (LSD) test was employed to assess significant differences between the treatment means at 5 percent level of probability.

RESULTS AND DISCUSSION

Two steers from Lot 1, died of urinary calculi near the end of the finishing phase. Generally, there was no problem in getting the animals to consume their rations. Apparently, the levels of urea fed did not adversely affect the palatability of the rations. The animals had good and healthy appearances throughout the test period. After the animals had been slaughtered the carcasses were normal and had a uniform appearance, good conformation, and graded choice generally.

The feedlot and the carcass data obtained have been summarized in Tables 6, 7 and 8.

During the wintering phase, all animals on the ration that contained urea alone made significantly smaller gains than those fed soybean meal or urea plus added grain. The ration with urea plus 6 lbs. of grain produced significantly greater weight gain than the ration which contained soybean meal with or without added grain. There was, however, no significant difference in the weight gain produced between those rations that were supplemented with either soybean meal alone, soybean meal plus 3 pounds of grain or urea plus 3 pounds of grain.

In the finishing phase, it is normally expected that the animals which gained less during the wintering phase will gain more during the finishing phase than those that gained a greater amount. This is the result of compensatory growth. The animals that had lower weight gains during the wintering phase did not have sufficient energy to gain weight at a rapid rate. So, they were more concerned with the building of body framework and vital tissues during the wintering phase than those that produced greater weight gain because they had sufficient energy. During the finishing phase

Table 6. Comparison of urea with soybean meal with varying levels of grain during the wintering phase, December 17, 1965 to April 8, 1966--112 days.

Lot No.	1	2	3	4	5
Source of added protein	SBM	Urea	SBM	Urea	Urea
No. steers per lot	14	14	14	14	14
Average initial wt., lb.	519	525	520	518	519
Average final wt., lb.	689	665	703	710	730
Average daily gain, lb.	1.52	1.24	1.63	1.72	1.88
Average daily ration, lb.					
Sorghum silage	24.8	24.1	21.1	20.7	17.1
Alfalfa hay	2.0	2.0	2.0	2.0	2.0
Soybean meal	1.0	---	1.0	---	---
Grain-urea supplement	---	1.0	---	1.0	1.0
Sorghum grain	---	---	3.0	3.0	6.0
Protein, lb.	1.1	1.1	1.3	1.3	1.5
TDN	6.5	---	---	---	---
Feed per cwt. gain, lb.					
Sorghum silage	1634	1939	1291	1205	910
Alfalfa hay	132	161	123	117	106
Soybean meal	66	---	61	---	---
Grain-urea supplement	---	80	---	58	53
Sorghum grain	---	---	184	175	319

Table 7. Comparison of urea with soybean meal during the finishing phase, April 8 to October 13, 1966--188 days.

Lot No.	1	2	3	4	5
Source of added protein	SBM	Urea	SBM	Urea	Urea
No. of steers per lot	12	14	14	14	14
Average final weight, lb.	1186.7	1103.9	1177.5	1132.1	1126.4
Average daily gain, lb.	2.61	2.34	2.53	2.25	2.11
Average daily ration, lb.					
Sorghum grain	17.8	15.8	17.6	16.9	15.4
Soybean meal	1.0	---	1.0	---	---
Grain-urea supplement	---	1.0	---	1.0	1.0
Alfalfa hay	2.0	2.0	2.0	2.0	2.0
Prairie hay	2.0	2.0	2.0	2.0	2.0
Protein, lb.	2.4	2.3	2.4	2.4	2.3
Feed per cwt. gain, lb.					
Sorghum grain	680	678	698	751	729
Soybean meal	38	---	40	---	---
Grain-urea supplement	---	43	---	45	47
Alfalfa hay	77	86	79	89	95
Prairie hay	77	86	79	89	95
Shrinkage to market, %	2.35	3.01	2.37	2.21	0.95
Average hot carcass wt., lb.	714.1	655.1	718.6	674.6	686.9
Av. dress %, feedlot wt.	60.18	59.35	61.03	59.58	60.98
Av. dress %, market wt.	61.67	61.19	62.51	60.93	61.56
Av. fat thick., 12th rib, in.	0.63	0.49	0.65	0.49	0.47
Av. est. kidney knob, %	2.46	2.40	2.57	2.54	2.39

Table 7. (cont.).

Lot no.	1	2	3	4	5
Av. ribeye area, sq. in.	12.50	12.54	12.48	12.87	12.83
Av. degree of marbling[1]	6.25	6.64	6.50	6.42	6.42
Av. conformation[2]	9.75	8.21	9.86	10.36	8.79
Av. yield grade[3]	3.17	2.86	3.36	2.86	2.57
Carcass grades:					
Top choice	--	--	3	1	--
Av. choice	10	5	7	8	10
Low choice	2	7	4	4	4
Top good	--	2	--	1	--

[1]Marbling: Slightly abundant--4; Small amount--7; Moderate--5; Slight amount--8; Modest--6; Trace--9.

[2]Conformation: Top prime--11; Av. prime--10; Low prime--9; Top choice--8; Av. choice--7.

[3]Average yield grade: Scored 1 to 5. Lower score indicates a higher percentage of trimmed, boned major retail cuts.

Table 8. Analysis of variance on feedlot and carcass data.

	Total degrees freedom	Treatment mean square	Error mean square	Level of sig.
Wintering A.D.G., lb.	69	0.7859	0.0561	0.001
Finishing A.D.G., lb.	67	0.5580	0.0638	0.001
Combined A.D.G., lb.	67	0.1959	0.0357	0.001
Hot carcass wt., lb.	67	9719.2500	2108.7777	0.01
Back fat thick., in.	67	1.0109	0.2731	0.01
Carcass grade	67	1.0492	0.3972	0.05
Yield grade	67	1.2824	0.3133	0.01
Conformation	67	10.5415	1.8713	0.001
Est. kid. knob, percent	67	9.3175	5.6643	NS[1]
Ribeye area, sq. in.	67	49.4250	102.5175	NS
Degree of marbling	67	0.2616	0.2511	NS

[1]Not significant at 5 percent.

Table 9. Assessment of significant differences between treatment means.

	LSD[1]	Urea + 6 lb.	Urea + 3 lb.	SBM + 3 lb.	SBM	Urea
Wintering ADG, lb.	0.1788	1.88 ± 0.09^{a}	1.72 ± 0.06^{ab}	1.63 ± 0.06^{b}	1.54 ± 0.06^{b}	1.24 ± 0.04^{c}
Finishing ADG, lb.	0.1986	2.11 ± 0.06^{d}	2.25 ± 0.05^{cd}	2.53 ± 0.09^{ab}	2.61 ± 0.08^{a}	2.34 ± 0.07^{bc}
Combined ADG, lb.	0.1486	2.02 ± 0.05^{b}	2.05 ± 0.04^{b}	2.19 ± 0.06^{a}	2.22 ± 0.06^{a}	1.93 ± 0.05^{b}
Hot Carcass wt., lb.	36.1127	686.86 ± 12.05^{ab}	674.57 ± 13.07^{b}	718.64 ± 14.97^{a}	714.08 ± 11.09^{a}	655.14 ± 10.00^{b}
Backfat thickness, in.	0.12995	0.47 ± 0.05^{b}	0.49 ± 0.03^{b}	0.65 ± 0.05^{a}	0.63 ± 0.06^{a}	0.49 ± 0.03^{b}
Carcass grade	0.4956	6.71 ± 0.12^{a}	6.64 ± 0.21^{ab}	6.93 ± 0.19^{a}	6.83 ± 0.11^{a}	6.21 ± 0.19^{b}
Yield grade	0.4401	2.57 ± 0.17^{c}	2.86 ± 0.10^{bc}	3.36 ± 0.17^{a}	3.17 ± 0.21^{ab}	2.86 ± 0.10^{bc}
Conformation	1.0757	8.79 ± 0.43^{bc}	10.36 ± 0.29^{a}	9.86 ± 0.43^{ab}	9.75 ± 0.44^{ab}	8.21 ± 0.21^{c}
Est. kidney knob, %	0.1872	2.39 ± 0.08^{a}	2.54 ± 0.08^{a}	2.57 ± 0.05^{a}	2.46 ± 0.04^{a}	2.39 ± 0.06^{a}
Ribeye area, sq. in.	0.7962	12.83 ± 0.35^{a}	12.86 ± 0.28^{a}	12.47 ± 0.22^{a}	12.50 ± 0.27^{a}	12.53 ± 0.24^{a}
Degree of marbling	0.3940	6.43 ± 0.14^{a}	6.43 ± 0.14^{a}	6.50 ± 0.14^{a}	6.25 ± 0.13^{a}	6.64 ± 0.13^{a}

Figures in the same row with different superscripts are significantly different ($P < 0.05$).

[1] Least Significant Difference (Fisher's) was used to assess the significance of each possible difference between two treatment means.

when sufficient energy was provided, the animals that had lower weight gain in the previous phase tended to compensate for this weight gain because most of the available energy was now diverted towards gaining weight. This was true in this experiment, with some exceptions. The animals which received urea without grain during the wintering phase gained significantly greater than those that received urea plus 6 pounds of added grain, but not significantly greater than those that received urea or soybean meal plus 3 pounds of grain. Both of the lots which received soybean meal made significantly greater gains than those that received urea plus grain. The lot which received soybean meal only during the wintering phase gained significantly faster than all the lots that received urea.

When weight gains for the wintering and finishing phases were combined, the rations which contained soybean meal were significantly superior to the rations which contained urea, in terms of weight gain produced. There were no significant differences between the rations which contained urea.

Since the animals which were fed soybean meal produced the greatest gain, they would be expected to have the heaviest carcasses. The carcass weights of the animals fed soybean meal were significantly greater than those fed urea except the lot which received 6 pounds of added grain during the wintering phase.

The soybean meal rations were equal in producing back fat thickness but produced significantly more than the rations containing urea. There was, however, no significant difference between rations containing urea in terms of back fat thickness produced.

The ration containing urea without added grain produced the lowest carcass grades, all the other rations being equal in this respect.

The rations containing urea produced significantly better yield grades than those containing soybean meal. This was due primarily to the fact that the animals which received urea were not as fat.

The ration containing urea plus 3 pounds of added grain produced the highest conformation score while the ration containing urea alone had the lowest conformation score. There was no significant difference between the ration containing urea without added grain and the ration containing urea with 6 pounds of added grain. Those fed soybean meal and urea plus 3 pounds of added grain were equal. Also, there was no significant difference between the soybean meal rations and the urea ration which contained 6 pounds of added grain.

There were no significant differences between the treatments in producing kidney knob, ribeye area and degree of marbling.

These results may not be altogether unexpected. The urea ration with 6 pounds added grain was apparently superior to the soybean rations in producing weight gains during the wintering phase probably because this is a time when the animal is more concerned with the maintenance of body temperature and nitrogen equilibrium more than any other thing. Also there was a sufficient amount of energy for the synthesis of needed protein. In the finishing phase that followed, the animals fed soybean meal not only caught up but went ahead by the end of the finishing period and had the highest gain. However, the superiority of soybean meal, a natural protein, over urea is not very much from an economic point of view because of the low cost of urea.

Results show that a source of readily available energy like grain is required for efficient utilization of urea. Though there was no significant difference in the overall test between urea rations containing 6 pounds or 3 pounds added grain, the latter proved slightly superior to the former despite the higher level of energy the former contained. This indicated that there is a maximum level of energy required for urea utilization above which there may be no beneficial effect. Also beyond this maximum level of energy, any added grain may be contributing more natural protein for utilization by rumen microorganisms such that urea becomes less utilized.

Considering the overall test, the addition of soybean meal a natural protein, to rations produced significantly greater gains. However, with added grain, urea performed almost equally well. Urea alone, as the only source of added protein, produced satisfactory gain but addition of soybean meal improved performance a great deal.

This work consisted of a single trial and it would not be correct to try to state accurately the level of energy required for the efficient utilization of urea. About 0.14 lb. of urea per head per day may be recommended. As shown in the literature review and in this experiment, some source of readily available energy like starch or grain greatly improves the utilization of urea. From this test, it may be said that 3 lb. of grain (the amount calculated to be in the silage consumed daily) would be sufficient for the utilization of about 0.14 lb. of urea, but larger quantities of grain may be desirable. It may, however, be tentatively stated that some natural protein like soybean meal should be fed and the balance of the animal's requirement made up with urea. Also as already cited in the literature review, thorough mixing of urea with the ration is advisable since this would give a uniform distribution of urea throughout the ration. This would ensure a slow and steady release of ammonia in the rumen, a condition that would help to check toxicity of urea and also lead to greater efficiency of urea utilization.

SUMMARY

Seventy Hereford steer calves averaging 520.5 pounds were used in the wintering and finishing phases of this test. The animals were randomly allotted to five lots of 14 animals each. A comparison of 5 supplements was made. Two of the supplements contained soybean meal which represented the source of natural protein. The urea supplement consisted of 14 percent urea and 86 percent sorghum grain. The supplements compared were urea only, urea plus 3 pounds of grain, urea plus 6 pounds of grain, soybean meal only, and soybean meal plus 3 pounds of grain. All the rations were isonitrogenous. All the experimental animals received 2 pounds of alfalfa hay per head daily throughout the 300 days of the test period. During the wintering phase, sorghum silage was fed to all the animals ad libitum. Two pounds of prairie hay replaced the silage during the finishing phase.

The steers were weighed at the start of the experiment and every 4 weeks thereafter until the experiment ended. All the animals were then slaughtered and carcass traits were obtained. Analysis of variance was made on average daily gain (A.D.G.) during the wintering phase, the finishing phase, and the wintering and finishing phases combined, and the various carcass traits.

It was found that there were significant differences among all the three sets of A.D.G.'s tested, at the 5 percent level of probability. During the wintering phase, the ration which contained urea without added grain produced significantly lower weight gain (1.24 ± 0.04 lb.) than any of the remaining rations. The urea rations which contained 3 pounds and 6 pounds added grain were equal in producing weight gain (1.88 ± 0.09 lb. and 1.72 ± 0.06 lb., respectively). The rations which contained urea plus 3

pounds of added grain, soybean meal plus 3 pounds of added grain and soybean meal alone were equal in producing weight gain during the wintering phase (1.72 ± 0.06 lb., 1.63 ± 0.06 lb. and 1.54 ± 0.06 lb. respectively). The urea ration with 6 pounds of added grain produced significantly better weight gains during the wintering phase than any of the soybean rations.

In the finishing phase, it is normally expected that the animals which gained less during the wintering phase will gain more during the finishing phase as a result of compensatory growth. This was true in this experiment with some exceptions. The animals that received urea without grain during the wintering phase gained significantly faster (2.34 ± 0.07 lb. daily) than those that received urea plus 6 pounds of added grain (2.11 ± 0.06 lb. daily), but not significantly greater than those that received urea or soybean meal plus 3 pounds of added grain. The last two rations named produced weight gains of 2.25 ± 0.50 lb. and 2.53 ± 0.09 lb. respectively. The ration which contained soybean meal without added grain produced the greatest weight gain (2.61 ± 0.08 lb. daily) during the finishing phase.

When weight gains for the wintering and finishing phases were combined (300 days), the soybean meal rations, with and without added grain, were significantly superior to the rations containing urea in terms of weight gain produced. The soybean rations, with and without added grain respectively, produced A.D.G.'s of 2.19 ± 0.06 and 2.22 ± 0.06 lb. while the urea rations produced A.D.G.'s of 2.02 ± 0.05 lb. (urea plus 6 lb. grain), 2.05 ± 0.04 lb. (urea plus 3 lb. grain) and 1.93 ± 0.05 lb. (urea plus 0 grain). Statistically, all the rations containing urea were supposed to be equal in producing weight gains.

The animals which were fed soybean meal produced the greatest gain;

therefore, they had carcass weights significantly greater than those fed urea, with the exception of the lot which received 6 pounds of added grain during the wintering phase. This lot had sufficient energy throughout the period of the test.

The soybean rations produced significantly more back fat thickness than the urea rations.

The ration containing urea without added grain produced the lowest carcass grades, all the other rations being equal in this respect.

The rations containing urea produced significantly better yield grades than those which contained soybean meal. This was primarily due to less carcass fat.

The ration containing urea plus 3 pounds of added grain produced the highest conformation score while that containing urea had the lowest score.

There were no significant differences in kidney knob, ribeye area and degree of marbling.

From the results of this experiment the following tentative conclusions have been made: Some natural sources of protein like soybean meal should be fed to the animal and the balance of the protein requirement of the animal should be made up with urea. Fourteen hundredths of a pound of urea per head daily may be recommended. Three pounds of grain would be sufficient for the utilization of 0.14 pound of urea, but larger quantities of grain would be desirable. Thorough mixing of urea with the ration would also be desirable since this would give a uniform distribution of urea throughout the ration, a situation that would ensure a slow and steady release of ammonia. This would not only check urea toxicity but would also lead to greater efficiency in urea utilization.

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LEVEL OF ENERGY FOR THE EFFICIENT
UTILIZATION OF UREA

by

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B. Sc. (Hons), University of Ibadan, 1965

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Husbandry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1967

The purpose of this study was to determine the level of energy, as grain, required for the efficient utilization of urea.

Seventy Hereford steer calves averaging 520.5 pounds, randomly allotted to five lots of 14 animals each, were used in the wintering and finishing phases. The supplements were soybean meal and isonitrogenous mixture of 86 percent sorghum grain and 14 percent urea. The five treatments were SBM, SBM plus 3 pounds grain, urea, urea plus 3 pounds grain and urea plus 6 pounds grain. During the wintering phase, all animals received two pounds alfalfa hay per head daily and sorghum silage was fed ad libitum. Calculation indicated that the silage supplied approximately 3 pounds of grain per head daily. Two pounds of prairie hay replaced the silage during the finishing phase and sorghum grain was fed ad libitum. At the end of the test, all animals were slaughtered and carcass information obtained. Analysis of variance was made on average daily gain (A.D.G.) during the wintering phase, the finishing phase, and the wintering and finishing phases combined and on the various carcass traits.

During the wintering phase, the ration which contained urea without added grain produced significantly less gain than the others. Urea rations with 3 and 6 pounds added grain were about equal in weight gain produced. Rations containing urea plus 3 pounds of added grain, SBM plus 3 pounds added grain and SBM alone produced equal weight gains during the wintering phase. The urea ration with 6 pounds of added grain produced significantly greater weight gain than those containing SBM.

In the finishing phase, animals that received urea without added grain during the wintering phase gained significantly more than those that received urea plus 6 pounds of added grain but not significantly more than those that received urea or SBM plus 3 pounds of added grain. The ration which contained SBM without added grain produced the greatest weight gain during the finishing phase.

Combined wintering and finishing gains were significantly greater for animals fed rations containing SBM. All rations containing urea produced equal weight gains.

Animals fed SBM produced significantly heavier carcasses, with the exception of the lot which received urea plus 6 pounds of added grain during the wintering phase, had significantly more back fat and significantly lower yield grade because of the fat. Animals fed urea without added grain had the lowest carcass grade with all other treatments being equal in this respect. There were no significant differences in kidney knob, ribeye area or degree of marbling.

The results of this experiment indicate that natural sources of protein like SBM are more efficient than urea, especially with rations low in grain. Satisfactory gains were produced with 0.14 pound urea when the ration contained about 3 pounds of grain; however, additional grain produced greater gains which indicates better use of the urea.