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Urea In Rations For Cattle and Sheep

A Summary of Experiments At The Oklahoma Agricultural Experiment Station 1944 to 1952

OKLAHOMA AGRICULTURAL EXPERIMENT STATION
Oklahoma A. & M. College, Stillwater
A. E. Darlow, Director Louis E. Hawkins, Vice Director

Foreword

Changes in feed supplies and in methods of livestock management necessitate the investigation of new and untried feeds. Evaluation of these feeds to determine the content and availability of protein, fat, carbohydrates, minerals and vitamins is an important step toward more efficient livestock production—that is, greater gains per dollar of feed cost.

This bulletin summarizes the various studies of urea as a livestock feed conducted at the Oklahoma Agricultural Experiment Station from 1944 through 1952.

The general reader will be most interested in the introduction, pages 7 to 12. This describes the role of urea as a possible extender of the Nation's available protein feed supply, and summarizes conclusions from this Station's work concerning the amount of urea which can be used in livestock rations.

The remainder of the bulletin provides research workers, county agents, and others having a more intensive interest in the subject with a concise report of each of the Station's studies on this subject through 1952. More extended reports of most of these studies are available elsewhere, as shown by the list of publications on page 35.

The studies reported herein were conducted by the Experiment Station's Departments of Animal Husbandry and Agricultural Chemistry Research. Many of the contributions made by former staff members and graduate students of these departments are shown in the references, page 35. Their contributions, and especially those of Dr. H. M. Briggs, who initiated the studies, are gratefully acknowledged.

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Prepared for Publication by

WILLIS D. GALLUP, L. S. POPE, AND C. K. WHITEHAIR

Departments of Agricultural Chemistry Research & Animal Husbandry

Inquiries relating to the practical application of the information reported herein should be addressed to the Department of Animal Husbandry Oklahoma A. & M. College, Stillwater

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The Importance of Protein

The kind and amount of protein supplement are important factors in balancing rations for farm livestock. The roughages on which most profitable beef cattle and sheep husbandry are based are often too low in protein to secure the most economical gains and efficient production. In fattening rations, for example, when the protein level is too low, gains are reduced and the cattle may sell for less on the market due to lack of finish. Lack of protein results in inefficient use of the other feeds in the ration, thus reducing rate of gain and over-all performance of animals.

During the past few years, the supply of protein has failed to keep pace with the large increase in cattle numbers. It becomes necessary then, to think in terms of extending our available protein supply while reducing the cost of protein to the farmer and rancher.

The great number of functions served by protein in the animal body attest to the vital importance of this nutrient in animal rations. Protein is the principal constituent of the soft tissues of the body, and the activity and growth of these structures is dependent upon a constant supply of protein in the ration. It is needed for maintenance of body weight, growth, and the production of meat, milk, eggs, and wool. All these animal products contain nitrogen, as protein, derived from feed sources.

The liberal feeding of protein to secure rapid rate of growth and high production has thus created a demand for high-protein feeds. This demand, which at times exceeds the supply, has been the principal motive for the investigation of chemical compounds which might be used to extend protein supplies. Urea is foremost among the materials being investigated.

Urea as an Extender of Protein

Any compound used to extend the supply of protein feed must necessarily contain nitrogen. Nitrogen is an essential element in all of the amino acids which combine to form protein; and protein is the only one of the major feed constituents (proteins, carbohydrates, and fats) which contains nitrogen.
which contains nitrogen.

Urea is a colorless and odorless compound manufactured from such common raw materials as coal, air and water. At present, thousands of tons are being produced annually for use in industry and agriculture.

Pure urea contains 46.7 percent nitrogen. One pound furnishes as much nitrogen as 2.9 pounds of pure protein or six to seven pounds of oil meal.

Urea resembles common table salt in appearance. It can be readily distinguished by its lack of a "salty" taste and the fact that it becomes moist when a small portion is rubbed between the fingers. Ammonia is liberated when it is heated.

Nutritionally, urea is like protein only in that it contains nitrogen. It cannot be used to advantage in feeds for animals with simple stomachs such as swine and chickens; but it can be used by ruminants such as cattle and sheep because these animals have a large fore-stomach (rumen) where feed undergoes fermentation before digestion. In this paunch, or rumen, feed materials are broken down by fermentation into simpler compounds and re-combined into new ones by bacteria and other microorganisms naturally residing there. Here urea contributes its nitrogen to the formation of protein.

The Formation of Protein

The process of protein formation in the rumen is largely a process of growth and multiplication of rumen bacteria. Such microorganisms normally function to break down coarse, fibrous feed before digestion. The bacteria must have a supply of nitrogen to develop and multiply. The bacteria can obtain the nitrogen from compounds such as urea and combine it with other nutrients to build their own body protein. This transformation of a simple compound of nitrogen into protein, constituting growth of the bacteria, is frequently referred to as "bacterial synthesis of protein."

As the bacteria population of the rumen increases, many of the bacteria mix with feed residues and pass down the animal's digestive tract. Here the protein in the bacteria is digested and absorbed in the same manner as feed protein. The large number and the activity of these microorganisms make considerable quantities of non-protein nitrogen in feed available as protein to ruminating animals. Some non-protein nitrogen is present in natural feeds, and an additional amount can be included in the ration by adding some other source of non-protein nitrogen such as urea.

How Urea is Changed to Protein

Bacterial synthesis of protein from urea proceeds in two major steps: (1) the urea is broken down to ammonia, and (2) the ammonia is then combined with carbohydrate fragments to form protein in the bacterial cells.

The second step must keep pace with the first one to prevent the accumulation of ammonia; thus rapid growth and multiplication of the rumen bacteria are necessary. Rapid growth of bacteria can best be assured by providing in the ration: (a) readily-available carbohydrate (energy) contained in cereal grains and molasses; (b) a relatively low level of natural protein supplements, and (c) minerals.

Production of ammonia in excess of the immediate needs of the bacteria is a waste of nitrogen and may be detrimental to the animal if the excess is great. **Dosing with urea, or allowing animals to consume large amounts over a short period of time, may lead to disastrous results** (See page 32).

By feeding urea only as recommended below, excess ammonia production can be avoided.

Amount of Urea to Feed

Experiments with cattle and sheep at the Oklahoma Agricultural Experiment Station show that urea nitrogen is most efficiently utilized when it supplies up to, but not much more than, 30 percent of the total nitrogen in a fattening-type ration, or about 25 percent of the total nitrogen in a pelleted feed mixture for range feeding.

Fattening-type rations which contain only 7 percent protein can readily be brought up to 10 percent protein equivalent by including one percent of urea. Likewise, in range pellets to be fed at the rate of one, two, or three pounds per head per day, protein can be increased from 30 percent to the equivalent of 40 percent by including about 3.5 percent of urea.

Less favorable results have been obtained with range pellets in which 50 percent or more of the total nitrogen was supplied by urea.

Due to the nature of urea and the fact that excessive amounts may be harmful to animals, undiluted commercial preparations of urea are not recommended for home mixing. Urea in supplemental feeds and rations requires thorough preparation to insure its even distribution and to prevent its settling out in the mixture.

Urea should be combined with a carbohydrate feed when it is used to replace one of the common high-protein supplements such as cottonseed meal. The usual recommendation is six parts of grain and one part of urea to replace seven parts of 41-percent meal. It is seldom advisable to use the urea-carbohydrate mixture to replace all of the usual high-protein supplement in a ration. In Station feeding trials, best results were obtained when the mixture replaced not more than 50 percent of the regular protein supplement.

Additional minerals, especially phosphorus, may be needed when as much as 25 to 50 percent of the protein in the supplement is provided by urea.

State laws govern the use of urea in commercial mixed feed. Regulation No. 8 of the Oklahoma state feed law reads:

> Urea may be used as an ingredient in commercial mixed feeds for cattle, sheep, and goats if the protein calculated from urea is no greater than one-third of the total crude protein content. The labeling must clearly show the amount of protein derived from urea and must be set up in the Registration and on the tag as follows:
>
> Crude Protein, not less than________________(percent)
> (This includes not more than ______________(percent)
> equivalent crude protein from non-protein nitrogen.)

Urea Feeds Used in Trials

The pelleted feeds used in most of the feeding trials reported in this bulletin were made up of different proportions of cottonseed meal, hominy feed, and urea, plus 10 percent blackstrap molasses.

The pellets were generally of three types, classed according to the proportion of the total nitrogen supplied by urea: 25 percent, 50 percent, and 75 percent. In all three types, the combination of urea with other protein was adjusted so that the pellets contained the equivalent of 42 to 45 percent crude protein (nitrogen x 6.25). An 85-percent pellet was used in two fattening trials with steers. Its composition is given on page 19. Other specially-prepared pellets were used in feeding trials with ewes; their composition is given on page 25.

The 25-percent pellet was composed of 75 parts cottonseed meal, 11 parts hominy feed, 10 parts molasses, and 4 parts "Two-Sixty-Two." The 50- and 75-percent pellets contained 8 and 12 parts of Two-Sixty-Two, respectively, with changes in the proportion of cottonseed meal and hominy feed to provide similar amounts of total nitrogen in each.

Two-Sixty-Two is one of the commercial urea preparations used by feed manufacturers in making pelleted feeds containing urea. The name comes from the fact that this form of urea contains 42 percent nitrogen. Protein is usually calculated as 6.25 times the amount of nitrogen present; therefore Two-Sixty-Two has a protein equivalent of 6.25 times 42, or 262.

Summary of Feeding Trial Results

Fattening Rations

Yearly feedlot trials with fattening calves extended over a period of eight years and involved 210 calves being full-fed on grain for approximately 165 days. Pelleted protein supplements containing urea were fed in amounts ranging from one-half to two pounds per head per day. Pellets in which urea supplied the equivalent of either 25 percent or 50 percent of the protein (nitrogen) produced gains equal to those produced by the common plant protein supplements. Pellets with 85 percent of the protein supplied by urea were unsatisfactory.

Wintering Rations

Yearling heifers were successfully wintered on dry grass and the 25-percent urea pellet during three successive winters. The pellet was fed at the average rate of 2½ pounds per head per day. The same pellet fed at an average rate of three pounds per head per day was used for wintering two-year-old steers during three successive winter trials, and for wintering mature beef cows during one year.

For Sheep

Metabolism trials repeatedly showed that sheep are able to utilize urea nitrogen as a substitute for protein; but for some reason, urea was not satisfactory as a source of part of the protein in lamb-fattening rations. Further feedlot trials with practical fattening rations containing urea are underway.

Ewes made good use of urea nitrogen. In two different years, urea was used to supply one-third of the total nitrogen in the concentrate feed of ewes during the last 115 days of pregnancy and the first 42 days of lactation. Gains and fleece weights of ewes, and the 42-day weights of their lambs were only slightly less than those for ewes fed an equivalent amount of cottonseed meal.

Other Feeds Used With Urea

In metabolism tests, low-protein roughages such as non-legume hay and cottonseed hulls were not efficiently supplemented with urea alone. Much of the nitrogen in the urea was wasted unless some carbohydrate feed such as a cereal grain was added to the ration.

Corn, milo, barley, dehydrated sweet potatoes, molasses, and combinations of corn and molasses were approximately equal in promoting the efficient use of urea nitrogen in fattening rations.

Different protein concentrates, such as cottonseed meal, soybean meal, and corn gluten meal, were equally well supplemented by urea in fattening rations.

Urea feeding had no effect on the normal metabolism of calcium, phosphorus, and vitamin A by sheep. Its favorable effect on the digestibility of low-protein rations was the same as that of other high-protein supplements.

Small amounts of methionine, a sulfur-containing amino acid found in high-quality protein, slightly increased the value of urea in sheep rations.

Feeding Trials In Metabolism Stalls

Rations containing urea have been tested in a series of feedlot, pasture, and nitrogen balance trials with both cattle and sheep. The nitrogen balance trials, conducted in metabolism stalls on the Oklahoma A. & M. College campus, permitted determination of the digestibility of the various nutrients in the ration and afforded a means of determining the relative efficiency of utilization of the urea nitrogen.

The feedlot trials, which provided information of a practical nature, were meant to duplicate, insofar as possible, conditions found in practical livestock feeding operations. Results of these trials are reported on pages 11 and 12 and 20 to 30.

In making nitrogen balance studies, steers or wethers are confined in specially constructed stalls which permit collection of all excreta and accurate measurement of the amount of feed eaten. From chemical analysis of the feeds and excreta, it is possible to calculate the digestibility of the rations, the biological value of the total nitrogen in the rations, and the utilization of the urea nitrogen.

Supplementing Prairie Hay

The first series of balance trials compared cottonseed meal, pure urea, Two-Sixty-Two and a pelleted mixture of hominy feed, molasses, and urea as protein supplements when fed with 10 pounds of prairie hay to yearling steers weighing about 500 pounds. The different supplements were fed in amounts which supplied similar amounts of nitrogen, roughly equivalent to that contained in 1.5 pounds of cottonseed meal.

When the hay was fed unsupplemented, the steers refused approximately 10 percent of the daily allowance. Addition of each of the supplements increased hay consumption and increased the amount of nitrogen (protein) retained by the animals. From observations in these and related experiments, it was evident that the urea was of value as a protein supplement, but should be fed at the lower levels. Consequently, in a second series of trials, three pelleted supplements were prepared in which urea supplied only 25, 50, and 75 percent of the total nitrogen. The three pellets were compared with 2.25 pounds of cottonseed meal, when fed on an equivalent protein basis, as supplements to 10 pounds of prairie hay.

Pellets in which urea supplied 25 and 50 percent of the nitrogen resulted in nitrogen retentions similar to cottonseed meal. These higher retention values, as compared with those of the first trial, are ascribed in part to the higher energy content of the ration, as well as to the decreased proportion of total ration nitrogen supplied by urea. The 75-percent urea pellet supplied urea in excess of that recommended for satisfactory use in rations of this type. Repetition of these trials with lambs fed similar rations as those fed the steers yielded essentially the same results. (1,2)*

Supplementing Maintenance, Wintering and Fattening Rations

As a further test of the value of urea nitrogen in the 25- and 50-percent pellets, balance trials were made comparing these pellets with similar ones containing the same feed but no urea, and therefore less nitrogen. All pellets were fed as supplements to hay in maintenance- and wintering-type rations, and as supplements to corn and hay in fattening-type rations. Steers were fed one pound of supplement per day in the maintenance rations, three pounds in the wintering rations, and slightly over one pound in the fattening rations. Lambs were fed similar rations in the same proportion, but only 14 percent of the quantity fed steers.

Nitrogen retention by the steers and lambs on each type of ration was increased by the additional nitrogen supplied by urea in the supplements. The 50-percent pellet was as efficient as the 25-percent pellet in most trials. In one balance trial with wintering rations, steers refused to eat their daily supplement allowance of three pounds of the 50-percent pellet, supplying 112 grams of urea per day. Apparently this amount of urea is too great for satisfactory use in rations composed largely of dry roughage. The total nitrogen content of this ration was equivalent to 18 percent protein, whereas the other urea rations contained 14 percent or less. (3)

Frequency of Feeding

The possibility that urea utilization is affected by frequency of feeding was investigated by feeding the 25-percent pellet twice daily in one series of balance trials and on alternate days in another. The amounts fed with 10 pounds of prairie hay were equivalent to three pounds of supplement daily. The steers fed twice daily retained 15.7

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* Numbers in parentheses refer to publications giving complete details of the experiment. See page 35.

grams of nitrogen as compared to 13.1 grams by those fed on alternate days. Although this difference was not statistically significant, it is believed from observations made in other experiments that lengthy intervals between feedings are unfavorable for efficient nitrogen utilization. (3)

Urea With Various Carbohydrate Feeds

Among the questions raised in connection with the use of urea in cattle rations are those relating to its practical value in high-roughage rations. Readily-digestible carbohydrate feed appears to be necessary in such rations to facilitate conversion of the urea nitrogen to protein by rumen organisms.

Apparently some carbohydrates are more valuable than others for supplementing high-roughage rations which include urea. Therefore several experiments were conducted with steers to determine the comparative value of some of the commonly-used carbohydrate feeds for this purpose.

The feeds selected for supplementation with urea were corn, barley, milo, dehydrated sweet potatoes, and different combinations of corn and molasses. These feeds were used separately to formulate fattening rations containing about 7 to 8 percent protein. Each ration was supplemented with urea to increase its protein equivalent to 10 percent because previous studies had shown that urea nitrogen utilization could best be measured when it supplied less than 35 percent of the total ration nitrogen.

The results of these metabolism studies showed that the urea nitrogen in all rations was well utilized, regardless of the type of carbohydrate feed it supplemented. In one series of trials with corn and sweet potato rations, approximately 50 percent of the added urea nitrogen was retained by the steers. In rations containing molasses as a complete or partial (50 percent) replacement for corn, the digestibility of the total nitrogen was less, and it was less efficiently used, than that in rations containing only corn as the carbohydrate feed. (4)

Urea With Various Protein Concentrates

The possibility that urea can be more effectively used with some protein concentrates than with others has been suggested in the work of other investigators. To test this possibility, three low-protein rations were supplemented with equal amounts of urea and fed to lambs in nitrogen balance experiments. One ration was made up with cottonseed meal, another with soybean meal, and a third with corn gluten meal. The other constituents in all three rations were cottonseed hulls, corn, purified carbohydrates, fat, and minerals. The urea supplement increased the protein content of each ration from 7.8 percent to the equivalent of 10.6 percent.

When the lambs were fed these rations without the urea supplement, they retained about one gram of nitrogen (equivalent to 6.25 grams of protein) per day. With the addition of urea to the rations, they retained over two grams per day. The increases in nitrogen retention effected by urea were unrelated to the source of protein concentrate in the rations. Further additions of urea to produce rations over 12 percent protein equivalent failed to induce further increases in nitrogen retention. Apparently the proportion of urea nitrogen (over 40 percent of the total) was too high in these latter rations for efficient utilization. (5)

Methionine in Urea Rations

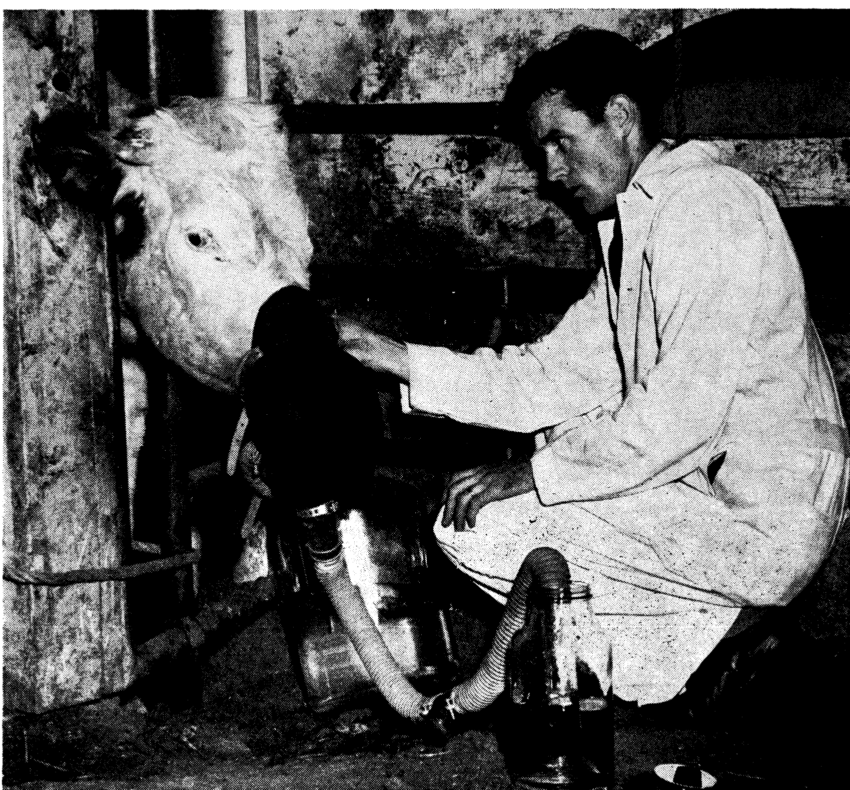
Low-protein rations containing urea are apt to be deficient in methionine. This is a sulfur-containing amino acid required by animals and present in only limited amounts in many feed proteins. Although ruminants are able to synthesize this amino acid, their demand at times may exceed the amount synthesized.

To determine the value of supplementing low-protein and urea rations with methionine, nitrogen balance trials were carried out with lambs fed a 7-percent protein ration and a 10-percent protein ration. These rations were composed of cottonseed hulls, corn, cottonseed meal, and a mineral mixture containing inorganic sulfur and trace elements. In the 10-percent ration, the equivalent of 30 percent of the total protein was supplied by urea. Both rations were fed with and without supplements of methionine. The amount of methionine added to each ration ranged from 1.6 to 6 grams per day.

In these experiments, addition of methionine to the low-protein ration was of little or no value. When methionine was added to the urea ration, however, it produced a small increase in the average digestibility of ration nutrients and a small increase in nitrogen retention. Crude fiber digestibility was increased from 41 to 48 percent, and protein digestibility was increased from 51.8 to 56.3 percent. Nitrogen retention, expressed as a percentage of the intake, increased from 18.2 to 21. Although these differences were too small to have statistical significance, the trend of results suggests that supplemental methionine may be of greatest value in rations containing a large proportion of non-protein nitrogen such as urea. (6) Tests with fattening lambs also gave evidence of the beneficial effect of methionine supplements.(7)

Urea and the Utilization of Phosphorus

The minimum daily phosphorus requirement of fattening lambs is believed to be close to two grams per 100 pounds of body weight. To determine the possible effect of urea on this requirement, a series of phosphorus balance trials was conducted with lambs weighing about 65 pounds. In each trial four or more lambs were fed a basal ration of known phosphorus content without urea, and an equal number of lambs was fed the same ration supplemented with urea. In different trials, the rations supplied from 0.86 to 1.90 grams of phosphorus per day. Urea furnished from 12 to 35 percent of the total nitrogen in



The contraption on the steer's nose is a gas mask. It was used to detect the presence of ammonia in gases given off by steers fed urea. Feeding too much urea at one time may lead to excess ammonia production and disastrous results. Urea nitrogen is most efficiently utilized when it supplies up to, but not much more than, 30 percent of the total nitrogen in a fattening-type ration (See Page 9).

the supplemented rations. The amount of phosphorus retained by the lambs on each basal and corresponding urea-supplemented ration was determined from chemical analyses of feeds and excreta.

The results showed that about 1.4 grams of phosphorus, or slightly over two grams per 100 pounds body weight, was required to maintain the lambs in phosphorus equilibrium. The presence of urea in the ration did not affect this requirement. (8)

Urea and the Utilization of Vitamin A

Vitamin A is of special importance in the rations of cattle and sheep. It is usually supplied in the ration as carotene, a yellow pigment present in green feeds, which is converted by the animal to vitamin A. This conversion and the efficient use of vitamin A by the animal is influenced somewhat by other nutritional factors and by other ration constituents. Several experiments 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.

As a general plan in these experiments, lambs were partially depleted of their body stores of vitamin A by feeding a low-carotene ration for a period of about 100 days. Following this depletion period they were divided into four groups. Group 1 was fed a ration containing cottonseed meal. Group 2 was fed a similar ration with half of the cottonseed meal replaced by urea and carbohydrate feed. Group 3 was fed a ration containing soybean meal, and Group 4 was fed a similar ration with half of the soybean meal replaced by urea and carbohydrate feed. The lambs in all groups were individually fed equal, but limited amounts of vitamin A daily. In some experiments the vitamin A was supplied as fish liver oil, and as carotene in others.

Periodic determinations were made of the amount of vitamin A in the blood plasma of the lambs in each group, and determinations were made of the amount of vitamin A stored in their livers at the termination of the experiment. These values showed that the lambs fed the cottonseed meal rations stored slightly more vitamin A in the liver than those fed the soybean meal rations. Partial replacement of either of these protein supplements in the ration by urea did not affect the efficiency of utilization of vitamin A. (9)

Feedlot and Pasture Tests With Cattle

The value of urea as a substitute for part of the protein in rations for fattening calves in dry lot was determined in trials conducted each year over an 8-year period. In most of these trials, the 25- and 50-percent pellets were compared with cottonseed meal; in two trials an 85-percent pellet was fed. The 85-percent pellet was made up of either corn or hominy feed, 10 percent molasses, bone meal, and sufficient urea to provide the equivalent of about 43 percent crude protein. The composition of the 25- and 50-percent pellets is given on page 11.

From 1944 to 1952, seven wintering trials were conducted with steers and heifers on dry, native range grass supplemented with the 25-percent pellet. One wintering trial was conducted with pregnant cows and breeding bulls.

Fattening Trials with Beef Calves

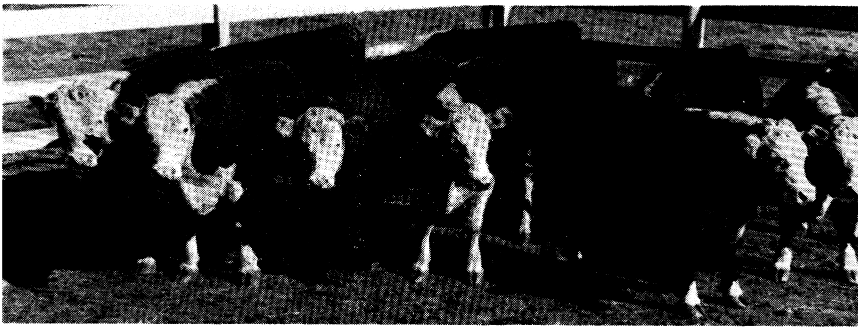
During the 8-year period, a total of 210 steers and heifers were used. Most of the cattle were steer calves purchased annually from a large commercial herd in the state. In four trials, part of the calves came from the experimental herd. With the exception of one trial, where yearling steers were used, the calves were approximately 7½ months of age when placed on test.

How the Tests Were Made

The calves were given a preliminary period of about three weeks before the start of each trial to recover from weaning and become accustomed to the ration to be fed. They were then divided into uniform lots of 10 calves each on the basis of weight, sex, grade and expected outcome.

The calves were worked up to a full feed of grain within six weeks after the start of the trial. Thereafter, they were fed as much corn as they would clean up by the next feeding. Salt, and a mineral mixture of equal parts of salt, ground limestone and bone meal were available to the steers at all times.

In each trial, cottonseed meal or cake was used to supplement the grain ration of calves in the control lot. The same amount of pelleted feed supplement in which urea supplied 25, 50 or 85 percent of the



In fattening trials, calves fed urea containing supplements produced gains equal to those produced by the common plant protein supplements (See pages 11 and 20).

total nitrogen (crude protein) was offered to the calves in the experimental lot. The amount of protein supplement fed varied somewhat from trial to trial, depending in part on whether there was alfalfa hay in the ration, but was within the range of 0.5 to 2 pounds per steer daily. The total protein content of the supplements was equivalent to 40 to 45 percent. The length of the feeding period ranged from 153 to 181 days. An average of three consecutive daily weights taken during the afternoon was used as the initial and final weights for each trial.

The feeding procedure was the same with the exception of the first three trials. In these, the steers were placed on a self-feeder of grain when safely on feed. Prairie hay was fed once daily and the protein supplement was placed each day in the trough of the self-feeder. In the other trials, one-half the daily allowance of grain, protein supplement and sorghum silage were fed morning and evening. One pound of alfalfa hay per steer was fed once daily—at the time of the morning feed—in the latter trials.

Results of the Feeding Trials

The data on weight gains of the cattle, average daily rations and feed required per hundredweight gain are given in Table I. The appraised value or the actual selling price of the cattle, where available, is also shown. Carcass data were not complete for each trial and therefore are not included.

It is evident from the weight gains that the pelleted feed mixtures containing 25 and 50 percent of their crude protein as urea were satisfactory protein supplements in these trials. There was little difference between lots in grain consumption or in feed required to produce 100 pounds of gain. Average daily gains were nearly identical. However,

Table I.—Summary of Feeding Trials Comparing Urea Supplements With Cottonseed Cake In Rations for Fattening Steer Calves.*

Level of Substitution†	25 Percent Urea N		50 Percent Urea N		85 Percent Urea N	
Protein Supplements	C. S. Cake	Urea Pellets	C. S. Cake	Urea Pellets	C. S. Cake	Urea Pellets
Number of trials	4	4	7	7	2	2
Total number of calves**	39	40	69	70	15	15
Avg. length of feeding trial, (days)	163	163	168	168	166	166
Avg. weights (lbs.)						
Initial	465	461	479	476	488	486
Final	790	786	816	810	833	779
Avg. daily gain	2.00	2.00	2.01	1.99	2.08	1.76
Avg. daily ration (lbs.)						
Ground shelled corn††	11.08	10.96	11.19	11.08	12.18	11.15
Cottonseed cake	1.70	-----	1.33	-----	1.32	-----
Urea pellets	-----	1.67	-----	1.27	-----	1.21
Alfalfa hay	1.00	1.00	1.00	1.00	1.00	1.00
Prairie hay***	1.95	1.95	1.95	1.95	2.51	2.21
Sorghum silage	9.49	9.60	7.76	7.71	7.72	7.50
Salt and mineral	.04	.04	.06	.06	.07	.04
Feed required per cwt. gain (lbs.)						
Concentrates	649	638	628	624	660	727
Roughages	300	305	333	332	324	360
Feed cost per cwt. gain (dollars)	21.33	21.38	19.65	19.48	21.18	22.76
Avg. selling price per cwt. (dollars)†††	27.13	26.62	28.80	28.75	33.40	32.40

NOTE: Annual Reports from which this table is summarized are found in the following publications of the Oklahoma Agricultural Experiment Station: Mimeographed Circulars M-127 (1944) and M-136 (1945); Bulletin B-296 (1946); and Miscellaneous Publications MP-11 (1947); MP-13 (1948); MP-15 (1949); MP-17 (1950); MP-22 (1951); MP-27 (1952), and MP-31 (1953).

* In two trials in which the 25- and 50-percent urea pellets were compared to cottonseed cake (1944-45 and 1945-46), an equal number of steer and heifer calves was used in each lot. In the first trial with 85-percent urea pellets (1944), five yearling steers per lot were used. In all other trials, steer calves approximately 7½ months of age were used.

† Percentage of total nitrogen supplied by urea in the urea pellets. The composition of the pellets is given on pages 11 and 19.

** In four trials (1944 to 1948), 25- and 50-percent urea pellets were compared simultaneously with cottonseed cake. For ease of comparison in this table, the basal cottonseed cake lot for these years is repeated in the data presented.

†† In one trial with the 85-percent urea pellets (1944), the grain fed was a mixture of corn, wheat, and oats.

*** Prairie hay was the only roughage fed in two trials with 25- and 50-percent urea pellets (1944-45 and 1945-46), and in one trial with 85-percent urea pellets (1944). In all other trials, 1.0 pound of alfalfa hay and a limited amount of sorghum silage was fed per steer daily. The amounts shown in this table are the average daily consumption for the trials in which the roughages were fed.

††† Average selling price per hundredweight is either the appraised value given the lot at the completion of the trial, or the actual selling price on the Oklahoma City market. No market value was available for cattle in the 1945-46 trial with 25- and 50-percent urea pellets, nor for the 1944 trial with yearling steers fed the 85-percent pellets.

the urea-fed cattle sold at a slightly lower price than those fed cottonseed meal. Due to the cost of preparing the urea supplement, feed cost per hundredweight gain was about the same for the urea-fed steers as for those fed cottonseed cake.

In contrast, when 85-percent urea pellets were fed and compared to cottonseed meal, gains were reduced by 0.32 pound per steer daily, and the concentrates necessary to produce 100 pounds of gain were increased by 67 pounds. Likewise, the roughage requirement was also increased and the feed cost per hundredweight gain was $1.58 more than for the cottonseed meal lot. The selling price of the cattle was also decreased. The 85-percent urea pellets proved to be slightly unpalatable and this may have adversely affected grain consumption.

Thus it would seem from these results that urea can be used to replace 25 and 50 percent of the total nitrogen of the protein supplement without adversely affecting the gains and performance of fattening cattle. In such supplements, it is necessary to use some carbohydrate feed such as ground corn or hominy feed to make up the difference in energy. In addition, a small amount of molasses (10 percent or so) helps prevent settling out of the urea from the mixture, helps improve the palatability of the supplement, and may provide additional factors which favor urea utilization.

Although the 85-percent pellets in these trials were considerably cheaper than cottonseed meal, the poor performance of the cattle fed this urea supplement resulted in less profit from the feeding operation. It should be borne in mind that in fattening rations of this type, the cost of grain is by far the most expensive part of the total feed cost and that the efficiency with which steers utilize grain largely determines the profit or loss from the feeding operation.

Wintering Steers and Heifers on the Range

For three successive years, yearling Hereford heifers weighing from 640 to 700 pounds were divided into two groups and wintered on dry native grass and protein supplements for 100 to 148 days. The heifers in one group were fed a supplement of cottonseed meal and those in a corresponding group were fed the pelleted supplement with 25 percent of its nitrogen (crude protein) as urea. The two supplements, which contained equal amounts of protein, were fed every other day in amounts equivalent to 2.45 pounds per head daily. (1,10)

In another test in 1948, heifer calves were wintered on the range with cottonseed meal and 25-percent urea pellets for 141 days. (11)

In a third comparison, two-year-old steers were wintered on dry, native grass and approximately three pounds of cottonseed cake or urea pellets in three successive years. (12) In all trials, the cattle had access to salt and a mixture of two parts salt and one part bone meal.

The results of these wintering trials are shown in Table II. Steers or heifers fed the 25-percent urea pellets wintered as well as those fed an equal amount of cottonseed meal, with the exception of the single trial with heifer calves in 1948. In the case of the heifer calves, winter gains were somewhat reduced when the 25-percent urea pellets were fed.

It is recognized that the proper amount of protein supplement for winter rations is more important for a weanling calf than for older animals, therefore a difference in winter gains produced on weanling calves should be a critical test of the relative feeding values of the supplements being compared. Further, the level of protein supplement fed in the trials with yearling heifers and two-year-old steers was quite high, and it is possible that the natural protein in the urea pellets may

Table II.—Wintering Heifers and Steers on Dry Native Grass with Supplements of Cottonseed Meal and 25-Percent Urea Pellets; Summary, 1944-1950.

	Cottonseed Meal	25-Percent Urea Pellets
Wintering Yearling Heifers (Avg. of 3 trials, 130 days)		
Total number of heifers	26	25
Avg. daily supplement fed (lbs.)	2.48	2.46
Avg. weights (lbs.)		
Initial	675	671
Final	709	713
Total gain	34	42
Avg. daily gain	0.26	0.32
Wintering Heifer Calves (one trial, 141 days)		
Total number of heifer calves	10	10
Avg. daily supplement fed (lbs.)	2.57	2.54
Avg. weights (lbs.)		
Initial	419	419
Final	484	468
Total gain	65	49
Avg. daily gain	0.46	0.35
Wintering Two-year-old Steers (Avg. of 3 trials, 144 days)		
Total number of steers	30	30
Avg. daily supplement fed (lbs.)	3.14	3.08
Avg. weights (lbs.)		
Initial	875	875
Final	877	880
Total gain	2	5
Avg. daily gain	0.02	0.04

have approached the minimum requirements of the cattle. Thus, in these tests the urea pellets may not have been fed at a critical level. Further trials are being conducted with heifers to study urea utilization in range supplements.

In the Breeding Herd

In further tests during the 1946-47 season, 10 pregnant beef cows were satisfactorily wintered on dry range grass and a daily supplement of three pounds of the 25-percent urea pellet. (13) No difficulties were encountered with any of the cows.

Eight head of breeding bulls were wintered on the range and fed an average of 2.9 pounds daily of 25-percent urea pellets as a supplement to 2.9 pounds of ground corn, 2.9 pounds of oats, and 12.1 pounds of prairie hay. The bulls gained satisfactorily during the 140-day wintering period and breeding efficiency was not impaired the following season. (14)

Tests With Sheep

Pregnant and Lactating Ewes

Ewes have a relatively high requirement for protein during late pregnancy and early lactation. Thus, it seemed that with ewes a critical test could be made of the value of urea when added to a low-protein ration. The performance of ewes so fed was compared to that of ewes receiving the same low-protein rations supplemented with cottonseed meal. (7,15)

How the Tests Were Made

Fine-wool ewes of Texas origin, four and five years of age, were used during the two-year test. They were drenched with phenothiazine and bred to a purebred Hampshire ram. During the breeding period, the ewes were fed a liberal ration of oats, cottonseed meal and alfalfa hay. When it was apparent that most of the ewes were bred, they were started on the experimental rations.

In the first trial, the ewes were divided equally into three lots on the basis of body weight. In the second trial, allotment was made according to body weight and previous lamb-production records.

The experimental rations were fed for approximately 115 days before lambing and during the first 42 days of lactation. Ewes of all lots received two pounds per head daily of fair-quality prairie hay as the roughage. In addition, each ewe received about one pound of pelleted feed daily during pregnancy and during the first seven days of lactation. From the seventh to the 42nd day of lactation they were fed two pounds of pellets. The pelleted feeds were:

Lot 1 — Low-protein pellets containing 10.6 percent crude protein made up of 84 percent ground corn, 4 percent cottonseed meal, 10 percent molasses, and 1 percent minerals.

Lot 2 — Urea pellets containing the same feeds as Lot 1, but with 2.1 percent urea added at the expense of corn to raise the crude protein level to 15.6 percent.

Lot 3 — Cottonseed meal pellets containing the same feeds as Lot 1, but with an increased proportion of cottonseed meal to provide 15.3 percent crude protein.

The pelleted feeds were approximately equal in energy. Dicalcium phosphate was added to the pellets fed Lots 1 and 2 to provide the same phosphorus content as contained in the pellets for Lot 3. In addition, the ewes had access at all times to a mineral mixture of two parts salt and one part steamed bone meal. The ewes were fed their respective pelleted feeds in individual stalls during the first trial, but were group-fed during the second trial.

The ewes were weighed as soon as possible after lambing and removed to individual pens for seven days. The lambs were weighed at birth and at 42 days of age. Final weights of the ewes and their lambs were taken at the end of 42 days of lactation. The ewes were sheared after they had completed the lactation phase.

The average weight changes of the ewes during the experiment, their fleece weights, and lamb production records are shown in Table III.

Results of the Tests

Ewes fed the urea and cottonseed meal pellets (Lots 2 and 3) gained significantly more weight during pregnancy and lost less during the

Table III.—Average Weight Changes, Fleece Weights and Lamb Production Records of Ewes Fed Urea and Cottonseed Meal as Sources of Supplemental Protein.
(Average of Two Trials)

	Lot 1 Low-Protein Pellets	Lot 2 Urea Pellets	Lot 3 Cottonseed Meal Pellets
Total number of ewes per lot			
Gestation phase	17	19	19
Lactation phase	14	18	17
Average ewe weights (lbs.)			
Initial weight	112	111	110
Weight after lambing	111	117	118
Gain or loss during gestation	−1	+6*	+8*
First day of lactation	115	118	117
42nd day of lactation	109	116	116
Gain or loss during lactation	−6	−2	−1
Average fleece weight (lbs., grease)	7.8	8.6	8.9
Number of lambs born			
Singles	10	12	16
Twins	14	14	6
Average birth weight (lbs.)			
Singles	10.3	11.1	10.8
Twins	8.7	8.7	9.2
Number of lambs raised**	14	18	17
Avg. birth weight (lbs.)	9.7	10.3	10.4
Avg. 42-day weight (lbs.)	30.0	34.6	35.5
Gain, birth to 42 days (lbs.)	20.3	24.3	25.1
Avg. daily lamb gain to 42 days (lbs.)	0.48	0.58*	0.60*

* Differences in favor of Lots 2 and 3 over Lot 1 were significant at the 1 percent level.
** Ewes with twins were given the larger lamb to raise as a single.

first 42 days of lactation than did ewes fed the low-protein pellets (Lot 1). In addition, they sheared heavier fleeces, maintained better appetites throughout the trial, and appeared in thriftier condition at the close of the trial.

That the ewes of Lot 1 were fed a ration inadequate in protein was indicated by their inability to gain during pregnancy, a greater loss of body weight during lactation, lack of appetite toward the end of the experiment, and a number of "breaks" in their wool (i.e., weak spots in the wool fiber often caused by low-protein rations).

There was no consistent difference in birth weights of the lambs within the twin and single groups. Lambs from ewes fed the urea and cottonseed meal pellets, however, made significantly greater gains to 42 days of age than lambs nursing ewes fed the low-protein pellets.

Although there were only slight differences in the average performance of ewes fed the urea pellets (Lot 2) as compared to those fed cottonseed meal pellets (Lot 3), these differences favored the latter group in every case. This suggests that the value of urea as a source of crude protein in this experiment approached, but did not equal, that of cottonseed meal.

Under practical farm conditions, the amount of concentrates normally fed ewes before lambing is somewhat less than was fed here. Rations of the type used in this experiment might be further improved by the addition of a small amount of legume hay. However, results of other tests reported elsewhere in this publication (pages 15 and 16) indicate that urea is best utilized when added to a ration inadequate in protein. The addition of legume hay would increase the protein content of the ration and the value of added urea would be reduced. The rations fed Lots 2 and 3 in these trials maintained the ewes in strong, healthy condition and their lambs made satisfactory gains to 42 days of age.

Fattening Lambs

Protein supplements are necessary when fattening lambs are fed grain and a non-legume roughage such as prairie hay. Nitrogen balance studies reported previously (pages 15 to 18) have shown that lambs can use urea as a protein substitute. Two feeding trials were conducted to study the value of urea in comparison to cottonseed or soybean meals as supplements to a low-protein ration for fattening lambs. (7,15)

How the Lambs Were Handled

Crossbred lambs averaging 4½ months of age were used in these experiments. The lambs were out of fine-wool ewes and sired by Hampshire or Suffolk rams. In each trial, three lots of 12 lambs each were fed three different rations. The lambs were divided into lots on the basis of breed, weight, and sex. Each lot contained an equal number of wether and ewe lambs.

The feeding trials in both 1951 and 1952 extended from the early part of July to the first part of October. The lambs were shorn a week previous to the start of the experiment and drenched with phenothiazine. They were housed at the experimental barn in pens which opened on small exercise lots.

The lambs of Lot 1 were fed a low-protein ration of corn, oil meal, beet pulp and prairie hay (8.1 percent crude protein). Lot 2 was fed the same ration, plus sufficient urea to increase the crude protein level of

Table IV.—The Value of Urea in Fattening Rations for Lambs; Average of Two 95-day Trials.

	Lot 1 Basal	Lot 2 Basal+ Urea	Lot 3 Basal+ Protein Supplement
Total number of lambs per lot	24	24	24
Average weights (lbs.)			
Initial	57	56	56
Final	90	89	93
Total gain	33	33	37
Avg. daily gain	0.35	0.35	0.39*
Average daily ration			
Corn (lbs.)	1.50	1.50	1.42
Oil meal (lbs.)**	.11	.11	.27
Dried beet pulp (lbs.)	.17	.17	.17
Prairie hay (lbs.)	.86	.87	.91
Ground limestone (gms.)	2.6	2.6	6.1
Bone meal (gms.)	4.7	4.7	----
Urea ("Two-Sixty-Two") (gms.)	----	12.3	----
Crude protein in ration (percent)	8.14	10.68	10.22
Feed per cwt. gain (lbs.)			
Corn	430	426	367
Oil meal	31	31	70
Dried beet pulp	49	49	44
Prairie hay	252	251	237
Urea	----	8	----
Feed cost per cwt. gain (dollars)	17.65	18.05	17.00
Selling price per cwt. (dollars)	26.00	25.54	25.41

* Significant at the 5 percent level.
**Cottonseed meal was fed in the first trial, and soybean meal in the second.

their ration to 10.5 percent. The daily intake of urea was 12.3 grams for lambs of this lot. In the ration fed Lot 3, the proportion of oil meal was increased to provide a crude protein content equal to that of the urea ration fed Lot 2. The lambs were hand-fed twice daily, with one-half of the daily allowance offered at each feeding.

Corn was full-fed according to appetite in the first trial. In the second trial, corn was full-fed to Lots 1 and 2, but the amount fed to Lot 3 was limited at a level which provided the lambs in the three lots with approximately equal amounts of energy from the concentrate mixtures.

Beet pulp was included in the ration to increase the palatability. It was weighed out dry, then moistened, and allowed to stand about 12 hours before feeding. Refused hay was weighed back at the time of the evening feeding. The calcium and phosphorus content of all rations was equalized by addition of the required amount of ground limestone and bone meal. Salt containing one ounce of cobalt chloride per 100 pounds was available to the lambs at all times.

The initial and final weights of the lambs were obtained from the average of two consecutive daily weighings. The lambs were weighed before the morning feeding after an overnight period without water.

Results of the Feeding Trials

Average results obtained in the two trials are shown in Table IV. Lambs of Lot 3—fed the basal ration with oil meal added to raise the crude protein level to approximately 10.5 percent—made the fastest gains and required the least corn and roughage per 100 pounds of gain. Feed costs per 100 pounds of gain were lowest for this group. However, the lambs of Lot 1 were the most profitable. This was due to the fact that one lamb in Lot 2 and three lambs in Lot 3 were noticeably inferior to the other lambs in these lots.

The lambs of both Lots 1 and 2 made satisfactory gains. The addition of about one-half ounce of urea (12.3 grams) to the daily ration fed lambs of Lot 2 did not increase the rate of gain in these tests. The additional cost of the urea resulted in higher feed costs per lamb for this group than for either Lot 1 or Lot 3.

From these summer fattening trials, it appears that the lambs used to advantage a protein supplement supplied as oil meal, but under the same conditions failed to make efficient use of urea. The fact that the lambs of Lot 1 made satisfactory gains on a basal ration containing only

8.1 percent crude protein may have obscured any benefit derived from the urea.

Oil meals, however, contain feed factors other than protein, and it is reasonable to believe that these factors (minerals and associated nutrients) which are not present in urea contribute to the value of oil meals as supplements to low-protein rations.

These results are in agreement with several reports from other experiment stations, yet are not in agreement with the results of Oklahoma Station feeding trials with mature ewes (pages 26 and 27) or metabolism trials with wethers (pages 15 to 18) which demonstrated the utilization of urea by sheep. Further, they are not in agreement with the results obtained in wintering and fattening beef cattle on urea rations (pages 19 to 24). It seems necessary, therefore, to continue experimental work on means of increasing urea utilization by fattening lambs before the compound can be widely recommended as a protein substitute in this phase of livestock production.

The Effect
Of Large Amounts of Urea

The question of whether feeds containing large amounts of ure can cause injury to cattle and sheep is often raised by livestock producer This problem was investigated in experiments with calves and olde steers.

Continued Feeding of Large Amounts

In these trials urea was fed in various combinations with molasse Molasses was used because urea could be readily mixed with it. Also, i is palatable and tends to "mask" the taste of urea. Five or six pounds o prairie hay were fed daily in addition to the urea-molasses mixture Steers would eat only sparingly of mixtures containing more than part urea to 5 parts molasses. In one trial two steers were fed eigh pounds daily of a 1 to 5 and a 1 to 6 urea-molasses mixture for 18 days Close observation of these animals and tissue analysis gave no indicatio that urea fed at these levels with molasses and hay was harmful. How ever, it should be emphasized that these animals always had feed befor them. They consumed their feed slowly. At each feeding there wa some refusal—approximately one pound of the mixture daily. It wa calculated that these steers consumed approximately 530 grams and 45 grams (one pound) of urea daily or about 100 grams per 100 pounds liv weight. This amount is several times more than the maximum amoun usually recommended for good results (not over 1/3 of the total nitroge nor more than three percent of the concentrate mixture).

Previous studies have shown that when urea is properly mixe with the concentrate portion of the ration at rather low levels, cattl can be fed large quantities without danger of toxicity. (1) In one ex periment, five steer calves were individually full-fed on a pelleted fee containing 4 percent urea by weight (25 percent of the total nitroge as urea) with prairie hay *ad lib.* The five calves averaged 455 pound at the beginning of the 14-day feeding period and consumed over 1C pounds of the pellets daily. They gained an average of one pound pe day during the experimental period, and it was calculated that they had consumed 0.37 pound of urea daily. This amount of urea wa equivalent to about 2.2 percent of the dry matter eaten. No evidence of toxicity or other abnormalities were noted.

Feeding Large Amounts after Fasting

Contrary to the above results, isolated reports from farmers in the state indicated that under certain feeding conditions urea caused trouble. It is known that forced feeding of urea is harmful.

Additional studies were carried out with steers that were fasted for two days and then offered 4 pounds of a molasses feed containing the equivalent of 7.5 grams of urea per 100 pounds body weight. When urea was gradually increased (2.5 grams per 100 pounds of body weight after each fasting period) and the amount of molasses held constant, a level of 15 to 20 grams per 100 pounds body weight was reached, after which the steers would refuse to eat the mixture. It was concluded, therefore, that the previous taste, or effect, of urea caused the steers to refuse to consume further quantities in mixtures containing a high proportion of urea. If, however, steers that had not previously been fed urea were fed the molasses mixture containing about 20 grams of urea per 100 pounds body weight, after two days of fasting, symptoms of poisoning appeared in 15 to 20 minutes. Toxicity symptoms and tissue changes produced in this manner were studied in seven calves. Two of these animals died and five recovered.

Toxicity Symptoms and Treatment

Shortly after rapid ingestion of a concentrated urea-molasses mixture the affected animal appeared uneasy, tended to kick at his flank, and showed muscular tremors. This was followed by incoordination, staggering and depression. The animal usually went down 30 to 45 minutes after eating the feed. The most noticeable symptoms while prostrate were severe tetanic convulsions and bloating. The tendency to bloat was evident in animals allowed to consume high levels of urea after fasting; however, it was not observed in other studies when large amounts of urea were force-fed.

In two animals, death occurred in two to three hours. On autopsy of these animals, there were no characteristic gross tissue changes. A strong ammonia odor was present in the rumen contents. Death was believed due to high levels of ammonia in the blood (8 milligrams per 100 cubic centimeters). Of the five animals that recovered, only two showed pronounced toxicity symptoms. Once toxic symptoms were pronounced, various substances were used in an attempt to treat the condition. Intravenous injection of calcium-gluconate with dextrose, together with a commercial product* seemed to be of definite value. However,

* Fort Dodge Laboratories, Ft. Dodge, Iowa. Contains sodium thio-sulfate, dextrose, and trypan blue.

this treatment did not appear to be of any value in other trials when large amounts of urea were force-fed. This difference may be due to the fact that in the forced-feeding experiments much higher levels of urea were given. It was concluded that rapid consumption of urea in amounts exceeding approximately 20 grams per 100 pounds of body weight will produce toxic symptoms in cattle that have been fasted or given limited feed.

In further investigations to study the toxic symptoms which follow rapid consumption of urea or its forced administration, water solutions of urea were given orally to cattle by means of a rubber tube. Urea in amounts over 100 grams when given in this manner proved toxic to 500-pound yearling steers. It produced a rapid increase in blood ammonia. (16, 17)

Summary

In summary, it may be said that urea may produce harmful effects under certain unusual feeding conditions. These conditions would be: (1) Starved or fasted animals; (2) rapid consumption of urea-containing feeds ("hoggish" appetite of individual animals), and (3) the animals having not previously been fed urea-containing feeds.

The amount of urea that can be fed and also the detrimental effects that may occur will probably vary somewhat. For example, it

Rapid consumption of feeds containing large amounts of urea improperly mixed may produce harmful effects. Urea toxicity was experimentally produced in this animal. Symptoms of bloating, convulsion, and prostration are noted (See page 32).

has been demonstrated that larger amounts of urea can be fed in the presence of carbohydrate feed than in its absence. Also, animals accustomed to a high-protein ration can apparently handle larger amounts of urea than those which have been subsisting on low-protein roughages. From the extensive feeding and metabolism trials reported earlier, together with the toxicity experiments given here, urea toxicity would not be expected in animals that are accustomed to properly-mixed rations containing urea in the recommended amounts.

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