Effective Utilization of Urea by Beef Cattle

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INTRODUCTION

The use of urea as a partial substitute for the protein requirements of ruminants is not new. In 1891 Zuntz recognized and presented evidence that microorganisms in the rumen could synthesize bacterial protein from non-protein nitrogen compounds such as urea. The shortage of natural protein supplements in Germany during World War I led to the extensive use of urea in dairy feeds in 1918 and was widely used in Europe in 1925. Urea was introduced into the United States in the thirties but was not accepted as an ingredient in ruminant diets until the research of Hart and co-workers in 1937. In the early fifties it was shown that urea could effectively replace 25 to 33 per cent of the protein nitrogen in cattle rations. However, the use of urea lagged and was not widely accepted until Beeson et al. (1964a), Garrigus (1964) and Conrad and Hibbs (1967) revealed that urea utilization by ruminants (beef cattle, dairy cattle and sheep) could be improved by combining urea with dehydrated alfalfa meal in a supplement.

Each year urea is replacing a larger per cent of the supplementary protein in cattle and sheep rations. Research at Indiana, Iowa, Illinois, Michigan, Minnesota and Tennessee has shown that 50 to 100 per cent of the supplementary protein can be furnished from urea. However, even with supplements where 90 per cent of the protein equivalent is from urea, only about one-third of the total protein in the ration is supplied from non-protein nitrogen; the remainder is supplied from grain and roughages. Eventually urea and/or other non-protein nitrogen compounds will be used as the major sources of supplementary protein for ruminants.

Today urea or other non-protein nitrogen compounds can furnish 33 per cent of the total protein requirement of beef cattle; higher levels cause a depression in gain and feed efficiency.

In the past seven years the feed use of urea has doubled. The USDA predicts that the domestic sales of urea for feed use are expected to reach a level of 195,000 tons in 1970 — more than three times the 60,000 tons used in 1956.

NITROGEN METABOLISM AND PROTEIN SYNTHESIS

Urea is not a protein. It is only a simple nitrogen compound, NH₄-C-NH₂, from which the microorganisms can obtain nitrogen, synthesize amino acids and finally bacterial protein provided that all the nutrients essential for protein synthesis are present. The use of urea as a substitute for natural protein gave poor and erratic results in its early history because too many workers did not recognize that a complicated array of nutrients are needed for optimum urea utilization.

1/ Part of this information was published in the Proceedings of the Distillers Feed Research Council, Vol. 24, p. 44-51, March 5, 1969, Cincinnati, Ohio

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Figure 1.Nitrogen Metabolism in the Ruminant

Even today (1969) research workers have not discovered all the nutrients or balance of nutrients or rumen conditions which are essential for maximum production when all the nitrogen is supplied by urea. In the past 70 years, scientists have progressed one-third of the way. In order to make urea more useful to the ruminant animal, we need more probing into amino acid synthesis by bacteria and protozoa. In other words, what limits the microorganisms in the rumen from synthesizing all the protein requirements for optimal growth, reproduction and lactation? The maximum practical limit of urea for lactation is only 25 per cent of the total protein needs.

In a simple stepwise fashion, urea metabolism in the rumen is as follows and illustrated in Figure 1.

1. Urea is rapidly converted to ammonia by the bacterial enzyme urease.

2. Ammonia is either utilized by the microorganisms for growth and protein synthesis or absorbed into the bloodstream.

3. The ten essential amino acids for swine and the rat can be synthesized from urea by bacteria in the rumen. Microbial protein has a high biological value.
CONDITIONS ESSENTIAL FOR UREA UTILIZATION

The following conditions are essential for energy utilization:

1. **High level of bacteria population in the rumen**

2. **Slow release of ammonia from urea**

Bartley, at Kansas State University, recently developed (1969) a combination of urea and gelatinized starch (STAREA) which shows promise in slowing up the release of ammonia which theoretically should improve urea utilization.

3. **Too to four weeks adjustment period**

This is necessary for maximum utilization of non-protein nitrogen.

4. **Low level of natural protein in the diet**

Urea utilization is depressed when used with increasing levels of natural protein. Microorganisms prefer the nitrogen from natural protein to non-protein nitrogen because natural proteins such as soybean meal furnish other nutrients which are beneficial to bacterial and protozoan life.

5. **Urea fed simultaneously in a supplement or ration which furnishes all the known nutrients for urea-protein synthesis**

6. **High quality ingredients in high-urea supplements**

This is necessary so the formula will be isocaloric with soybean meal and contain the nutrients necessary for optimal urea utilization. Do not use high-fiber filler feeds in urea supplements such as ground corn cobs, oat hulls, rice hulls, cottonseed hulls, grain screenings, cellulose, paper and sawdust.

7. **High energy-limited roughage rations than on low energy-high roughage rations.**

8. **Urea supplements should be homogenous**

9. **Dry high-urea supplements should be kept as dry as possible**

They tend to pick up moisture because urea is very hygroscopic. Proper pelleting will help prevent caking.

**NUTRIENTS ESSENTIAL FOR OPTIMAL PROTEIN SYNTHESIS FROM UREA**

The nutritional factors which are known to be essential for the maximum utilization of urea are as follows:

1. **Readily available source of energy which can be supplied by grain or molasses**

It requires about 86 pounds of corn or its equivalent and 14 pounds of urea (42% N) to equal the protein and energy value of 100 pounds of soybean meal. Urea has no energy value.

2. **Adequate levels of calcium and phosphorus**

Biologically available phosphorus is especially needed for the synthesis of bacterial protein.

3. **Required level of trace mineral elements**

Special attention should be given to supplying the required level of trace mineral elements, especially iodine, cobalt and zinc. Other trace minerals are required but are usually present in adequate quantities in natural feedstuffs. Excessive feeding of trace minerals may depress animal performance and protein synthesis.

4. **Nitrogen-sulfur ratio should not be wider than 15:1**
Sulfur usually is a limiting nutrient in high-urea diets for the microbial synthesis of methionine and cystine. Experimental evidence indicates that the nitrogen-sulfur ratio should not be wider than 15:1, and more recent data suggest that a ratio of 10:1 may be required. Sodium sulfate or flowers of sulfur are effective sources.

(5) Unidentified urea-protein synthesis factors should be furnished

Unidentified urea-protein synthesis factors (UPF) are contained in dehydrated alfalfa meal (DeHy) and distillers dried grains with solubles (DDGS) (Beeson and Horn, 1967). These should be used as a source of unidentified nutrients for stimulating the microbial synthesis of protein from urea. High-urea supplements or grain mixtures should contain a ratio of 2 parts of DeHy or DDGS to 1 part of urea. No doubt there are other sources of the urea-protein synthesis factor (UPF).

(6) Three to four per cent iodized salt

Add 3 to 4 per cent iodized salt to improve the palatability and mask the taste of urea. Urea alone is distasteful to animals.

(7) Fortify with proper levels of synthetic vitamin A

Furnish a minimum of 20,000 I.U. of vitamin A daily for growing and finishing cattle and 30,000 I.U. daily for pregnant and lactating animals.

(8) Fortify with vitamin D if cattle are confined

Vitamin D₂ or D₃ should be added when beef cattle are fed in confinement away from the sun's rays (ultraviolet).

(9) Fortify with vitamin E if natural feedstuffs are low

Vitamin E remains a question mark but may be indicated under certain feeding regimes when the natural feeds are low in biologically available E.

USE OFUREA DURING PREGNANCY AND LACTATION

It has been well-established that if urea is fed improperly or at excessive levels, it can be toxic. However, there is no good evidence at present that the proper feeding of urea over extending periods of time has any deleterious effect on cows during reproduction or lactation.

Research by Hart et al. (1939a,b) indicated that the feeding of urea at a level of 4.3 per cent of the ration for 12 months to milking cows caused pathological changes in the kidneys and liver but found no changes in these organs when 2.8 per cent urea was fed continuously.

In Poland, urea has been fed over long periods of time to dairy cows at a level of 2.0 per cent of the grain ration without any observable deleterious effects by veterinarians.

A. I. Virtanen (1963, 1966), a Nobel Prize chemist, reported that dairy cows could be maintained and produce milk on a purified protein-free diet composed essentially of pure cellulose, starches, sugars, minerals and vitamins with almost 100 per cent of the dietary nitrogen from urea and ammonium salts. Although these were not high-producing cows, it does illustrate the potential a ruminant animal has for the utilization of non-protein nitrogen. For a period of six years, lactating cows averaging 450 kilograms in weight, produced more than 4000 kilograms of milk per year. Nutrient analysis of the milk, known as O-milk, was similar to the milk from cows fed a normal ration. Virtanen has also shown that hemicellulose from wood can be used for lactating cows if properly balanced with urea and other essential nutrients.

Oltjen et al. (1965) fed identical twin Angus heifers on two different
rations: a purified diet with urea as the only source of nitrogen or crude protein was fed to one twin, and the other twin received a ration of natural feedstuffs. A 51-pound normal heifer calf was born to the twin on the purified diet, which at least illustrates in part that embryonic life can be nourished from a cow fed non-protein nitrogen.

According to research by Rupel et al. (1943), Loskutova and Berkovic (1964) and Archibald (1943), the feeding of urea did not have any harmful influence upon fertility even when fed for a period of 2 to 3 years.

In light of our new knowledge on the use of urea, more research needs to be conducted on the effect of health, longevity and reproductive performance in ruminants.

UNIDENTIFIED UREA-PROTEIN FACTORS (UPF)

Both basic and applied research have revealed that microorganisms cannot synthesize protein from urea efficiently unless some source of UPF is present in the ration. Beeson et al. (1964a, 1964b) and Perry et al. (1967) showed that dehydrated alfalfa meal was an essential component for formulating a high-urea (64%) supplement to make it comparable to natural protein (see Table 1, Purdue 64 formula). Later Beeson and Horn (1967) revealed in carefully controlled nitrogen balance studies that nitrogen retention was increased 66 per cent by feeding 5 per cent dehydrated alfalfa meal in a corn and cob meal-urea-mineral diet and 79 per cent by the addition of 5 per cent distillers dried grains with solubles. In these studies, daily levels of 227 to 300 grams of either dehydrated alfalfa meal or distillers dried grains with solubles were adequate amounts.

Research by Conrad and Hibbs (1967) has indicated quite clearly that by combining urea and dehydrated alfalfa meal into a pellet, a higher level of urea could be fed without causing any depression in feed intake or milk production. The original DeHy-100 pellet was composed of 66 per cent dehydrated alfalfa meal, 31.6 per cent urea, 2.0 per cent monosodium phosphate and 0.4 per cent sodium metabisulfite (a preservative). Later sodium propionate was used to replace sodium metabisulfite. From DeHy-100, the daily urea intake ranged from 0.6 pound (273 grams) to 0.9 pound (409 grams), which is far above previously recommended levels. If urea is properly utilized for protein synthesis, higher levels can be fed without deleterious effects.

Garrigus (1964) working with lambs revealed that dehydrated alfalfa meal contained an unidentified factor that would stimulate growth. When 'DeHy' was included as 20 per cent of a lamb ration and as a substitute for corn cobs, the lambs gained 75% faster with 41 per cent less feed than the controls. The Illinois workers reasoned that alfalfa meal increased the microbial population in the rumen, and thus increased protein synthesis from urea.

Three good sources of urea protein factors (UPF), are dehydrated alfalfa meal, distillers dried grains with solubles, and distiller solubles. No doubt there are other good sources which must be identified.

DRY VS. LIQUID HIGH-UREA SUPPLEMENTS

Feedlot tests with beef steers by Perry et al. (1967), Gay and Vetter (1967) and Kercher and Pauls (1967) have shown rather clearly that there is no significant difference in the nutritional value or cattle response to high-urea dry or liquid supplements provided the supplement and/or ration contains the same essential nutrients with the proper balance. In other words, cattle do not distinguish between the same nutrients fed in a dry or liquid form. There is no nutritional advantage in liquid supplements or liquid feeds; it is just another way to balance the ration for growing, finishing and maintaining of cattle.

Several experiments have shown that a mixture of molasses, urea, phosphorus, calcium, sulfur, trace minerals, vitamins and water will not give optimum performance
with cattle unless the supplement and/or ration contains some source of unidentified urea factors such as dehydrated alfalfa meal or distillers solubles.

When beef heifers (Perry and Beeson, 1968) were self-fed on a ration of rolled shelled corn, ground corn cobs and either Supplement A (natural protein) or a liquid molasses-urea-phosphorus supplement (64 per cent crude protein), the daily gain was significantly better on Supplement A. Heifers gained 2.49 pound daily on Supplement A and 1.74 pound daily on liquid 64. The feed per pound of gain was 10.8 and 13.0 pounds, respectively. Heifers fed on a high-energy ration balanced with Supplement A gained 30 per cent faster on 17 per cent less feed than the heifers on a molasses-urea-phosphorus liquid 64 supplement.

FORMULATING LIQUID PROTEIN SUPPLEMENTS

Liquid protein supplements built essentially around molasses, urea and phosphorus were not too successful until recent years (1967) for two major reasons: (1) The supplements were fed on a free-choice basis, and many digestive and toxicity problems were encountered and (2) no source of unidentified urea factors such as dehydrated alfalfa meal, distillers solubles or alfalfa solubles were included in the diet to improve the utilization of non-protein nitrogen by rumen microorganisms. Many tests have shown that a mixture of molasses, urea, minerals and vitamins will not give optimum performance in cattle unless the ration and/or supplement contains some source of urea-protein factors (UPF).

For optimum performance and feed utilization, a liquid supplement must contain the following basic ingredients:

(1) Molasses or a liquid carbohydrate source of equal value

(2) Urea or other effective water soluble non-protein nitrogen compounds or soluble natural proteins

(3) Phosphorus in soluble form such as phosphoric acid, mono- or disodium phosphate and ammoniated polyphosphate

(4) Calcium supplied as calcium chloride or calcium hydroxide.

(5) Soluble trace minerals such as cobalt sulfate, potassium iodide and zinc sulfate

(6) Sulfur as soluble sodium sulfate in a ratio of 15 parts nitrogen to 1 part sulfur

(7) Vitamin A palmitate - stabilized, water-dispersible type

(8) Urea-protein (synthesis) factor (UPF) contained in dehydrated alfalfa meal, distillers dried grains with solubles and distillers solubles. Add distillers solubles at a level of 2.5 per cent on a dry matter equivalent basis.

(9) Antibiotics are not too stable in liquid supplements.

(10) Diethylstilbestrol - stable, water-dispersible type.

Research at Purdue (Perry et al., 1967), Iowa (Gay and Vetter, 1968) and Wyoming (Kercher and Paules, 1967) has revealed that if liquid supplements are formulated properly according to the specifications given in the preceding ten points, they are equal to high-urea dry supplements. Actually, there is no difference in the nutritional value of liquid and dry supplements built around urea if the supplements contain the same basic nutrients. Thus, it is a matter of personal choice and ingredient costs as to which is used by cattle feeders.
ORDER OF MIXING INGREDIENTS

If ingredients in liquid supplements are not mixed in the proper sequence, the product will "set up" into a gelatin-like mass and some compounds will "salt out." The proper order is as follows:

1. Dissolve urea in warm water (about 150°F)
2. Mix urea solution with warm molasses (120°F)
3. Add source of soluble phosphorus
4. Add calcium chloride or calcium hydroxide
5. Mix in water-soluble trace minerals
6. Add water-dispersible vitamin A
7. Premix stilbestrol in warm water (100°F)
8. Add water-stable antibiotics
9. Add water-soluble urea-protein factor as distillers solubles (2.5 per cent of mixture on a dry matter equivalent basis)
10. High-urea supplements, such as Purdue 64 or Purdue Liquid 64 (Table 1), are suitable for supplementing brood cow rations at the rate of 1.0 pound per head daily during pregnancy and lactation. Do not free choice!
11. Formulas of Purdue supplements recommended for balancing the rations of beef cattle are given in Table 1.

RECOMMENDED LEVELS AND PRACTICES TO FOLLOW IN FEEDING UREA

1. Do not feed urea or supplements containing urea to newly arrived or shipped-in cattle for a period of 21 to 28 days.
2. Do not feed urea to cattle that have been starved or off feed for 36 hours until they have had a chance to fill the rumen with feed.
3. For growing or wintering cattle, feed a maximum of 0.15 pound (68 grams) of urea daily.
4. For fattening steers or heifers on grain and roughage, feed no more than 0.22 pound (100 grams) of urea per head daily.
5. Do not feed urea to young calves until after the rumen develops which is about 6 to 8 weeks of age.
6. Formulate complete cattle rations so that no more than 33 per cent of the crude protein or nitrogen is derived from urea. Protein supplements may contain 85 to 90 per cent of the protein from urea; but when blended with natural feedstuffs like grain and roughage, the total contribution of protein from urea is usually less than 33 per cent.
7. Do not feed urea over and above the protein requirement. Add only enough properly balanced urea supplement to meet the protein needs.
8. Urea should be either thoroughly mixed in a properly balanced supplement or in a complete ration.
9. Do not free choice or self-feed urea supplements; the daily allowance must be controlled by proper mixing in a ration or by feeding a daily amount in a supplement, such as 1.0 pound of Purdue 64 which furnishes 0.22 pound (100 grams) of urea daily.
REFERENCES


Table 1. Formulas for Purdue supplements

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Per 1000 lb</th>
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<tbody>
<tr>
<td>Soybean meal</td>
<td>lb.</td>
<td>640</td>
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<tr>
<td>Cane molasses</td>
<td>lb.</td>
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</tr>
<tr>
<td>Dehydrated alfalfa meal (17%)</td>
<td>lb.</td>
<td>140</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td>lb.</td>
<td>52</td>
</tr>
<tr>
<td>Iodized salt</td>
<td>lb.</td>
<td>18</td>
</tr>
<tr>
<td>Premix a/</td>
<td>lb.</td>
<td>10</td>
</tr>
<tr>
<td><strong>Purdue Supplement A (32% protein)</strong></td>
<td></td>
<td><strong>1000</strong></td>
</tr>
<tr>
<td>Urea (45% N)</td>
<td>lb.</td>
<td>200</td>
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<tr>
<td>Cane molasses</td>
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<td>140</td>
</tr>
<tr>
<td>Dehydrated alfalfa meal (17%) b/</td>
<td>lb.</td>
<td>510</td>
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<tr>
<td>Dicalcium phosphate</td>
<td>lb.</td>
<td>105</td>
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<tr>
<td>Iodized salt</td>
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<td>35</td>
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<tr>
<td>Premix c/</td>
<td>lb.</td>
<td>10</td>
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<tr>
<td><strong>Purdue Dry 64 (64% protein)</strong></td>
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<td><strong>1000</strong></td>
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<tr>
<td>Liquid urea (32% N) d/</td>
<td>lb.</td>
<td>290</td>
</tr>
<tr>
<td>Cane molasses</td>
<td>lb.</td>
<td>385</td>
</tr>
<tr>
<td>Ammoniated polyphos (10-34-0)</td>
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<td>90</td>
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<tr>
<td>Distillers solubles (27% dry matter)</td>
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<td>93</td>
</tr>
<tr>
<td>Salt solution (28% salt + 72% water)</td>
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<td>90</td>
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<tr>
<td>Calcium chloride</td>
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<tr>
<td>Sodium sulfate</td>
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<tr>
<td>Premix e/</td>
<td>lb.</td>
<td>30</td>
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**Purdue Liquid 64 (64% protein)**

<table>
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<tr>
<th>Item</th>
<th>Unit</th>
<th>Per 1000 lb</th>
</tr>
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<tbody>
<tr>
<td><strong>a/</strong> Premix: 10 million I.U. vitamin A; 5 gm. DES; 525 gm. zinc oxide; 2 gm. cobalt carbonate; 7 lb. soybean meal.</td>
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<tr>
<td><strong>b/</strong> Distillers dried grains with solubles will effectively replace 50 to 100% of the dehydrated alfalfa meal to supply urea protein factors (UPF).</td>
<td></td>
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<tr>
<td><strong>c/</strong> Premix: 20 million I.U. vitamin A; 10 gm. DES; 1250 gm. zinc oxide, 4 gm. cobalt carbonate; 7 lb. dehydrated alfalfa meal.</td>
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<tr>
<td><strong>d/</strong> Liquid urea - 70% urea and 30% water.</td>
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<tr>
<td><strong>e/</strong> Liquid supplement premix: 20 million I.U. vitamin A (soluble); 9.5 gm. cobalt sulfate (21% Co); 4350.0 gm. zinc sulfate (23% Zn); 10.0 gm. stilbestrol (soluble DES); 19.0 lb. water (H O).</td>
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