Agricultural Extension Service
University of Minnesota

Extension Folder 354 – 1977

NPN in the Dairy Ration

D. E. Otterby, J. G. Linn, and M. F. Hutjens*

Protein supplements usually are the most expensive portion of the dairy cattle ration. Use of urea on other NPN (nonprotein nitrogen) compounds may be an alternative to meeting the cow's protein requirements while reducing protein costs. However, many aspects of NPN feeding should be considered to obtain maximum benefits from such compounds.

Composition and Importance of Protein

Proteins are complex chemical structures composed of carbon, nitrogen, hydrogen, oxygen, and sulfur. Each protein unit is made up of numerous building blocks known as amino acids. There are over 20 different naturally occurring amino acids combined in many different ways to form protein.

Proteins or their building blocks, amino acids, function in many different ways in the animal's body. Amino acids promote growth of muscle, bone, and connective tissue. All body reactions controlled by enzymes such as the digestion of food in the small intestine, are controlled by proteins as all enzymes are protein. Milk is a rich source of protein, so dairy cows need diets containing recommended protein levels to maintain milk production. Dietary shortage of protein will reduce production level, impair proper growth, and affect animal health.

Definition of Terms

Nitrogen (N) – Chemical element found in the earth's crust, atmosphere, and living matter.

Nonprotein nitrogen (NPN) – Any compound that supplies nitrogen other than in the form of a complex protein molecule, e.g., urea, amino acids, ammonia, etc.

Crude protein (CP) – Used to describe the protein content of a feedstuff. Includes not only the protein complex of a feed but all other nitrogen compounds in the feed. Determined by analytically measuring the nitrogen of a feed and multiplying by 6.25. True proteins contain 16% nitrogen on the average. The factor, 6.25, is derived from 100/16.

Digestible protein – CP content of a feed multiplied by its digestibility. Digestibility equals weight of nutrient in feed minus weight of nutrient in feces divided by weight of nutrient in feed. Generally, forage proteins are 60% digestible and grain proteins 80%. However, these values will vary depending on stage of maturity, leafiness, weathering, heat damage, and other factors affecting feed quality.

Soluble protein or nitrogen – Protein or nitrogen compounds that are readily degraded to ammonia in the rumen. They are determined by measuring the amount of protein that is soluble in a liquid phase. This liquid can be rumen fluid, water, or other chemical solutions.

Insoluble protein or nitrogen – Protein or nitrogen compounds that are not degraded in the rumen or are not solubilized in the liquids used to determine solubility. These compounds pass through the rumen and then become available for digestion in the small intestine. Other terms used to describe insoluble proteins or nitrogen proteins are:
- undegraded protein or nitrogen
- unavailable nitrogen

However, all of these terms are unspecific as to exactly where the unavailability is: rumen, small intestine or totally unavailable to the animal. It is generally assumed these terms are referring to rumen availability.

Heat damage or heat damaged protein – This term refers to the protein content of feedstuffs made unavailable to the animal from heating by commercial processing or improper fermentation. Temperatures above 50°C cause a complex reaction between protein and cell wall carbohydrates (this results in a caramelized appearance to the feedstuff). The complexes formed cause significant artifact lignin (undigestible protein-carbohydrate complex). Proteins that are mildly damaged can be digested by enzymes in the animal's small intestine. If severe destruction has occurred, the protein may be totally unavailable. Extent of heat damage can be determined by two procedures, pepsin insoluble nitrogen or acid detergent fiber nitrogen (ADF-N). Pepsin (protein digesting enzyme) insoluble nitrogen measures the total amount of insoluble nitrogen occurring naturally plus that caused by heating. ADF-N measures the total amount of nitrogen found in the artifact lignin complex.

Metabolizable protein – A new concept developed in response to problems from feeding urea in certain types of rations. The system recognizes that variable degradation of natural proteins and variable synthesis of microbial proteins occur in the rumen. The variability of the degradation and synthesis of protein is used to predict the amount of amino acids available for post-ruminal absorption.

Urea fermentation potential (UFP) – Amount of urea or nonprotein nitrogen that can be used with a given feed or combination of feedstuffs. Feeds can either have a positive or negative UFP value. A positive ration value such as +10 means 10 grams of urea can be added to the rations and used beneficially. Negative values indicate adequate ammonia is already being produced in the rumen and no NPN should be added to the ration.

NPN Compounds

Most NPN compounds are composed of carbon, nitrogen, oxygen, hydrogen, and sometimes phosphorus. Urea is the most common NPN compound. Other NPN compounds are available but haven't been as widely used because of cost, toxicity problems or federal regulations. Some of the NPN compounds follow:

*D.E. Otterby is a professor, J.G. Linn, an assistant scientist, both in the Department of Animal Science, University of Minnesota. M.F. Hutjens is an extension dairyman, Agricultural Extension Service and an associate professor, Department of Animal Science.

Ammoniated products — Low protein feeds and milling by-product feeds such as ammoniated molasses, ammoniated condensed distillers molasses solubles, ammoniated citrus pulp and ammoniated beet pulp have been treated with ammonia and been fed as nitrogen sources for ruminants. These products have been found less satisfactory than urea for protein substitutes because of animal palatability, toxicity problems, and a short storage life.

Ammonium products showing promise as protein substitutes are the ammonium salts. Monoammonium phosphate (11% nitrogen, 68.25% crude protein equivalent) and diammonium phosphate (18% nitrogen, 112.5% crude protein equivalent) are two products that are sources of NPN and phosphorus supplementation.

Urea — Urea is a white compound, bitter tasting to ruminants. Most feed grade urea contains about 45% nitrogen and has a protein equivalent of 281% (45% x 6.25). Urea, absent in plants, is a normal end product of nitrogen metabolism in mammals.

Biuret — Biuret is formed by heating urea. Although it is an acceptable protein substitute for beef cattle, it is illegal to feed it to dairy cattle.

Plant NPN — Most commonly known plant NPN is nitrate. Normal plant nitrate levels are nontoxic and can be used by ruminants as a source of nitrogen. However, under drought conditions or other conditions causing large accumulations, plant nitrate levels may reach toxic proportions and should be analyzed before feeding. Other plant NPN compounds are amino acids, broken fragment of protein complexes, and other minor N sources.

Liquid supplements — Liquid supplements are generally composed of molasses, urea or other NPN compounds, minerals, and vitamins. Liquid supplements are formulated to varying crude protein contents. Cattle frequently find liquid supplements very palatable and may consume considerable quantities at one time. Because of this and the variability of cows, intake of desirable levels of protein may not be achieved on a free choice basis. If liquid supplements containing NPN compounds are fed free choice, exclusion of other NPN compounds in the ration is advisable. Those supplements containing high amounts of crude protein are not intended for free choice feeding (over 60%).

Table 1 shows nitrogen content and crude protein equivalent of urea and other NPN compounds.

Table 1. Nitrogen content and crude protein equivalent of NPN compounds

	Nitrogen	Crude-protein equivalent
	(%)	(%)
Urea (feed grade)	45	281
Monoammonium phosphate	11	69
Diammonium phosphate	18	112
Ammonia (NH_3)	82	512
Nitrate (NO_3)	23	144

NPN Use

Rumen bacteria require nitrogen in simple forms such as ammonia (NH_3) and amino acids. NPN compounds such as urea are readily converted into ammonia and carbon dioxide (CO_2) in the rumen. The following diagram illustrates the process of incorporating ammonia into bacteria protein and presenting the microbial and undegraded feed protein to the lower digestive tract:

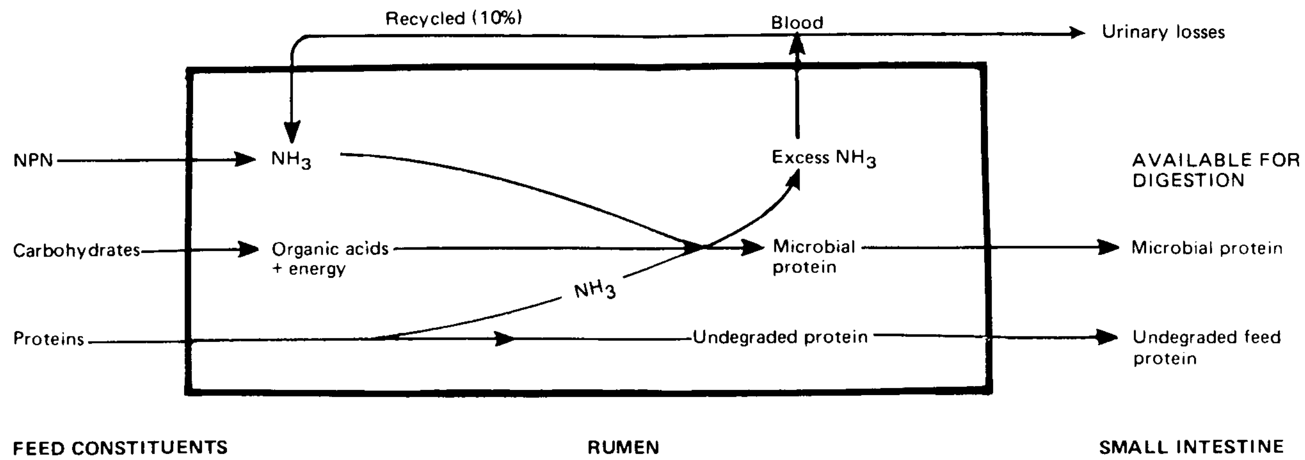

Figure 1. Utilization of feed-nitrogen in the rumen

Natural or plant proteins found in alfalfa, corn or soybean meal can be converted to ammonia and organic acids or remain undegraded depending on its solubility. Plant carbohydrates supply energy in the form of organic acid for the reincorporation of ammonia into microbial protein. Hence, two sources of protein (microbial and plant) are then presented to the lower digestive tract for further breakdown and the absorption of amino acids.

NPN compounds entering the rumen are rapidly converted to ammonia and carbon dioxide by bacteria. When adequate energy is available, the ammonia from NPN is then synthesized into microbial protein. Ammonia formed from the breakdown of plant proteins is also used for synthesis of microbial protein. Corn or other high starch feeds are the best sources of carbohydrate-energy for incorporation of ammonia into microbial protein. Feeding NPN feeds in high forage-lower energy diets is inefficient because of the low availability of readily fermentable carbohydrates. Considerable amounts of ammonia can escape protein incorporation and be lost from the body via urinary excretion. Ammonia or urea toxicity can occur if ammonia levels become too high in the blood. Symptoms of this ammonia toxicity in progressive order are uneasiness, tremors, excessive salivation, rapid breathing, bloat, tetany and finally, death.

Soluble Proteins

The soluble protein concept is gaining in popularity. It refers to a protein's solubility in the rumen or as it is measured in various other chemical solutions. It is an estimate of the extent of protein degradation in the rumen. The purpose of considering protein solubility in conjunction with NPN use is to assure that proper ruminal ammonia levels are achieved. Too low ammonia level in the rumen causes a nitrogen shortage to bacteria and, consequently, feed digestibility is reduced. If the opposite occurs, wastage or even ammonia toxicity can occur. NPN sources will be most effectively used when ruminal ammonia levels are low as they would supply the major portion of ammonia for microbial needs. High energy rations containing corn, oats, barley, or corn and cob meal would be most favorable rations for feeding NPN as they all have generally low ruminal protein degradation. Feeding NPN with rations high in casein, ensiled or fresh alfalfa forage and possible high moisture grains would be less favorable in NPN use because they have readily soluble proteins.

Most dairy rations containing 12-13 percent crude protein are adequate in ammonia for microbial growth. Any additive of large amounts of soluble protein feedstuffs above this would not be beneficial. Increasing ration crude protein levels above this should be done with feedstuffs containing less soluble proteins such as soybean meal.

Feeding Urea

The following guidelines apply to successful urea use:

- All dairy rations should be assessed for protein content before either supplemental NPN or natural protein is added to the diet. Protein may not be needed.
- Feeds most successfully supplemented with NPN are high in energy, low in protein, and low in natural NPN (i.e., grains and corn silage). Drought-stricken corn silage made from heavily fertilized corn may contain considerable NPN.
- Maximum amounts of urea to feed:
  - —1 percent urea in grain mix.
  - —0.5 percent in corn silage (10 lb/ton). If 0.5 percent is added to corn silage, the amount in the grain should be decreased. The addition of 10 lb of urea/ton of corn silage will increase the protein content from 8 percent to 11-12 percent on a dry matter basis (depending on losses incurred).
  - —0.4 to 0.5 lb urea/head/day.
- Urea is not a palatable feed and should be mixed thoroughly into the grain mix or silage. Molasses can improve acceptability.
- If cattle have not been fed urea previously, a 7-10 day adjustment period in which the urea is gradually increased will help to maintain feed intake and production.
- Frequent feeding of urea containing feeds favors increased use.
- High levels of urea can be toxic. Excessive intakes should be avoided. Urea should not be top-dressed.
- Amount of urea used should be limited in early lactation.

Cautions in Feeding Urea

If too much urea is fed at one time, or if sufficient carbohydrates are not readily available, excess ammonia may build up in the rumen faster than the bacteria can use it. This build-up can result in a waste of nitrogen and possibly the animal's death. **Therefore, it is recommended that not more than 1 percent of the grain mix is urea.** When urea is mixed with wet feeds, disagreeable ammonia odors may develop, particularly if the feed is stored, or left in the bunk any length of time. No more than 0.4 to 0.5 pound of urea should be fed to a cow each day.

Urea should not be fed to cows unless mixed with another feed. It is unpalatable, so most cows would not eat it alone. It is also impractical to weigh out accurately the small amounts each animal could use. **It is very important to mix urea uniformly in the ration; improper mixing may result in poisoning animals eating excess amounts.**

Urea is not recommended for grain mixtures containing raw soybeans. An enzyme called urease in the raw bean is able to convert urea to ammonia which in turn may be lost and make the feed less palatable. Little difficulty is encountered when roasted beans or soybean meal is used with urea.

Rumen microbes require some time to adjust to urea. Also, cows may refuse mixtures that have been altered greatly. Therefore, it is recommended that urea be gradually increased to the desired level over a 3-week period.

Proper mineral and vitamin supplementation are especially important when urea is fed. Be certain that the ration is balanced for calcium, phosphorus, trace minerals, and vitamin A. Sulfur may need to be added to rations consisting largely of corn and corn silage. With grain mixes that contain 1 percent urea, 2 pounds of elemental sulfur or 5 to 10 pounds of sodium sulfate, calcium sulfate or potassium-magnesium sulfate should be added per ton.

Some dairymen have been concerned about the effect of urea on animal health and reproduction. If urea is used as recommended and the ration is balanced for other nutrients, cows will produce well, reproduce, and maintain good health. An extensive field trial in Michigan showed no difference in reproductive function between cows fed and not fed urea.

How to Use Urea in a Ration

If uniform mixing facilities are available, add 1 percent of urea or 20 pounds per ton to the grain mixture to raise the crude protein equivalent of the mixture about 2.8 percent. **Mix thoroughly.**

Urea also can be used in making up a high-protein concentrate. A mixture of 100 pounds of ground shelled corn and 13 pounds of urea equals 100 pounds of soybean meal in protein and energy equivalent.

A mixture of 56 pounds of ground shelled corn, 7 pounds of urea, and 43 pounds of soybean meal also equals 100 pounds of soybean meal in total energy and protein equivalent, and can be used as a substitute for part of the soybean meal. However, it should not be used for top-dressing because of possible bitter taste when fed.

Many commercial protein supplements contain some urea. The tag lists the amount of crude protein equivalent supplied by urea. For example, supplement XYZ contains 36 percent crude protein of which 11.2 percent crude protein is supplied by urea. This means that 100 pounds of supplement contain 36 pounds of crude protein, of which 11.2 pounds of crude protein is supplied by urea. The percent of urea in the supplement may be calculated as follows: $\frac{11.2}{281} \times 100 = 4$ percent.

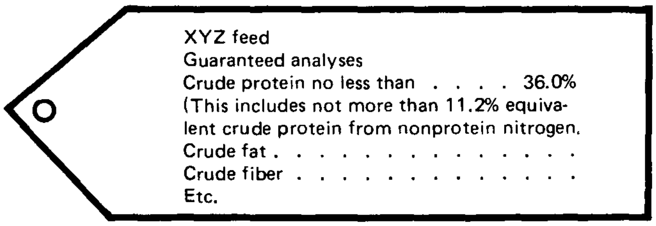

Figure 2. Feed tag

If you feed your high producing cows 4 pounds of this commercial supplement daily, the cow consumes 0.16 pound of urea. This is a safe level of urea feeding, (4% x 4 pounds = 0.16 pound/cow/day).

The following are examples of 12 percent and 16 percent crude protein concentrate mixtures with and without urea:

12 PERCENT CRUDE PROTEIN

1,790 pounds corn & cob meal
210 pounds soybean meal
2,000 pounds

OR

1,920 pounds corn & cob meal
20 pounds urea
60 pounds soybean meal
2,000 pounds

16 PERCENT CRUDE PROTEIN

1,100 pounds shelled corn
550 pounds oats
350 pounds soybean meal
2,000 pounds

OR

1,180 pounds shelled corn
600 pounds oats
20 pounds urea
200 pounds soybean meal
2,000 pounds

If more protein than needed is fed in the ration, some of the urea will be wasted because it contains no energy. It is, therefore, difficult to figure the savings in every instance that might be made from the use of urea. Assuming urea is fully used, the savings that may be made through its use can be illustrated as follows:

100 pounds corn @ 4 cents = $4.00
13 pounds urea @ 10 cents = 1.30
$5.30

If soybean meal costs $10/100 pounds, $4.70 is saved on each 100 pounds of supplement. Current prices can be used to calculate the cost and possible savings with any of the mixtures mentioned.

Use of NPN on Corn Silage

In much of Minnesota, more nutrients per acre can be grown in corn silage than in any other crop. Equipment is available to make and feed silage with a minimum of labor. Dairymen are increasing the proportion of corn silage in the ration; some use it as the sole roughage.

Corn silage is relatively low in protein, containing only about 2.3 percent crude protein as fed, or 8.3 percent protein on a dry matter basis. Additional protein often is needed in rations high in corn silage.

Ten pounds of urea can be added to a ton of silage at filling time to produce a palatable feed. This amount raises the crude protein from 2.3 percent to about 3.7 percent as fed, or from 8.3 percent to 11 or 12 percent on a dry matter basis. Growing animals and dry cows fed urea-treated silage as they only feed would normally consume enough silage daily to supply the protein they need.

Urea must be mixed uniformly with silage. Usually urea and silage will be well mixed by the time of feeding if the recommended amount is spread over the top of the load in self-unloading wagons, blown into the silo, and removed from the silo by a mechanical silo unloader. Adding urea to silage placed in piles, trenches, or bunkers is not recommended because it could be unevenly distributed in the stored material.

Much of the urea is converted to ammonia during the silage fermentation. Most of this is tied up as salts by acids produced in the silage. Urea should not be added to extremely wet silages or to dry silage. Excessive leaching may occur in very wet material and ammonia losses may occur in dry silage. Under normal conditions, a 10 percent loss of urea-nitrogen may be expected. Strive for corn silage dry matter content of about 35 percent. When large amounts of urea-corn silage is fed with little or no other forage, exclude urea from the grain mixture. Sixty pounds of corn silage x .5 percent urea = .3 pound urea/cow/day. This level is safe, but near the cutoff level.

Anhydrous ammonia applied by the cold flow method is another NPN compound that can be added to corn silage to increase CP content. Ammonia is usually added at the rate of 6 pounds (5 lb N) per ton achieving a 11-12 percent CP silage on a dry matter basis. Other commercial products are also available. Again, lower levels of NPN should be fed in grain mixtures when ammonia or NPN-treated silage is fed.

Summary

- Substituting NPN for natural protein in the dairy ration usually will result in a lower cost ration.
- NPN has little or no energy value—it only supplies nitrogen.
- NPN must be mixed thoroughly in the ration.
- Urea intake should not exceed .4 to .5 pound per cow per day; 1 percent in the grain mixture is maximum.
- Where the ration already has ample protein, additional nitrogen fed either as NPN or as protein is wasted and only adds to cost. NPN has no purpose except to substitute for part or all of the protein supplements usually purchased.
- Soluble protein content of feedstuff should be evaluated when NPN is going to be added to the ration.
- The ration should be checked for vitamin and mineral contents.

For additional information see: "Feeding the Dairy Herd," University of Minnesota Extension Bulletin 218, and "Corn Silage in Dairy Cattle Rations," Dairy Husbandry Fact Sheet No. 7.

Issued in furtherance of cooperative extension work in agriculture and home economics, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Roland H. Abraham, Director of Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota 55108. The University of Minnesota, including the Agricultural Extension Service, is committed to the policy that all persons shall have equal access to its programs, facilities, and employment without regard to race, creed, color, sex, national origin, or handicap.