

Nitrogen in Animal Production

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Over the centuries protein has molded mankind. Nations blessed with adequate protein of animal origin have had populations larger in stature, have enjoyed longer lives with less disease and have experienced lower infant mortality than those where protein, limited in both quality and quantity, favored a small stature for survival. So it is today. Lack of quality protein still limits the stature and health of populations. Man cannot live by bread alone.

Nitrogen is of equal importance in the plant-soil complex and in the animal production area. It is the element unique to the high-quality protein-rich foods derived from animal products. Animal products for human consumption are of special importance because of their quantity of essential amino acids—the chemical building blocks of the proteins in meat, eggs, and milk, and of all other proteinaceous materials. Nitrogen is a major nutritional requirement in the diets of food-producing animals.

Protein metabolism of domestic (and wild) animals from the aspects of food consumption, digestion, absorption, and eventual utilization by the animal's body is largely synonymous with nitrogen metabolism. In a sense, animals consume protein to obtain nitrogen. The quantitative data available on protein requirement of animals and man are, strictly speaking, nitrogen requirement with the exceptions as indicated for monogastric animals, including man. Growth in farm animals is synonymous with synthesis and accumulation of total body protein (nitrogen accumulation).

All attempts by modern society and more specifically by the animal industries to improve the efficiency of domestic food animal production are in the final analysis efforts to improve the efficiency of protein or nitrogen use by the animal: breeding faster-gaining, more efficient, leaner meat animals or heavier producing cows or hens. Unfortunately, the feedstuffs that are protein or nitrogen rich tend to be generally more costly in the real economic world of production costs. We attempt to produce as much as possible from minimum inputs. This is why we seek the hen that lays 20 more eggs per year, the dairy cow with 20,000 pounds milk production, the steer that can reach acceptable market weight rapidly and produce a yield grade two choice carcass grade, or the hog that will produce a 5.5 square inch loin eye, the 18 pound ham, and comparably leaner bacon at the same 230 pound weight on less feed consumption. The goal is the same: to produce the maximum salable animal protein relative to what is fed to animals, including not only the animals slaughtered but all breeding herds required to produce the slaughter hog, lamb, or steer.

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Animals do not represent a net loss in the nitrogen economy of our food supply. The nitrogen that the animal's body is unable to utilize is excreted in the urine or feces and recycled into the soil where it becomes available for plant production. This assumes animal manures are, in fact, returned to the soil. Animal manures, "organic fertilizer", have long been recognized for their soil fertility values and for their potential contributions as a "soil amendment."

North Dakota is more fortunate than many states in that our higher energy feed sources have higher protein content. Barley, oats, proso and wheat have over 30 per cent more protein than does corn. Less of the more costly protein supplement is needed to balance the rations and meet the animals requirements with homegrown feeds. However, selection of the proper protein supplement becomes more critical for balancing the rations for monogastric animals. Proteins in grains are all lacking in some of the essential amino acids, especially lysine. Common plant protein supplements, such as linseed oil meal and sunflower seed oil meal, are also deficient in lysine. Therefore, in the case of the pig and chicken, it is necessary to balance rations on the basis of amino acid content as well as protein level.

Protein Needs Are Actually Nitrogen Requirements

Fermentation by bacteria and protozoa in the rumen requires nitrogen to synthesize amino acids and proteins which later become available to the host animal. Protein requirements for ruminants refer to need for those nitrogen-containing materials in feedstuffs that are digested and absorbed into the animal's body through the gut wall. The dietary protein requirements for ruminants (dairy cattle, beef cattle, and sheep) for practical purposes can be reduced to one of metabolizable or biologically available nitrogen.

In the case of ruminants, a factor relevant to efficiency of nitrogen metabolism must be recognized. Many low-cost growing and feeding programs for ruminants may involve rather extended periods of time to reach acceptable slaughter weight and condition. Animals produced under such systems, will, in fact, consume more total protein or total dietary nitrogen than cattle pushed to market weight under modern feedlot conditions. The important difference is that cattle which are raised largely on range, pasture, and forages consume most of their lifetime protein or nitrogen intake from a source that is far less costly per unit of protein, both from the standpoint of dollars worth of protein consumed by the animal and from the standpoint of use of protein containing feedstuffs that could otherwise potentially be consumed by man or monogastric food-producing animals.

Simple Stomach Animals Require Amino Acids

The monogastric or simple stomach animals (humans, swine, poultry, rodents, etc.) have a more highly developed dietary requirement for nitrogen. These species have similar dietary requirements for nitrogen, but their nitrogen intake must be in the form of certain amino acids, of which ten are nutritionally essential. Some of these amino acids, lysine and threonine, for example, cannot be reformed or transaminated by the monogastric animal's body and are considered nutritionally "indispensable" at certain minimum levels in the diet. The dietary needs for certain others, methionine for example, can partially be met by transamination or reformation from other amino acids in the diet. Methionine is worth mentioning since it and cystine are two amino acids that contain sulfur as well as nitrogen. These sulfur-containing amino acids are of particular importance and interest because of the animal's physiologic need for inclusion in hair, wool, and feathers.

Much of the dietary protein intake of the domestic monogastrics (swine and poultry) comes from grains that are slightly damaged or otherwise ineligible for human consumption. By-products from commercial processing of oil seeds form a major source of supplementary protein, as do packing plant by-products that are inedible for humans. Synthetically produced amino acids, specifically lysine and methionine, are commercially available to replace naturally formed amino acids in the diets of swine and poultry whenever the natural sources of supplementary protein become in short supply or highly priced for any of several reasons. The future seems bright for increased usage of synthetic amino acids as natural sources of amino acids essential for monogastric nutrition find more demand in human diets. Economics presumably will dictate that the natural protein feedstuffs rich in those amino acids needed to complement diets based on feed grains will continue to be used to meet the protein needs of swine and poultry.

Improved Animal Performance - Improved Nitrogen Metabolism

Livestock breeders who are selecting for improved animal performance are basically seeking to improve ability of their animals to synthesize protein. Improving the genetic efficiency of nitrogen metabolism is the biological basis of these efforts. Improvement in both rate of protein synthesis and gross efficiency of protein use are goals for all food-producing animal genetic improvement programs. Breeders are indirectly selecting for greater ability to synthesize protein either at a faster rate per day or from less total dietary protein per unit of product produced.

The dairy cow that can produce 20,000 pounds of 3.1 per cent protein milk per year has considerably greater capacity to synthesize protein than the cow capable of producing a maximum of 12,000 pounds of 3.5 per cent protein milk per year. The modern hog that can reach 235 pounds live weight with a 57 per cent lean carcass at 170 days obviously must be genetically capable of more rapid and efficient nitrogen metabolism than the old-fashioned hog that takes 190 days to reach 220 pounds and yields a carcass producing only 52 per cent lean when they are grown in the same environment. The modern hog requires

a diet higher in nitrogen (higher levels of certain essential amino acids) to demonstrate this superior inherited protein converting ability but produces a leaner, more acceptable carcass. This carcass is worth more to the retailer and is preferred by consumers. Likewise, turkeys produced today reach far heavier weights at 22 weeks of age than was considered feasible even three decades ago. The steer that can reach 1250 pounds at 18 months of age and produce a 53 per cent cutability (per cent of grossly trimmed retail cuts from round, loin, rib, and chuck) carcass obviously synthesizes considerably more muscle protein per day and per unit of protein consumed than the steer that reaches slaughter condition at a weight of 975 pounds at the same 18 months of age but produces only a 48 per cent cutability carcass.

Urea Is Most Common NPN Material in Feeding

The great majority of the non-protein nitrogen used in livestock rations today is urea from commercially prepared supplements. A few of the larger feedlot or dairy operations purchase urea and include it in rations of their own formulation.

Urea, whether used for protein substitution or fertilizer, is a simple nitrogenous compound with the chemical formula NH_2CONH_2 . Ruminal enzymes called ureases readily hydrolyze or split the compound into ammonia (NH_3) and carbon dioxide (CO_2), both very common substances. Hydrolysis or splitting of the urea compound occurs relatively rapidly once the material reaches the animal's rumen and becomes of nutritional and even potential toxicologic significance. When all conditions are near ideal for urea utilization, urea can theoretically furnish the equivalent of 281 per cent crude protein. In other words, the rumen can produce 2.8 pounds of microbial protein from each pound of urea consumed in the ration.

Uniform mixing of urea into rations is important, since excess consumption of urea can and does result in toxicity, even death. The animal may not be able to cope with the excess ammonia released at one time from an inordinately large intake of urea. The typical North Dakota livestock operation does not have the mixing equipment needed to assure maximum utilization and adequate safety.

Urea is commonly incorporated into various supplements designed for feeding dairy cattle, beef cattle, and sheep. Most commercial feed companies provide their customers a choice of supplements either with or without urea. In nearly all cases, the urea containing supplements cost less per ton and less per unit of crude protein equivalent. Labels of such supplements contain the following information: "does not contain more than (XXX) per cent non-protein nitrogen." The livestock producer must evaluate whether his ration and animals are of such nature that NPN can logically substitute for natural (vegetable) protein. A large number of research trials suggest that urea can replace natural protein at levels of up to 1/3 of the dietary protein need for many production rations.

Several dietary and animal factors are required in order for urea to effectively replace or substitute for natural protein. A substantial amount of rapidly fermentable carbohydrate is required. This means the ration must furnish relatively large amounts of starch or sugar. Urea is relatively ineffective as a protein substitute in rations

containing large proportions of mature forages, such as straw or medium or poorer hays. Apparently this is due to the much slower rate of digestion (rumen fermentation) of carbohydrate materials in mature feedstuffs as compared to grains or higher quality forages. Special care must be taken to insure the ration's adequacy in terms of the major minerals, especially phosphorus, sulfur, and all the trace minerals. Potassium may be more important than previously thought. Sulfur is of particular importance when urea is used as a protein substitute; however, only diets based heavily on corn silage and corn grain have consistently shown improvement from sulfur inclusion.

Protein supplements designed for feeding with low-grade roughages often contain up to about one-third of their crude protein equivalent from urea. Liquid supplements are an exception to this general formulation rule. Liquid supplements may be formulated with as much as 97 per cent of the crude protein equivalency coming from urea. This largely explains why low quality rations deficient in protein and based on lower quality roughages have not been supplemented as successfully with liquid supplements as with supplements containing vegetable protein exclusively. Some other limitations to use of urea in ruminant protein supplements should be mentioned. High producing dairy cows are not able to utilize large amounts of urea in their rations and still maintain the milk production level they would attain with all-vegetable protein supplementation. Lower producing cows, however, seem able to utilize urea as a major source of supplementary dietary nitrogen. Rate of protein synthesis from urea becomes the important and limiting factor. The very high producing dairy cow may require as much as 6 to 8 pounds dietary crude protein daily; from this she may synthesize as much as 2.7 pounds of milk protein daily. It is apparently impossible for her rumen to synthesize microbial protein at a rate fast enough to furnish a significant part of this high need for protein.

A very few situations exist where the total dietary nitrogen supply (natural protein and NPN) may be utilized slightly more efficiently when the diet contains some non-protein nitrogen than when the dietary protein is strictly of vegetable or natural origin. The prime example here is a feedlot steer on a diet high in corn grain. The abundance of fermentable starch in that steer's diet requires some readily available source of protein or nitrogen (ammonia, strictly speaking) for combination with organic acids resulting from the large amount of starch being fermented.

North Dakota and other Northern Great Plains states are in a unique situation insofar as our feed grain supply and potential optimum use of non-protein nitrogen is concerned. Barley and oats, wheat, durum, rye, and millet contain at least 30 per cent more protein than does corn. Comparatively little corn grain is used in production rations in much of our region. Since our feed grain supply averages substantially higher in crude protein than that of the Corn Belt states, there is consequently less potential for use of urea or other NPN material, or for any kind of protein supplement, than the corn growing and feeding area. Many least-cost, high-performance rations can be formulated on North Dakota farms and ranches using strictly homegrown feeds that require no dietary protein supplementation of any kind to provide the animal's dietary needs for protein for the desired level of performance. Obviously many rations will require protein sup-

plementation because of inadequate forage quality, very high animal production or performance expected.

Another animal use of NPN that deserves mention is the combination of urea and one of our high-protein feed grains in lieu of vegetable protein. A commercial product of gelatinized starch and urea has been studied and shown to be quite effective where protein supplementation is needed. Other studies have recently shown that a similar barley and urea extrusion product gave as good over-wintering performance in steers as plant protein supplementation.

Plant-Animal Aspects of Nitrogen Fertilization

Nitrogen levels in the soil affect the nitrogen fractions (proteins) in the plant. Cooperative research among the Departments of Botany, Agronomy, Soils, and Animal Science along with several branch stations and the Sheyenne Grazing Association have studied the effects of various soil nitrogen levels on plant growth and protein fractions. Results of this research indicate that as soil nitrogen levels increase, plant proteins increase, as well as total forage production. Protein levels increase for each level of nitrogen added to the range site in the Sheyenne Grasslands. One hundred pounds of nitrogen/acre increased the protein level approximately four percentage units. The added nitrogen levels also improved other nutritional fractions, such as reduction in fiber levels and an increase in digestibility; however phosphorus and calcium levels decreased with added nitrogen.

Another 3 year study involving nitrogen fertility levels on some common native grasses was conducted at the Dickinson Station. Samples were taken throughout the grazing season and analyzed for total, true, and non-protein nitrogen (NPN) components. The average of each protein fraction of the grasses was higher when nitrogen was added to the soil. No nitrogen resulted in a seasonal average of protein of 8.56 per cent compared to 11.60 per cent when 100 pounds of nitrogen was applied. This same trend was observed with the true protein and the NPN fractions. The grass protein fractions were unaffected by high nitrogen levels when sampled 3 years after 400 pounds of nitrogen were added, indicating low carry-over of added nitrogen in the soil from year to year. When nitrogen was added every other year higher protein levels in the grasses resulted only in the year it was added.

The greatest effect of the nitrogen addition on the protein content in the grasses was during the early part of the grazing season. When no nitrogen was added the total protein and NPN fractions at the beginning of the grazing season were 11.30 per cent and .20 per cent, respectively, and with nitrogen addition were 15.31 per cent and .45 per cent. At the end of the grazing season these same fractions on the control dropped to 6.27 and .10 per cent compared to 7.98 and .23 per cent when nitrogen was added. As in the Sheyenne Grasslands experiments, phosphorus levels decreased with added soil nitrogen, but the short upland grasses were higher in digestibility. This was not true with the western wheat grass or needle and thread. None of the nitrogen fertility experiments at any level or any season of the year produced any toxic levels of NPN for grazing ruminants nor were there any toxic levels of potassium to calcium plus magnesium ratios as they would relate to grass tetany.

In summary, concerning nitrogen additions to soils producing forages the following general statements can be made. Forage production is increased. The total, true and non-protein nitrogen fractions are all higher and the greatest increase is during the early part of the grazing season. There were no toxic levels of NPN observed at levels of up to 100 pounds of nitrogen added annually. Protein fractions in the grasses were unaffected by high nitrogen levels applied 3 years prior to sampling. All protein fractions decreased as the grazing season progressed but the grasses where nitrogen was added were higher in protein throughout the season. Digestibility increased and fiber and phosphorus decreased with added soil nitrogen. The increase in grass protein fractions reduced the need for protein supplementation for grazing ruminants in seasons when protein levels in unfertilized forages would be inadequate to meet protein requirements.

Semen Storage

Characteristics of economy, safety, and remaining in the liquid state over a temperature range satisfactory for preservation of semen fertility (-270° to -321° F.) have established liquid nitrogen as the only refrigerant used worldwide for semen preservation. Artificial insemination permits widespread use of superior proven sires on far more females than they could ever be mated to naturally, resulting in much faster genetic improvement than otherwise possible. Equally important, A.I. permits rapid and thorough genetic evaluation of promising but unproven young sires on a large number of females under varied environments for both favorable and undesirable traits. Artificial insemination on a commercial scale involving large numbers of dairy and beef cows and more recently swine depends upon a worldwide refrigerant; nitrogen in the liquid state has proven to be the most satisfactory material available.

Newer Animal Uses for Nitrogen Compounds

Elevating Protein Content of Silage

Among the high potential economic uses of nitrogen is the application of simple nitrogenous compounds to corn silage at ensiling time to increase the crude protein content. Dry matter of corn silage normally contains about 8 per cent crude protein. By adding appropriate amounts of non-protein nitrogen materials, protein content can be increased to 12 per cent or more. The earliest research using NPN to increase crude protein of corn silage at ensiling time was done with urea. This increase can be obtained by incorporating 10 pounds of feed grade urea per ton of corn silage at ensiling time. This appears to be an economic practice but has never gained the acceptance and usage researchers feel it deserves. The addition of urea to silage at ensiling time has been shown experimentally to be slightly more effective than adding the same amount of urea at feeding time. Increased accumulation of bacterial protein in the nitrogen-treated silage is thought to be the basis for the difference in animal performance due to time of treatment.

Feed grade diammonium phosphate has also been experimentally used successfully as a source of nitrogen for upgrading crude protein content of corn silage. Since much of its cost is based upon its content of phosphorus as well as nitrogen, it is more costly as a source of nitrogen than

is urea. However, its phosphorus content also becomes available for nutrition of the animal consuming the treated silage.

A more recent development has been the use of a specially buffered solution of ammonia (NH₃) and minerals, particularly phosphorus and sulfur, plus trace elements for addition to corn silage. This commercial, ready-mixed product has given excellent performance.

The most recent research development in the use of nitrogenous materials for low-cost increase of crude protein content of corn silage is the application of 7 pounds per ton of anhydrous ammonia directly into corn silage at ensiling. This is the same material as is knifed into the soil as nitrogen fertilizer. Application of cold liquid ammonia to corn forage was given Food and Drug Administration approval for on-farm usage in August, 1978. Application can be done either at the silage blower for upright silos or into the blower of the field cutter when a horizontal silage storage is used. To date, corn is the only silage which has been adequately investigated insofar as NPN additions are concerned. Corn silage is typically richer in readily fermentable carbohydrate than other forage crop silage; it is not likely that NPN additions will prove as effective with other silage crops as it has with corn.

Forage Preservation

A recent area of research is the use of anhydrous ammonia gas for aid in preservation of stored forages. Recent research suggests ammonia to be one of the most effective preservation materials yet tested for mold prevention and preservation of hays (baled or stacked) with moisture levels too high for safe storage. The forage obviously must be enclosed in an air-tight structure or device to provide adequate ammonia penetration and operator safety.

A still newer research area involves application of ammonia to lower quality dry forages, including straws and other crop residues. Early research indicates improvement in animal digestibility due to ammonia treatment. Voluntary intake of the treated residues or hays is similarly improved, with the potential for using larger amounts of such low-quality feedstuffs in maintenance rations and possible inclusion of moderate levels of such NH₃ treated materials in production rations requiring higher energy intake. Mechanism of this observed increase in digestibility is thought to be the breakdown by ammonia of the bonding of cellulose to lignin in the treated forages. Further research is essential to properly evaluate these two potentially high value uses for ammonia in animal production.

Ruminal Protein Degradation Affects Efficiency of Nitrogen Utilization

As mentioned earlier, ruminants can use non-protein nitrogen to supply much of their protein needs. The bacteria and protozoa use the ammonia (nitrogen) to synthesize amino acids (protein) to meet their own needs. As the "bugs" are passed from the ingesta in the reticulo-rumen to the true stomach and gut they are digested and provide amino acids to their host animal. However, quality of bacterial protein, meaning the level and balance of amino acids in the protein, may be less than desired by the

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BULK THIRD-CLASS

1. The cost of accumulating nitrogen by summer fallowing increases rapidly with higher crop prices. Higher crop prices increase the value of the crop given up for summer fallow more than it raises the value of the increased crop yield the year after fallowing.

2. The cost of nitrogen from summer fallowing decreases as nitrogen fertilizer prices increase. Higher nitrogen prices increase the cost of the crop foregone for summer fallow more than it increases the cost of the extra crop yield after fallow.

3. Nitrogen accumulated in summer fallow costs the least in western North Dakota and increases in cost in eastern areas. Although the amount of nitrogen build up from summer fallow is less in the west, both the summer fallowing cost and the value of the crop given up are lower in the west. In addition, the extra moisture increases yields more in the west than in the east, making summer fallowing a more profitable practice.

At very high nitrogen fertilizer prices and low crop prices, summer fallowing is an economic means of acquiring nitrogen in West and West Central North Dakota.

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host animal. Research has demonstrated that if some of the better quality protein supplied in the feed could "by-pass" degradation by the "bugs" and "pass-through" the rumen unaltered, the host animal could be provided with a better balance of amino acids for its own use. This area of research, getting protein to "by-pass" bacterial degradation, is challenging. Several factors affect the amount which passes through the rumen. Lower solubility of the protein in the rumen, either inherent in the protein or altered by heat treatment, increases the amount of protein passed through the rumen. Treatment with certain chemicals such as formaldehyde prevents the "bugs" from

Even when summer fallowing is not an inexpensive means of acquiring nitrogen, farmers use the practice to reduce income variability, improve labor distribution, and control weeds. Higher nitrogen fertilizer prices will tend to reduce the cost of accomplishing these objectives.

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degrading the protein.

Research is needed to know how much protein should be by-passed and how much should go to the "bugs". In the past, quality of protein was not considered of much consequence in ruminants but with a better understanding of this concept, quality of protein is becoming important in ruminant rations in increasing the efficiency of protein utilization.

Research to uncover the truths of nitrogen use and metabolism leaves much to be learned on the efficient use of protein in animal production in spite of all research that has been completed.