Protein Utilization in the Ruminant

Ivan G. Rush, *Ph.D.*
Extension Beef Specialist
University of Nebraska Panhandle Station
Scottsbluff, Nebraska

Protein is one of the most important nutrients to be considered in the ruminant animal. Today, much is being said about the future shortage of quality protein in the world. Because of this concern, as well as today's relatively high cost of natural protein, much research has recently been conducted with low quality or synthetic protein in ruminant rations. The ruminant animal is utilized to produce high quality protein from nitrogen sources that could not be utilized by humans or other simple stomached animals.

This research has led to a much closer look at the site of digestion, as well as factors involved in nitrogen or protein utilization at the various sites. Many excellent review articles have been written concerning nitrogen utilization which include, Protein requirements for cattle, Symposium (1), Alternate nitrogen sources for ruminants, (2), Urea and other nonprotein nitrogen compounds in animal nutrition (3), and, Progress in the utilization of urea as a protein replacer for ruminants (4), which the reader may refer to for more details. The purpose of this paper is to summarize some of the present research and thoughts on nitrogen utilization in the ruminant.

Terminology

Before discussing nitrogen utilization, it may be wise to briefly review some terms that relate to protein. Crude protein is defined as nitrogen times a factor of 6.25. It is known that the protein in most feedstuffs contains 16% nitrogen, therefore, feeds are analyzed for the nitrogen content and the result is multiplied by 6.25 ($100 \div 16 = 6.25$). Not all natural plant proteins contains 16% nitrogen. For example, wheat has a slightly different percentage. However, protein values are based on the standard 6.25 factor. This has caused considerable confusion because oftentimes it is assumed that crude protein is equivalent to the actual natural protein content. Feeds that contain nonprotein nitrogen (NPN) have considerable discrepencies in natural protein and crude protein. Because urea theoretically has 282% crude protein, (45.1% nitrogen X 6.25 factor = 282) when it is added to a feed it increases the crude protein content (nitrogen level) considerably, but does not contribute any natural protein to the feed itself. Consequently, it is important to recognize that the crude protein fraction of a feed may include both high quality protein and NPN.

Paper presented at the Bovine Nutrition Seminars AABP District 9, May 26-27, 1983, Denver, Colorado.

Crude protein can be further broken down into digestable, metabolized, and net protein. Some people prefer to use digestible protein in ration formulation, because it is felt that it is more accurate in balancing the actual protein requirement. In some cases, digestible protein may be more accurate, especially when low quality roughages that are low in digestibility are considered. However, digestible protein is highly inaccurate when feedstuffs that are high in NPN are fed. Consequently, it is questionable if digestible protein is any more accurate than crude protein in most practical ration formulations. Metabolizable protein indicates the quantity of absorbed amino acids in the small intestine, which accounts for the loss of undigestible protein, plus the loss of nitrogen in the urine. It is difficult to determine metabolizable protein accurately because of indigenous nitrogen. Net protein is defined as the protein that is actually formed into body protein. Several attempts have been made to determine net protein which is highly beneficial. However, the accuracy of the values needs to be improved.

Nitrogen Utilization in the Rumen

As protein enters the rumen, it is partially broken down by rumen microorganisms to ammonia and other carbon fragments. Some of the protein escapes rumen degradation and passes onto the small intestine where most of it is digested as amino acids. The portion that escapes rumen breakdown is often referred to as bypass protein. The quantity that bypasses the rumen, and factors that affect breakdown will be discussed later.

The rumen organisms, both bacteria and protozoa, utilize most of the available ammonia along with available carbon fragments and energy, and consequently, synthesize microbial protein. These organisms are later digested in the small intestine and amino acids are absorbed and utilized in protein synthesis in the animal's tissue. Because microbial protein is high quality (proper balance of amino acids), it is possible for cattle to meet most, if not all, of their protein requirements from feedstuffs that do not contain the proper amino acid balance.

It is important to consider two requirements in protein nutrition. The first is for the rumen microorganisms, *per se*, and the second is for the total animal. Obviously, they are closely related, however, the rumen organisms must have enough free ammonia to maximize fiber digestion, but not in excess so that some of it is lost or poorly utilized.

Energy Affects NPN Utilization

Usually the cost of NPN is much lower per unit of nitrogen than from natural protein, and therefore, it is desirable to maximize its use. The amount of NPN that can be utilized is related to the amount of available energy in the ration. This is the reason large quantities of urea or other NPN sources are successfully utilized in feedlot rations, and also why they are poorly utilized in low energy rations.

Minerals Affect NPN Utilization

Most synthetic NPN compounds, such as urea, contain only nitrogen and carbon, and are devoid of the other minerals and vitamins. Probably the most important mineral that affects NPN utilization is sulfur, as it is required in methionine, and most feeds contain enough sulfur to meet minimum requirements. However, there are always exceptions that need to be considered. The nitrogen-sulfur ratio should be approximately 12:1 to assure maximum microbial protein synthesis. Potassium is also an important mineral to consider when NPN is fed. For example, when urea is used to replace oil seed meal in supplements, additional potassium, calcium, phosphorus, and trace minerals will be needed in a supplement. Analysis usually indicates that low quality roughages are low in potassium, and research has shown that performance can be markedly improved when potassium is added to range supplements high in urea *(Table 1).*

TABLE 1. Effect of adding potassium to urea containing supplements for steers grazing winter range.

Principal Ingredients	Percent Potassium	Urea	Prot. Equiv. From NPN	Average Daily Gain
Soybean meal	1.90	0	0	0.34
Soybean meal and urea	1.35	5.0	35	0.09
Soybean meal and urea + 1.2% Potassium chloride	1.85	5.0	35	0.20

Karn, J. F. and D. C. Clanton, 1976 Neb. Beef Cattle Report. (5)

Bypass Protein

In the early 1970's, it was recognized by many researchers that urea performed differently with various natural protein sources. As was stated earlier, the rumen organisms require some nitrogen in the form of ammonia to maintain high rumen activity. When highly soluble protein sources are fed, they break down rapidly and free ammonia is produced. However, the incorporation of the available ammonia back into microbial protein is an inefficient process. Therefore, it is desirable to feed proteins that escape rumen breakdown and are digested in the lower tract. Feeding slowly degraded proteins as the sole source of nitrogen may create an ammonia deficiency in the rumen. Consequently, it would be desirable to feed a combination of high quality protein that escapes the rumen organisms breakdown, and a more economical source of NPN be fed to meet the microbial population ammonia requirement.

Grain proteins, such as brewers grains, distillers grains, and corn gluten meal, are high bypass proteins, although the protein quality is somewhat low. Also, protein sources that have been heated have high bypass values. Examples of heated sources would be dehydrated alfalfa, blood meal, meat meal, plus some processing methods used in oil extraction which can create a large amount of heat.

As the use of urea increased in cattle rations, Iowa State researchers sought ways to improve the feeding standards for expressing protein requirements. The measurements proposed were metabolizable protein (MP) requirements of cattle and urea fermentation potential (UFP) of feedstuffs. Metabolizable protein was defined as protein that escapes breakdown in the rumen and is digested as amino acids in the lower tract, plus it includes the digestion of microbial protein that passes to the lower tract. Urea fermentation potential is defined as the quantity of urea (or other NPN compounds) that could be used to form microbial protein. Feed composition tables and animal requirements were established based on mathematical formulas, *in vitro,* and animal feeding trials. The system is presently being used by some nutritionists. As more reliable data on degradation of feed proteins is collected, the MP and UFP values will be updated, which will make the system more exact and usable.

One of the major problems determining accurate values is that the amount of protein that actually escapes rumen breakdown and its relation to NPN utilization is often difficult to determine. Researchers throughout the U.S. have investigated ways to quantify the amount of protein that bypasses the rumen, which will eventually lead to specific natural proteins and NPN recommendations for all classes of cattle consuming various rations. Nebraska workers have

TABLE 2. Value of high bypass proteins.

Source	% Protein	Protein efficiency Value %	Protein source lb.	Corn lb.	Urea lb.	Cost/ton soybean meal equivalent[b]
Soybean meal	45	100	2000	—	—	$261
Corn gluten meal	62	200[a]	643	1218	139	$181
Brewers' grains	28	190	1619	229	152	$147
Distillers' grains	28	173	1853	12	135	$167
Distillers' grains plus solubles	28	137	2346	—	87	$202
Dehydrated alfalfa	17	190	2788	—	152	$191
Blood meal, ring dried	85	250	365	1473	162	$182
Blood meal, conventional	85	200	458	1405	137	$179
Meat meal	50	185	885	984	131	$210

[a]When fed with a high quality protein.

[b]Bsed on 11/3/80 and 11/10/80 "Feedstuffs" prices: SBM, $261; CGM, $290; BDG, $145; DDG, $165; Dehy, $126; BMRD, $420; BMC, $350; MM, $121; Corn, $121, and Urea, $200.

Klopfenstein et. al. (1)

compared various protein sources to soybean meal, and have estimated comparative values for the high bypass protein sources *(Table 2).*

Cornell workers have developed a microcomputer program to estimate net protein requirements for various classes of livestock. It is a complicated procedure that takes into account many interacting factors such as stage of growth, frame score, dry matter intake, form of dietary energy, and feed processing. Again, this system is relatively new and needs refinement. It does hold a great deal of promise in determining the amount of net protein that is needed so that rations could be balanced for the most optimum and economical gain.

References

1. Protein requirements for cattle: Symposium. 1982. Okla. Sta. Un. MP - 109. 2. Alternate nitrogen sources for ruminants. 1978. National Fert. Devel. Center, Tenn. Valley Author. Muscle Shoals, Ala. Bull. Y - 130. 3. Urea and other nonprotein nitrogen compounds in animal nutrition. 1976. National Academy of Sciences, Washington, D.C. 4. Helmer, L.G. and E.E. Bartley. 1971. Progress in the utilization of urea as a protein replacer for ruminants. A review. J. Dairy Sci. 54:25. 5. Karn, J.F. and D.C. Clanton. 1976. Potassium in range supplements. Neb. Beef Cattle Report EC 76-218.