Lecture 5

IMPORTANCE AND METHODS OF BY-PASS PROTEINS IN RUMINANT FEEDING

Protein in ruminant feed

The total protein content of feeds/forages (dietary proteins) is generally referred to as "crude protein". Crude Protein (CP) is calculated from the nitrogen content of the forage. The CP value is important since protein contributes energy, and provides essential amino acids for rumen microbes as well as the animal itself. The more protein that comes from forage, the less supplementation needed. Protein in forages is most correlated with forage maturity, as more mature forages have a lower percentage of crude protein.

Ruminants require two types of protein in their diet. One type is degraded in the rumen and is used to meet the needs of the microbial population, and the other bypasses the rumen and is used primarily to meet the productive needs of the animal.

Degradable proteins

When feeds/forages are ingested by ruminants, they are being transported to the rumen which is the first and largest compartment of the ruminant digestive tract. The dietary proteins entering the rumen are being attached by large population of microbes which degrade the proteins into simple compounds such as ammonia which the microbes utilize to build up their own cell walls.

When protein is degraded in the rumen it is called *rumen degradable protein*. Rumen degradable protein is essentially the food for rumen bacteria. When the microbes die they are passed through to the stomach and small intestines where they are digested by the animal. The resulting *microbial protein* is then absorbed into the animal's bloodstream.

Un-degradable proteins

Some of the protein in the diet does not undergo degradation in the rumen, but passes straight to the abomasum or stomach for digestion. When protein escapes rumen breakdown and passes to the stomach it is referred to as *rumen un-degradable protein* or *bypass protein* or *rumen escape proteins*.

BYPASS PROTEIN

What is 'Bypass' protein?

Bypass protein is also called Rumen escape or Un-degradable Protein (UDP). It is the portion of the protein from a feedstuff (copra or cottonseed meal) that escapes from being broken down in the rumen by microbes. Bypass protein passes relatively intact into the small intestine where it is digested by enzymes of the animal and directly used as a source of protein.

Definition: In clear terms, bypass proteins are defined as the portion of the protein from a feedstuff that escapes from being broken down in the rumen by microbes and passes into the small intestine intact where it is then digested by enzymes and utilized by the animal as a source of protein.

Bypass protein meals such as cotton seed meal are a by product of extracting oil from the seed. The protein meal generated has passed through heat and physical treatments that modify its molecular structure and render it relatively unbreakable to microbes in the rumen. However, it is still digestible by the animal as a protein source in the small intestine. Hence the term "Bypass" protein as it bypasses the main site of protein digestion in the animal.

Why is it important to 'bypass' the rumen?

The microbes in the rumen take the protein from different feedstuffs and they break it down to make their own protein – microbial protein. Although microbial protein is a high quality protein, it isn't a very efficient form of protein synthesis and not all-essential amino acids are supplied in proper balance. Hence, anything we can do to provide the animals with a source of protein that escapes from being digested by the microbes in the rumen and make it to the small intestine for digestion, is beneficial to ruminant animal's nutrition.

Bypass protein is important because a large percentage of the rumen degraded protein is absorbed as ammonia and, if in high concentrations, can be lost through the urine as urea. In high-producing animals this represents an inefficient utilization of protein, so increasing the amount of protein that is by-passed to the intestines constitutes a more efficient utilization of protein for growing or lactating animals on high-quality pastures. In forages, roughly 20 to 30 percent of the protein taken in by the animal is bypassed to the intestines. Lactating or growing cattle generally require 32 to 38 percent of their total protein intake to be in the un-degradable form. High-quality pastures can meet almost all the needs of high-producing livestock. For those animals that require supplementation, corn, cottonseed and linseed meals, brewers dried grains, corn gluten meal, distillers dried grains, and fish meal are typically high in bypass protein.

The microbial degradation of protein is an energy-dependant process. Carbohydrates are the energy-yielding nutrients in animal nutrition and are supplied by the production of volatile fatty acids in the rumen. Generally more microbial protein is synthesized from green forage diets than from hay or mature forage diets. When a ruminant animal grazes fresh forage on high-quality pasture, about 70 percent of the protein is degraded in the rumen by microorganisms, and about 30 percent escapes to the small intestine for absorption. Ruminant animals need approximately 65 to 68 percent of the protein to be rumen degradable for adequate rumen function and the development of microbial protein. But if more protein is degraded in the rumen, less is available to the animal for absorption in the small intestine. This is important because researchers believe that rumen un-degradable or bypass protein consists of certain essential amino acids that are missing or deficient in rumen degradable protein. Much of the rumen degraded protein is absorbed as ammonia and excreted out of the body via the urine, and is therefore a waste of protein. This is why bypass or undegradable protein is important, especially for high-producing livestock such as dairy animals, even in protein-rich-pasture diets.

Some animal nutritionists suggest that bypass protein has been overemphasized. This is because the total proportion of bypass protein in most forage is around 30 percent, which is very close to the requirements of the ruminant animal. In this case, they suggest, feeding the rumen microorganisms takes on particular importance, for if the rumen microorganisms are healthy, they will supply the ruminant with the nutrients they need to maintain body functions and remain productive. We must remember that ruminant animals evolved in symbiosis with rumen microorganisms in a grassland environment, and they are inherently adapted to this function.

What are the main benefits of ‘bypass’ protein?

The main benefit of ‘bypass’ protein is that the original amino acids in the protein meal are absorbed in the small intestine instead of converted to microbial protein in the rumen, thereby providing a different balance of essential amino acids for better animal nutrition hence, production. Another benefit of feeding meals with high ‘bypass’ protein is that the portion of the protein that is rumen degradable (RDP) breaks down in the rumen very slowly. This allows animals to source small amounts of protein over longer periods for microbial protein production, long after urea has been degraded and used in the rumen by the animals. Small quantities of ‘bypass’ protein fed at strategic times, have an enormously beneficial effect on production. ‘Bypass’ protein also provides an important protein source when the animal’s requirements for protein exceed those provided by microbial protein.

Factors Affecting Bypass Protein Variation in Forages

There are many factors that can influence the bypass protein content of forage. Listed below are common factors most often associated with creating variation in forage bypass protein content.

- **Maturity**

Numerous research projects have demonstrated that **immature forage legumes and grasses contain more degradable and less un-degradable protein than mature forages. Immature forages contain more non-protein nitrogen primarily composed of ammonia, nitrate, amines, amides, and free amino acids which are rapidly degradable in the rumen. With advancing maturity, true plant protein synthesis advances and the cell wall matrix becomes more complex, rendering forage protein less accessible to rumen bacteria and less degradable.** These factors ultimately reduce degradation potential of forage proteins. Maturity therefore is considered as having a profound and large influence on bypass protein content of forages.

- **Species**

Species is also known to affect bypass protein content of forages. **In general, legume protein is more degradable than grass protein. This is due in part to grasses containing more neutral detergent fiber which reduces rates of nutrient digestion. Variations also occur within grasses, and some grass species appear to have greater levels of bypass protein while others appear to be quite degradable.**

- **Fertilization**

Grasses assimilate soil nitrate (NO_3) and ammonium (NH_4) into non-protein nitrogen and true protein fractions. Increasing soil N supply increases forage N (crude protein). The increase in forage N (crude protein) is, however, disproportionate with the non-protein nitrogen pool increased to a greater extent than the true protein pool. Because non-protein nitrogen is readily degradable in the rumen, nitrogen fertilization generally reduces the amount of bypass protein.

- **Ensiling (Proteolysis)**

When forages are ensiled, bacteria ferment the forage and breaks forage protein down into smaller fractions which are more degradable by rumen bacteria. This process is called proteolysis. Some researchers estimated that only 9% of forage macro protein molecules remain after fermentation. The effect of proteolysis can have a dramatic effect on the bypass protein content of forages. The concept of proteolysis can be demonstrated from a study where Alfalfa silage was made at three different maturities and wilted for 0, 10, 24, 32, 48, and 54 hours before ensiling. Ruminal degradability of ensiled forages was then compared to non-ensiled forage (NE). In all cases, the percent crude protein remaining (bypass) was less for the ensiled forages as compared to the non-ensiled forages.

- **Heat Damage**

When forages are ensiled too dry and/or elimination of oxygen from the silage mass is not satisfactory, significant levels of heat can be produced during the fermentation process. Significant levels of heating can also occur when legume or grass hays are made too wet. In these situations when excessive heating occurs, forage protein may become bound (mallard reaction) to forage carbohydrate fractions, rendering the protein fraction less degradable.

Ways of protecting protein from degradation in the rumen

Protein requirements for high rates of growth in ruminants cannot be met solely from microbial protein synthesis in the rumen; therefore, supplementation with high quality rumen undegradable protein is necessary. Due to the high cost of protein supplements, ways and means of protecting the protein from degradation in the rumen whilst retaining the high digestibility is an urgent priority. Many experiments have demonstrated the beneficial effects of the technological processing of feeds, particularly heat treatment, in reducing the degradation of the crude protein in the rumen without decreasing digestibility in the small intestine. For highly producing ruminants, heat treatment of protein supplements has been used for increasing the amount of dietary protein escaping rumen degradation, and to increase the amino acid pool entering the small intestine.

There is no sure method that can be recommended for use on smallholder farms. Toasting and extrusion of the feed is appropriate for oilseed meals in the feed mill as may be dehydration of foliages. Reacting with formaldehyde has been used commercially in industrial countries but there are doubts as to the safety of the method for more widespread use.

None of these methods is feasible on smallholder farms. Sun-drying will have some positive effect in reducing protein solubility. There is also the possibility for mixing tannin-rich feeds with those rich in protein but low in tannins.

In summary, methods of decreasing protein and amino acid degradation in the rumen include:

1. Heat treatment
2. Chemical treatment
3. Encapsulation
4. Use of amino acid analogues
5. Selective manipulation of balances of rumen metabolic pathways
6. Oesophegeal groove closure

PROTEIN DIGESTION

Proteins are chemical compounds of great complexity and high molecular mass containing about 16 % nitrogen (N). Nitrogen is the chief element which distinguishes proteins from carbohydrates and fats. Since there is a fairly constant proportion of about 16 % nitrogen in protein, nitrogen is used to estimate the protein content of feeds by determining the nitrogen content of the feed and then multiplying this value by 6.25 (100/16 = 6.25). The estimate of protein obtained from nitrogen determinations is called crude protein (CP).

The building blocks of protein are 20 naturally occurring amino-acids which are linked together by di-peptide bonds in a manner similar to beads strung on a necklace. The ruminant cannot synthesize these amino-acids in its body, but the micro-organisms in the reticulo-rumen can. This protein is known as microbial protein.

Amino-acids are the essential building blocks of all living tissues. Proteins are not absorbed as such, but enter the bloodstream as amino-acids which are released during digestion in the duodenum. To produce milk protein, the correct casein precursor amino-acids must be supplied to the udder.

In the ruminant, amino-acids are provided from two radically different sources. The first is the feed offered to the animal. Some of the protein in the feed will escape fermentation in the rumen and will arrive in the duodenum with its constituent amino-acids intact. This is called undegraded (UDP) or bypass protein and the constituent amino-acids can then be absorbed through the gut wall into the bloodstream.

The second source of amino-acids is from protein contained in the microbes' bodies. This microbial protein is derived from the nitrogenous feed material which is fermented in the rumen (called rumen degradable protein or RDP) by the same micro-organisms which transform the carbohydrate fraction of the feed into volatile fatty acids. The end products of the fermentation process are simple nitrogenous compounds, mostly ammonia, but also various other protein break-down products such as peptides and amides. Ammonia is also produced from any non-protein nitrogen in the foodstuff. The micro-organisms then proceed to use these simple materials as building blocks for their own body protein. These micro-organisms are constantly being swept down the gut with the rest of the digesta. The animal then digests these microbes in the duodenum and, during the digestion process, absorbs the amino-acids released from the microbes' body protein in the same way that it absorbs the amino-acids from the protein which has bypassed ruminal fermentation. The amount of protein which bypasses rumen fermentation varies between approximately 20 %, (in grazing) and approximately 40 to 60 % (for processed feeds, depending on the amount of heating, grinding, *etc*. employed in processing).

The unique ability of the ruminant to convert protein to ammonia, and subsequently into microbial protein is one of the most important aspects of ruminant nutrition, in that it allows the ruminant to convert non-protein nitrogen sources, such as urea, into ammonia through ruminal fermentation, and subsequently into microbial protein. This means that the ruminant can synthesize amino-acids from elemental nitrogen.

The rumen, however, has a limited capacity to convert ammonia to microbial protein. The maximum limit of conversion is considered to be 30 to 32 g N per kilogram digestible organic matter consumed by the animal. If more non-protein, or degradable nitrogen, is supplied than the microbes are able to convert into microbial protein, excessive ammonia may accumulate in the rumen. The excess ammonia produced has no nutritive value and is absorbed into the bloodstream across the rumen walls. The ammonia in the blood is converted to urea in the liver and excreted in the urine. It is possible to exceed the animals ability to convert ammonia into urea in the liver, resulting in ammonia toxicity (urea poisoning). If non-protein nitrogen alone is provided as the only protein source in the diet of the cow, her milk yield will be restricted to a very low level of approximately 9 litres per day over the lactation. Therefore if a higher production level is required, the amino-acids absorbed in the mid-gut must be derived from undegradable or bypass protein. The higher the production level, the greater the requirement for bypass protein.

Measures of expressing protein content

The present simple system of expressing the protein content of feeds, according to crude protein content (the CP system) does not take into account the degradability of protein. This system is therefore slowly giving way to other systems which take the role of undegradable protein into account. At present there are several major research efforts, in Europe and the United States of America, to develop and to perfect a new system of evaluating protein for ruminants. The modern trend is not to express the nitrogen content of feed as crude protein, but as the nitrogen from which it was derived.

This new system was recommended by the British Agricultural Research Council in 1980 and by the National Research Council (USA) in 1985. It takes into account the fact that the use of protein by the ruminant is dependant on the energy intake of the animal. This is because the ability of the microflora of the reticulo-rumen to synthesize microbial protein is directly dependant on the amount of energy supplied in the diet. The physical composition of the diet will also affect the natural degradability of the same protein source, such as by altering the rate of passage of the digesta through the reticulo-rumen.

Perhaps the best argument for adopting this new approach to determining the protein requirements of ruminants, is that ruminal digestion is an essential component of feed utilization in ruminants. The functioning of the rumen is dependant on a healthy microbial population which requires both energy and rumen degradable protein to survive. If insufficient degradable protein is available to the ruminal micro-organisms, the rate of fermentation in the rumen will be reduced, leading to a reduction in feed intake and consequently a decreased energy supply to the animal for production.

In conclusion, the advantage of the new system is that it describes animal protein requirements in terms of RDP (degradable) and UDP (bypass) protein. This allows for the formulation of rations with not only the correct quantity, but also the correct type of protein. Correctly formulated rations will lead to the most efficient possible use of protein by the animal in that a proper balance of RDP and UDP is required for optimal fibre digestion in the rumen. A surplus of RDP is wasteful in that the cow only benefits if ammonia is converted to microbial protein. Excess ammonia has to be excreted from the bloodstream, at an energy cost of 22.8 kilo Joules per gram of N. The cost of excreting surplus RDP in the diet has been calculated to cost British dairy farmers between 1.3 to 2.6 litres fat-corrected milk (FCM) per cow per day on a typical grazing system. Surplus ammonia in the bloodstream has also been shown to adversely affect reproduction. Dry matter intakes have also been shown to be depressed by high non-protein nitrogen (NPN) levels in the herbage.

Bypass Protein

Other feed ingredients have special features with respect to protein degradability for use by ruminants. These are classified as bypass or undegradable protein sources, of plant or animal origin, and have crude protein content greater than 20%, with at least 50% of this protein escaping breakdown in the rumen. Most often, these ingredients have been specially heat treated or dried. They are most suitable for the diet of high-producing, early-lactation dairy cows or rapidly growing starter beef cattle. Bypass protein sources are often highly priced per unit of crude protein. The protein composition (amino acid profile) and levels of degradable, undegradable and soluble protein fractions are particularly important.