TechNote 6

Protein metabolism

IN THIS TECHNOTE

Proteins are required by the dairy cow for many metabolic functions, including tissue function, growth, lactation, and reproduction. The protein in feed is reported as crude protein (CP) and is estimated based on the nitrogen (N) content of the feed. CP = N x 6.25.

Crude protein includes the rumen degradable proteins (RDP), undegradable dietary proteins (UDP), non-protein nitrogen (NPN) and undigestible dietary protein. The digestion and metabolism of dietary protein is outlined in Figure 1).

For more details see TechNote 3: What's in a feed, and online eLearning activity: The role of protein; dairynz.co.nz/feedright-module-5.

6.1 Metabolisable protein

Ruminants differ from single-stomached mammals. Although they need a constant source of protein, they do not need this protein to contain pre-formed amino acids (true proteins). This is because microbes in the rumen can use non-protein nitrogen sources (e.g. urea) to generate microbial protein and amino acids which the cow can use. Ruminants are also able to recyle nitrogen for later use, whereas in non-ruminants, any excess nitrogen is almost entirely lost in the urine.

The metabolisable protein, or the amino acids that the cow uses for metabolic functions, comes from two main sources:

- microbial protein,
- undegraded dietary protein.

6.2 Microbial protein

In the rumen, degradable proteins are broken down by microbes, firstly into peptides (short chains of amino acids), then into individual amino acids and ammonia. Non-protein nitrogen compounds, (e.g. from the diet or metabolism) may also be converted to ammonia in the rumen (Figure 1).

Rumen microbes then use the ammonia (along with the peptides and amino acids), for their own growth. Microbial growth also requires energy from fermentation of dietary carbohydrates in the rumen.

Rumen microbes are made up approximately 60% protein and the amino acid composition of microbial protein is relatively constant, regardless of the composition of the dietary protein that is degraded in the rumen or the amount of non-protein nitrogen that is used. All amino acids, including the essential ones, are present in microbial protein in a proportion similar to that required by the mammary gland for milk synthesis.

A portion of the rumen microorganisms flow into the omasum and then the abomasum, where the strong acid environment stops microbial activity and the digestive enzymes break down the microbial protein into amino acids. These amino acids are then absorbed through the small intestine for use by the cow.

If there is a shortage of ammonia in the rumen, feed digestibility is reduced, and dry matter intake drops. If there is an excess of ammonia, or a lack of fermentable energy in the rumen, the excess ammonia crosses the ruminal wall and is transported to the liver. Ammonia is toxic in high concentrations and in the liver it is converted to urea in a process termed ureagenesis. The urea is then released into the circulation and, depending on the protein content of the diet, follows one of two routes:

1. If the crude protein content of the diet is lower than required, the urea passes to the rumen either in saliva or directly from the blood through the rumen wall. In the rumen the urea is converted back to ammonia, and can be used to generate microbial protein.
2. If the crude protein content of the diet is greater than required, most of the urea travels to the kidneys and is excreted in urine. Some urea also ends up in milk (milk urea) and in the faeces.

For more details see TechNote 5: Carbohydrate metabolism, and online eLearning activities: The role of carbohydrates; dairynz.co.nz/feedright-module-4, and The role of protein; dairynz.co.nz/feedright-module-5.

6.3 Dietary protein

Some dietary proteins are resistant to degradation in the rumen. These are termed undegradable dietary proteins (UDP) or by-pass protein, and pass through the rumen unaltered. The degree of resistance varies with the type of protein, and factors such as the rate of passage through the rumen, and the speed at which the microbes process the feed. The undegraded dietary protein passes through to the abomasum, where enzymatic digestion begins and the resulting amino acids are absorbed from the small intestine for use by the cow.

6.4 Protein source

A dairy cow can live and produce milk on microbial protein alone. However, there is a limit to the amount of microbial protein that can be produced. Microbes can only use about 8 g of rumen degradable protein, or non-protein nitrogen, for every MJ of fermentable metabolisable energy. This means microbial protein synthesised in the rumen is enough to produce about 12 litres of milk, approximately 400 g milk protein. Therefore, if cows are producing more milk than this, they cannot do so with microbial protein alone.

Different feeds contain varying levels of the protein types (Table 1). For example: Canola meal contains about 65% crude protein of which 60% is undegradable dietary or by-pass protein and only a small proportion (12%) is soluble protein (degraded quickly in the rumen). In comparison, maize silage contains 8% crude protein, of which 30% is undegradable, while 50% is soluble protein.

Table 1. *Protein synthesis from different feeds.*

Diet	Process	Result	Considerations
High quality spring pasture	High levels of RDP. However, a fast rumen passage rate means a portion of RDP passes through the rumen undegraded and delivers amino acids to the small intestine.	Any protein requirements are met. Any excess RDP is converted to ammonia and excreted as urea.	Levels of urinary N may be an environmental concern depending on farm system, soil type and region.
Summer dry pasture	Levels of crude protein drop in pasture. A high proportion of protein is RDP.	Protein requirements of mid-lactation cow may not be met.	Supplementation with feeds high in UDP may increase milk production but economics (cost/benefit) must be considered.
Canola meal	High levels of UDP that by-pass the rumen unaltered providing dietary amino acids for the cow.	Good protein supplement, and will increase a milk production if metabolisable protein is limiting production.	Needs to be fed in a controlled environment and often an expensive supplement. Cost/benefit must be considered.
Low CP silage (e.g.maize silage)	Low levels of crude protein and predominantly RDP.	Protein requirements of lactating cow may not be met.	Supplementation with feeds high in UDP, or good quality pasture may increase milk production but economics (cost/benefit) must be considered.

When determining which feeds will meet the protein requirements of the dairy cow, the rumen passage rate must be taken into consideration. This is because the amount of rumen degradable protein that is actually used by the rumen microbes depends on the rate at which the protein can be degraded in the rumen and the rate at which the contents flow through the rumen.

The amount of protein degraded in the rumen depends on the rate of protein degradation and the rumen passage rate.

The protein in good quality fresh pasture is approximately 20 – 30% undegradable dietary protein and 70 - 80% rumen degradable protein. However, in spring, when the dry matter content of pasture is generally low, there is a fast rumen passage rate. This means some of the rumen degradable protein passes through the rumen before it can be degraded and used to produce microbial proteins. Thus, this portion of rumen degradable protein that is not degraded contributes to the dietary amino acid pool that is absorbed from the small intestine.

For more details see TechNotes 3: What's in a feed, and 4: Feed composition and characteristics, and online eLearning activity: The role of protein; dairynz.co.nz/feedright-module-5.

6.5 Milk proteins

In a lactating dairy cow, one of the primary uses of metabolisable protein is to synthesis milk proteins. A cow requires approximately 30 g of protein (amino acids) per kg of milk produced, therefore the majority of the amino acids absorbed into the mammary gland are used for milk protein production, with only a small proportion oxidised to provide energy (Figure 1).

About 90% of the protein in milk is casein, which has a high nutritive value.

Various whey proteins are also synthesised in the mammary gland including:

- α-lactoalbumin, essential for the synthesis of lactose (from glucose), and
- ß-lactoglobulin, involved in curd formation during cheese making.

Other proteins found in milk, such as immunoglobulins, are not synthesised within the mammary gland but are absorbed from the blood stream.

6.6 Further reading

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Figure 1. *Protein metabolism in the dairy cow.*