Various factors affecting microbial protein synthesis in the rumen

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Introduction

Rumen microbial protein represents a major source of amino acids to the ruminant animal. Microbial protein contributes about two thirds of the amino acids absorbed by ruminants. Although it is characterized by a relatively high proportion of non-protein nitrogen (25%, AFRC 1992) it has an invaluable role in the nutrition of ruminant animals. Daily microbial protein synthesis is different from the efficiency of microbial protein synthesis. Daily microbial protein synthesis is the product of the efficiency of microbial protein synthesis (Hoover and Stokes, 1991), which usually is defined as grams of microbial crude protein (MCP) / kilogram or 100 grams of organic matter (OM) digested in the rumen (Hoover and Stokes, 1991). The amino acid composition of microbial true protein is similar to that of protein in the main animal products, such as milk, lamb and beef (Orskov, 1992). Compared oil seed meals and legume grains microbial protein contains a higher proportion of methionine and lysine (DLG, 1976).

A major energy source of organic matter is carbohydrate for microbial protein synthesis; some researchers have suggested that it would be more appropriate if the efficiency of microbial protein synthesis is expressed as a function of carbohydrate digested rather than organic matter digested in the rumen (Nocek and Russell, 1988). The efficiency of microbial protein synthesis greatly differs in animals fed different diets, even within similar diets. The average efficiency of microbial protein synthesis was 13.0 for forage based diets, 17.6 for forage-concentrate mix diets, and 13.2 g MCP/100g for concentrate diets of OM truly digested in the rumen. Overall, the average efficiency of microbial protein synthesis was 14.8 g MCP/100g of OM truly digested in the rumen. The efficiency of microbial protein synthesis was predicted to be around 13g MCP/100g of total digestible nutrient (TDN) for beef cows (Burroughs et al., 1974; NRC, 1996).

Hoover and Stokes (1991) proposed that the rate of digestion of carbohydrates would have greater impact on the microbial protein synthesis. The microbial protein synthesis is reported to be low in animals fed high- concentrate diets because of reduced ruminal pH (NRC, 1996). The microbial protein synthesis is also low in low-quality forages because of slow carbohydrate degradation; in situ data showed that the ratio of degraded nitrogen to organic matter in the rumen greatly varied in the rumen in times after feeding. It seems that diets containing a mixture of forages and concentrates increases the efficiency of microbial protein synthesis because of an improved rumen environment for the growth of more diverse bacteria species. The aim of this paper is to discuss some factors, which could affect microbial protein synthesis in the rumen. These factors are discussed below

Dry matter intake: Data from the literature indicate that there is a strong positive correlation between DMI and microbial growth (Clark et al., 1992; Gomes et al., 1994; Djouvinov and Todorov, 1994). Although increasing the level of intake decreased the percentage of organic matter digested in the rumen. Therefore, more nutrients were supplied for microbial growth. Increasing the DMI with the addition of straw to barley-based diets significantly increased microbial protein synthesis in the rumen. Similarly, the supplementation of straw with starch linearly increased the amounts of OM digested and solid and liquid outflow rates. Therefore, increasing the level of starch linearly increased microbial yields, resulting in a strong correlation between the digestible organic matter intake and the microbial protein synthesis. The increase in microbial protein

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synthesis with increased feed intake is probably the result of the increased passage rate. The increased passage of microbial protein to the small intestine occurred as a result of the increased passage of both fluids and solids with increased intake (Gomes et al., 1994; Djouvinov and Todorov, 1994).

Supply of nitrogen compounds: The crude protein content of many practical diets may be greater than the 11% CP required to support optimal microbial growth; the resistance of proteins to microbial degradation may limit microbial protein synthesis. Protein degradation in the rumen is one of the main reasons for the inefficient utilization of protein in ruminants. On the other hand, nitrogen compounds, which are released during the protein degradation, are crucial for microbial growth in the rumen. It seems that proteins which have lower rates of ruminal degradation tend to improve the efficiency of microbial protein synthesis, probably because of the better capture of released N by rumen microbes. In modern protein systems it is required that the needs of rumen microbes for nitrogen compounds are fully covered either by degradable dietary protein or by metabolic nitrogen, which arise from the oxidation of amino acids in animal tissues and which can be recycled into the rumen. In some systems it is proposed that the capture of rumen degradable protein is not complete (INRA, 1988; AFRC, 1992) and therefore a surplus of rumen degradable protein is required.

The efficiency of microbial protein synthesis was greater in forages containing saponin and tannins, which reduce ruminal N degradability. The readily degradable fraction of protein is higher in forages than in grains. Approximately 40% of protein in fresh alfalfa is soluble in the rumen environment (Farquhar, 1985). Therefore, while 2 g of available N per 100 g digestible organic matter has been reported to be required for optimal microbial growth for animal fed forages, the level of degradable N in grains may limit microbial protein synthesis when supplemented at this level.

Supply of fermentable energy: Energy supply is usually the first limiting factor for microbial growth in the rumen. To estimate the microbial protein yield, modern European protein systems use information, which is directly or indirectly used in estimating the energy supply to the animal. The microbial protein yield can be estimated on the basis of metabolizable (ME), net energy for lactation (NEL), fermentable metabolizable energy, digestible carbohydrates or fermentable organic matter (Verbic and Babnik, 1997; GFE, 2001).

The maximum potential of rumen microbes to produce microbial protein can be explored only by the provision of high-quality forage. The problem of low microbial protein yield in diets containing low quality forages cannot simply be solved by supplementing diets with high amounts of concentrates. It has been shown that in diets containing high levels of concentrates the efficiency of microbial protein synthesis in the rumen is lower then in well-balanced forage based diets (ARC, 1984).

The primary function of the microbial carbohydrate metabolism is to release the ATP required for microbial growth. Thus, patterns and rates of microbial nitrogen metabolism are dependent upon the rates of carbohydrate fermentation (Hoover and Stokes, 1991). Fermentation rates of soluble sugars and starches are very high up to 2 h post feeding, but decrease almost completely approximately 4 h post feeding. Soluble sugars and starch provide higher levels of ATP than structural carbohydrate up to 4 h post feeding, but they provide almost no ATP for microbial growth after 4 h post feeding. Approximately 3 to 4 h post feeding, cellulose and hemi cellulose degradation start and continue for a long period (up to 96 h) post feeding, providing ATP for later microbial growth. Therefore, feeding a mixture of forage and concentrate resulted in greater microbial protein synthesis compared to feeding only concentrate or forage.

Forage: Concentrate ratio of diet: As indicated earlier, the average efficiency of microbial protein synthesis was higher in forage-concentrate mix diets than for all-forage diets. Synthesis of microbial protein is improved by varying the source and degradability of energy incorporated into the diet (Sinclair et al., 1995). In contrast to results of Salter et al, (1983), several studies have reported increased utilization of ruminal ammonia nitrogen for microbial protein synthesis when diets contained readily digestible carbohydrates rather than starch in high-fiber diets. As proposed by Hoover and Stokes (1991), the rate of carbohydrate digestion in diets and the synchronization of this rate with that of N release has an impact on microbial protein synthesis.

Microbial N synthesis was highest when highly ruminally available nonstructural carbohydrates were combined with highly ruminally available nonstructural carbohydrate were combined with

poorly ruminally available protein. This situation would suggest that N utilization for forages having high readily degradable protein (RDP) will improve microbial growth when forages are supplemented with ruminally available nonstructural carbohydrates (Huber and Kung, 1981).

Czerkawski, (1976) reported that sheep fed a diet composed of a mixture of hay and concentrate had greater microbial growth in the rumen compared to those fed concentrate and hay separately. The increase in microbial growth may have resulted from a better non-protein nitrogen to protein ratio in the mixed diet because the concentration of NPN is generally higher in forages than in concentrates. While forages may supply N as highly degradable protein or non-protein N, concentrates may slowly supply N mainly as peptides and / or amino acids needed for microbial protein synthesis (Baldwin and Denham, 1979). It could also be caused by better utilization of amino acids and peptides in the mixed diet.

Efficiency tends to be increased when readily fermentable carbohydrate is supplemented at less than 30 % of the total diet, but decreased when the supplementation level is greater than 70 % (Huber and Kung, 1981). The decrease in efficiency of microbial protein passage to the small intestine when diets containing more than 70 % concentrate are fed may occur because of a rapid rate of nonstructural carbohydrate degradation, resulting in an uncoupled fermentation (Polan, 1988).

As the proportion of forage increases in dietary dry matter, there is greater saliva flow, a higher ruminal pH, improved cation exchange capacity, improved hydration, improved mat formation, leading to decreased retention times and greater microbial growth as microbial generation times are reduced (Sniffen and Robinson, 1987).

Rumen environment: An important factor, which may alter the microbial protein yield in the rumen, is pH value. Low pH value can be deleterious to rumen microbes, and especially sensitive are protozoa. A low pH value is also expected to reduce the digestibility of fibrous plant tissues. Due to low pH value, energy within the rumen is diverted to non-growth functions, i.e. maintaining neutral pH in bacterial cells (Strobel and Russel, 1986).

Synchronized release of nitrogen and energy from diets: Matching the release of ammonia-N from dietary protein with the release of usable energy may improve N utilization (Salter et al, 1979). Sinclair et al. (1995) found that wheat straw and barley diets containing rapeseed meal as a slow release N source, or urea as a rapid release N source, contained equal amounts of rumen degradable protein and OM truly degraded in the rumen. The efficiency of microbial protein synthesis, however, was 11 to 20 % greater in sheep fed a diet supplemented with rapeseed meal than with urea. This increase in efficiency of microbial protein synthesis in sheep fed the rapeseed supplemented diet may have resulted from a lower rate of N and carbohydrate release and the better capture of these nutrients by rumen microbes. Similarly, synchronization for rapid fermentation with highly degradable starch and protein sources stimulated greater microbial protein flow to the duodenum when compared to diets with unsynchronized N and energy release (Herrera-Saldana et al., 1990).

In order to increase microbial yield, it seems that the manipulation of energy and N fermentation in the rumen should first be aimed at obtaining the most even ruminal energy supply pattern possible within a particular dietary regimen. The second goal is to supply the total daily amount of ruminally available N sufficient for use of the total amount of energy expected to be released in the rumen per day.

Rumen outflow rate / Rate of passage: One of the factors, which affect efficiency of microbial protein synthesis in the rumen outflow rate. Faster outflow rate is expected to reduce the maintenance costs of microbes because they spend less time within the rumen. In AFRC (1992) for instance, it is supposed that the efficiency of microbial protein synthesis can be increased by about 20 % if rumen outflow rate is increased from 0.02 to 0.08 / h. Rumen outflow rate is a function of dry matter intake and therefore it can be assumed that the efficiency of microbial protein synthesis in the rumen can be increase in dry matter intake. One of the most important factors, which limits intake of low quality roughages, is their slow rate of degradation in the rumen. High quality roughages are therefore expected not only to increase microbial protein yield by providing high amounts of fermentable substrate but also by increasing the level of intake.

Minerals and vitamins: In addition to N and carbohydrate supply, microbial yield is affected by the concentrations of trace minerals and vitamins (Sniffen and Robinson, 1987). Dietary sulfur concentration has been found to affect microbial growth (Sniffen and Robinson, 1987). The amount of sulfur required by rumen microorganisms for

synthesis of methionine and cysteine ranges from 0.11 to 0.20 % of the total diet, depending on the status of the cattle (NRC, 1996). Limited intake of sulfur may restrict microbial protein synthesis when large amounts of non-protein nitrogen are fed to ruminant animals, such as urea. Phosphorus is another mineral required for the synthesis of ATP and protein by rumen microbes. Microbial protein synthesis can be limited by an insufficient supply of P for microbial growth.

Conclusion: Dietary CP in ruminant diets serves as a source of metabolizable protein to the ruminant by providing both ruminal-degraded protein for microbial protein synthesis and ruminal undegradable protein. Microbial protein synthesis is dependent upon suitable N and carbohydrate sources. Even though trace minerals and vitamins are adequate for maximal microbial protein synthesis in many feeding conditions, inadequate trace minerals and vitamins, in some cases, could limit microbial protein synthesis. Protein sources, which are low in DIP, may limit the microbial protein synthesis when calculated to meet animal requirements based on dietary CP. In order to obtain maximal microbial protein synthesis, the nitrogen requirement of the rumen bacteria has to be met first. Nitrogen sources also must include amino acids and peptides in addition to NPN.

Diets containing a mixture of forages and concentrates increase microbial protein synthesis because of improved synchronization of nutrient release, an improved ruminal environment for more diverse ruminal bacteria species, increased amounts and types of substrates, increased intake and subsequently, increased rates of solid and liquid passage.

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