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# SOME RECENT APECTS ON NITROGEN METABOLISM AND PROTEIN REQUIREMENTS BY RUMINANTS

**A. Z. Mehrez**

Department of Animal Production, Faculty of Agriculture, University of Mansoura, El-Monsoura, Egypt

**Old system for expressing protein requirements of animals.**

$$\text{* Biological value} = \frac{\text{N retention + MFN + EUN}}{\text{Apparent digestible N + MFN}} \times 100$$

$$\text{* True protein requirement} = \frac{\text{EUN + MFN + N in hair, tissuse, milk and products of conception X 6.25 X 100}}{\text{BV}}$$

The system failed to discriminate among the qualities of different proteins with ruminant animals. This was later explained by the fact that dietary proteins are degraded to variable extents in the rumen and microbial protein is synthesized in the rumen. Therefore,protein reaching the abomasum is different from that consumed.

**Development in the knowledge of physiology of digestion and metabolism of N by ruminants.**

The position of a large fermentation sac, the reticulorumen, anterior to the abomasum has pronounced influence on the N metabolism by ruminant animals.

The symbiotic relation between the rumen microbiota and the host animal is simply that the microbes ferment most of the food ingested by the animal. The main end products of this anaerobic fermentation, are volatile fatty acids (VFA) $CO_2$, $CH_4$ and $NH_3$.

The microbes utilize the energy which can be extracted during the anaerobic fermentation process together with the N available from the proteolytic activity in the presence of the required minerals, vitamins and minerals and growth factors to build up cell material.

The VFA produced are absorbed and oxidized by the host tissues as the main source of energy. The microbial protein synthesized and dietary protein which is not degraded in the rumen are the main sources of amino acids for the host.

Generally, the overall fermentation process is advantageous to the host animal when it is fed on roughage diets containing a high proportion of cellulose. On the other hand, in animals fed cereal diets, fermentation of starch to yield VFA is energetically expensive from the stand point of glucose supply to the host because the energy cost of srarch digestion in the small intestine followed by absorption of glucose is low relative to that of hepatic gluconeogensis from propionate.

As far as protein is concerned, the extensive degradation of dietary protein in the rumen is a wasteful process for the host if the dietary protein is of higher biological value than of microbial protein synthesized.

The ability of most rumen bacteria to use $NH_3$ as the only source of N give the rumianants a distinct advantage of using nonprotein-N (NPN) sources and upgrading $NH_3$ released from hydrolysis into microbial protein.

**Utilization of NPN ruminants**

It has been known for over 120 years that ruminants can use NPN as a substitute of dietary true protein, however the practical implication was only practiced as from the frist world war.

Several NPN sources were examined i.e ammonium acetate, ammonium carbonate, ammonium lactate, ammonium bicarbonate, biurett and urea. The later is the most commonly used. Such sources are hydrolyzed in the rumen producing $NH_3$ and $Co_2$ by the enzyme urease present in the rumen mucosa and contents mainly from bacteria. There is no evidence that protozoa has a role in hydrolysis of NPN.

Rumen bacteria utilize $NH_3$ released for bacterial protein synthesis. Ammonia is considered an essential source of N for most species and stimulates the growth of others. Protozoa do not utilize $NH_3$ but engulf bacterial cells for the synthesis of protozoal protein which is of higher quality than of bacterial protein of

which 20% of its N is in the from non amino acid N.

**Thermodynamic limitations on microbial protein synthesis imposed by anaerobiosis.**

Microbial cell synthesis requires energy. Thus the extent of microbial growth and accordingly cell protein synthesis is dependent on the energy available to the microbes. Under anaerobic conditions, the proporation of energy not accountable for in end products of carbohydrate fermentation is small in comparison to situations where oxygen is available.

From stoichimetric relationships, it could be concluded that the heat loss in the anaerobic fermentation process is almost constant irrespective of the proportion of VFA produced. It amounts to almost 6.4% of the energy fermented. This is advantage to the host since the carbohydrate energy becomes available to its aerobic tissues. However it imposes strict thermodynamic limitations on energy available for microbial growth under the anaerobic conditions of the rumen.

Due to the technical problems encountered with distinguishing between microbial protein and undegraded dietary protein, a wide range of estimates were recorded in the literature, being 16.8 to 37.3 g protein/ kg digestible organic matter apparently fermented in the rumen. The accepted and applied value is 25.

**Protein quality of rumen microbes.**

| | Bacteria | Protozoa |
|---|---|---|
| Crude protein (%) | 45.5 | 52.3 |
| True digestibility (%) | 75.2 | 86.1 |
| Biological value (%) | 73.0 | 81.0 |

**Animal potential for protein deposition.**

1) Genetic potential: Mature size.
2) Effect of level of feeding : energy.
3) Sex.

**Contribution of microbial protein to satisfy the host needs.**

Microbial protein and the fraction of dietary protein

escaping rumen fermentation are major sources of N supply to the host animal.

Degration of dietary protein in the rumen is considered advantage to the host when its needs for protein exceeds the amount supplied by microbial cells which occurs in the case of young fast growing and high lactating ruminants. In many production systems, however, the need for protein by the host is met by the microbial protein. Thence, degradation of dietary protein is considered avantageous since the animals can be maintained on diets of low protein quality or even NPN sources.

In both cases, N requirements of rumen microbes must be met to ensure maximal rate of fermentation in the rumen and animal performance.

Optimal conditions and nutrients required for efficient NPN utilization:

1) Synchronization of $NH_3$ release and energy availability:
   a- Slowing $NH_3$ release:
      I- Inhibition of urease activity:
barbituric acid s-2 carboxy ethyI 3-thiosulfopropionate, copper sulfate, acetohydroxyamino acid, bacitracin or neomycin.

      II- Encapsulation of urea : fat, wax or Na-bentonite.
   b- Rapid fermentable carbohydrate: starch or molasses.
   c- Homogenous inclusion of urea (spraying) and more frequent meals per day
2) Slower $NH_3$ absorption: manipulation of rumen pH.
3) Minerals availability:
   a- N : S ratio = 10 : 1 .
   b- cobalt : vitamin $B_{12}$ synthesis.
   c- Potassium.
4) Branched chain fatty acids : branched chian amino acids

**Optimum $NH_3$ concentration in the rumen.**

1) In vitro studies for maximum microbial protein synthesis/unit substrate fermented = 5 to 7 mg $NH_3$/100 mI rumen liquor.
2) In situ studies for maximum rate of fermentation: 23.5 mg $NH_3$/100 ml all concentrate diet

17.5 mg $NH_3$/100 ml 67 concentrate : 33 roughage
13.5 mg $NH_3$/100 ml 33 concentrate : 67 roughage
12 mg $NH_3$/100 ml alkali treated roughage
7 mg $NH_3$/100 ml all roughage diet

**Extent of protein degradation in the rumen.**

1) Dietary protein source: solubility.
2) Level of feeding.
3) Basal diet.

**Protection of dietary protein from degradation in the rumen.**

1) Heat.
2) Tannins.
3) Fromaldehyde.
4) Amino acids analogue.
5) Esophageal groove.

**New concepts of assessing protein requirements of ruminants.**

1) Satisfying microbial needs.
2) Satisfying the host needs.

**Microbial requirements.**

I- Degraded protein in relation to energy:
Microbial needs - degradable N

II- Urea fermentation potential =

$$\frac{(0.1044 * TDN) - \text{degradable protein}}{2.8}$$

III- Optimum NPN concentration in the diet =

$$\frac{(\text{digestible OM} * 0.025) - (\text{dietary N} * \text{degradability})}{\text{concentration of N in NPN}}$$

**Host requirements.**

Capacity to retain N/energy during different physiological states.

1- Degraded nitrogen (RDN) required by rumen microorganisms:

RDN required (g/day) = $M_E$ * F * proportion of $D_O$

apparently digested in the rumen * efficiency of conversion of degraded N to microbial N.

where: $M_E$ = metabolizable energy intake (MJ/day).
F = factor for conversion of $M_E$ to $D_0$
18% of apparently digested energy is lost in $CH_4$ and urine 1 Kg $D_0$=19 MJ $D_E$
therefore, F=1/(0.82*19)
$D_0$ apparently digested in the rumen = 0.65
Microbial N Yield (g/Kj $D_0$ apparently digested in the rumen)= 30 Efficiency of conversion of degraded N to microbial N= 1.0.

The RDN required (g/day) = $M_E$ * 1/(0.82*19) * 0.65* 30 = 1.252 $M_E$ (1.25 $m_E$ , adopted).

**2- Net amino acid nitrogen supplied to tissues by rumen microorganisms (TMN)**

TMN (g/day)=RDN * proportion of total microbial N as amino acid N * apparent absorbability in the small intestine of amino acid N from microbial protein * efficiency of utilization of absorbed amino acid N.

where: (1) Proportion of total microbial N as amino acid N = 0.80
(2) apparent absorbability in the small intestine of microbial protein amino acids N = 0.70
(3) efficiency of utilization of absorbed amino acid N = 0.75

TMN (g/day) = RDN requirement * 0.80 * 0.7 * 0.75
= RDN requirement * 0.42
= 1.252 $M_E$ * 0.42
= 0.526 $M_E$ (0.53 $M_E$, adopted)

**3- Undegraded dietary nitrogen (UDN) requirement.**

a) if tissue N required (TN) < net amino acid N supplied to tissues by microbial protein (TMN), i.e. < 0.526 $M_E$

TN = $R_N$ = N retention + $L_N$ = Lactation N + $N_m$ = N for maintenance etc

no undegraded dietary N is required and the value for the UDN requirement is therefore O

Total N requirement will then equal RDN requirement
$= 1.252\ M_E$

b- If tissue N required (TN) > net amino acid N supplied to tissues by microbial protein (TMN) , ie. > $0.526\ M_E$,

UDN requirement = (tissue N - net amino acid supplied to tissuese by microbial protein) / (apparent absorbability of amino acid N in the small intestine * efficiency of utilization of absorbed amino acid N)

$$UND = TN - (0.526\ M_E) / (0.70 * 0.75)$$
$$= 1.91\ TN - 1.00\ M_E$$

**4- Total Nitrogen requirement.**
= RDN requirement + UDN requirement
provided that the UDN requirement is not 0.

$$\text{Total N requirement} = 1.25\ M_E + 1.91\ TN - 1.00\ M_E$$
$$= 0.25\ M_E + 1.91\ TN$$

**5- Protein concentration in dry matter.**
The minimum concentration of CP in the dry matter required by the animal =

$$\frac{(\text{RDN + UND requirement}) * 6.25}{\text{DM intake , kg/day}}$$