BIOLOGICAL VALUE OF PROTEIN IN RUMINANTS

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Summary

Conventional measurements of Biological Value made from nitrogen absorption in the entire digestive tract are generally inappropriate when estimating the protein requirements of ruminants. Similarly, measurements in rats, of the Biological Value of rumen microbes cannot be applied with confidence to ruminants. A direct measurement of the Biological Value of absorbed amino acids is required, and one measurement in calves is described. The need for precise estimates of Biological Value is illustrated.

I. INTRODUCTION

Estimates of the protein requirement of ruminants obtained from conventional feeding trials vary widely, and it is impossible to confidently select a value when formulating diets (Black, Pearce and Tribe 1973). Consequently, an alternative approach for determining dietary protein requirements, which involves three major steps, has been suggested (Black et al. 1973; Egan and Walker 1975). First, the tissue requirements for nitrogen (N) are estimated. Secondly, the quantity of absorbed amino acids needed to satisfy the tissue requirement is calculated by adjusting for the efficiency with which absorbed amino acids are used for protein synthesis and, finally, the dietary crude protein requirement is calculated by adjusting for the proportion of dietary N which is absorbed as amino acids by the animal. Recent information is available on the first and third steps, but the second step needs further examination.

Although the efficiency of utilization of absorbed amino acids for protein synthesis is best assessed by comparing the amino acid requirements of an animal with the amount absorbed from its digestive tract, this cannot be achieved in ruminants because their tissue requirements for amino acids are poorly defined. As a consequence, the concept of the Biological Value (BV) of absorbed N has been used. The BV of a protein is defined as that fraction of an increase in absorbed N which is retained in the body of an animal fed a protein deficient diet (Allison 1964). It is estimated either from the regression coefficient relating N retention to absorbed N or, when only one protein intake is used, from the sum of N retention and total endogenous N loss expressed as a fraction of absorbed N.

II. MEASUREMENTS OF BIOLOGICAL VALUE IN RUMINANTS

Measurements of BV in ruminants show a large variation. Lofgreen, Loosli and Maynard (1947) calculated that the mean BV observed in sheep was 0.66, but that 32% of the values fell outside the range of 0.58 to 0.74. This large variation can exist even when substantially the same protein source is used. For example, Deif, el-Shazly and Abou Akkada (1968) recorded a BV for rice gluten of 1.02 whereas Black (1970) estimated the BV of wheat gluten to be only 0.29 in growing lambs. Although BV depends upon the weight and physiological state of an animal,

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these observed differences can be largely explained by the influence of rumen micro-organisms on protein utilization in ruminants and by the methods used to estimate BV.

Protein utilization in ruminants given a constant energy intake can be broadly divided into three categories: (1) at low protein intakes where N availability is limiting the growth of rumen micro-organisms; (2) at moderate levels of intake where N is not limiting microbial growth, but where the absorption of amino acid-N is inadequate for the animal's needs; and (3) at high levels of protein intake where the requirements of both the microbes and the animal are exceeded. These stages are illustrated in Fig. 1 where a hypothetical relationship between N retention and apparent N absorption from the entire digestive tract is established for a young ruminant given a protein source which is not completely degraded within the rumen. The addition of protein to a protein-free diet will result in an increasing absorption of both dietary and microbial protein and this continues until N is no longer limiting the growth of microbial protein (line AD). The slope of AD will depend upon the amino acid pattern of the combined dietary and microbial sources as well as the quantity of endogenous N incorporated into microbial protein. The latter can result in more protein-N being absorbed from the small intestine than was fed to the animal and this can give rise to an apparent BV which is higher than the true BV of the N absorbed from the small intestine. When protein intake is raised above D, only the additional dietary protein not degraded in the rumen will flow to the small intestine. The efficiency of N retention will reflect the amino acid pattern of the protein source and the proportion passing undegraded from the rumen (line DE). As the protein intake is raised above E, where the animal's protein requirements are satisfied, there will be no further increase in N retention (line EF). The differences observed in the BV of gluten by Dief et al. (1968) and Black (1970) can be explained if the experiment of Dief et al. coincided with slope AD and that of Black with slope DE. When only one level of protein intake is used in the determination of BV, the estimated value will depend upon that level of intake. For example, if N absorption were X1, the BV estimated from line AD is quite different from the BV estimated from line AE if N absorption were X2.

Conventional measurements of BV, which are obtained using N absorption in the entire digestive tract, are therefore not appropriate for establishing dietary protein requirements of ruminants by the

![Fig. 1. Hypothetical relationship between nitrogen retention and apparent absorption of nitrogen in the entire digestive tract of a young ruminant given a constant energy intake and increasing levels of a protein source that is not completely degraded in the rumen.](image)
proposed method. Rather, the digestion of amino acid-N in the intestine should be estimated and then the BV of this absorbed N established.

III. BIOLOGICAL VALUE OF NITROGEN ABSORBED FROM THE SMALL INTESTINE

The BV of N absorbed from the small intestine of ruminants has been assessed by feeding rumen micro-organisms to growing rats. The values obtained range from 0.66 to 0.85 (see Mason and Palmer 1971), but would underestimate the BV of absorbed amino acids because of inclusion of the nucleic acid component of microbial N which is unlikely to be well utilized by animals. Furthermore, the BV of protein established in rats may not directly apply to other species. For example, the BV of cows' milk protein appears to be higher in rats (0.84, Block and Mitchell 1946) than in lambs (0.73, Black et al. 1973), perhaps because of the high cystine requirement for wool growth. No estimates have been made of the actual BV, to weaned sheep, of the mixture of amino acids absorbed from the small intestine. There is, however, some information available for calves (J.L. Black, I.J.F. Stobo and R.H. Smith, prepared for submission to British Journal of Nutrition).

Calves weighing approximately 100 kg were fed mixed concentrate-roughage diets of similar energy content but containing graded levels of either fishmeal or peanut meal proteins. Nitrogen balance was measured in one group of calves, whereas those in a second group were fitted with re-entrant duodenal and ileal cannulae and the absorption of nitrogenous material from the small intestine measured. The estimated BV of total N absorbed from the small intestine for calves fed fishmeal was 0.67 ± 0.11 and for calves fed peanut meal was 0.63 ± 0.15 (see Fig. 2). Similar estimates for non-ammonia-N (NAN) and NAN minus nucleic acid-N absorption in the small intestine were 0.73 ± 0.12, 0.70 ± 0.15 and 0.78 ± 0.14, 0.78 ± 0.21, respectively. The large standard errors demonstrate that many animals must be used if precise estimates of the BV of N absorbed from the small intestine of ruminants are to be obtained by this method.

IV. IMPORTANCE OF BIOLOGICAL VALUE ESTIMATES

As an example, the effect is shown in Table 1 of changing BV from 0.60 to 0.80 on the estimated dietary protein requirement of a 20 kg lamb given 711 g DM per day of ryegrass. The tissue N requirements

Fig. 2. The relationship between N balance and N absorption of calves fed increasing levels of fishmeal 0 and peanut meal . The basal diet with no added protein concentrate is shown by △. Each point is the mean of either two or four values.
Predicted effects of BV on the estimated protein requirement, liveweight gain and N balance of a lamb given perennial ryegrass

<table>
<thead>
<tr>
<th>BV</th>
<th>0.60</th>
<th>0.65</th>
<th>0.70</th>
<th>0.75</th>
<th>0.80</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein requirement (%)</td>
<td>25.8</td>
<td>23.8</td>
<td>22.2</td>
<td>20.8</td>
<td>19.7</td>
</tr>
<tr>
<td>Liveweight gain (g/d)</td>
<td>79</td>
<td>91</td>
<td>103</td>
<td>115</td>
<td>125</td>
</tr>
<tr>
<td>N balance (g/d)</td>
<td>2.1</td>
<td>2.5</td>
<td>2.9</td>
<td>3.3</td>
<td>3.7</td>
</tr>
</tbody>
</table>

were calculated from Black and Griffiths (1975) and the absorption of NAN from MacRae (1974). Clearly, the BV selected has a marked effect on the estimated requirement of this lamb. Similarly, the BV used is important when assessing whether animals are likely to respond to a protein supplement. Table 1 also shows the effect of BV on the estimated growth rate and N balance of the same lamb fed ryegrass containing 20.5% crude protein. Details of the experiment simulated and the procedures adopted are given by Black, Graham and Faichney (1975). If a BV of 0.60 was used, the calculation suggests that the lamb would need to absorb an extra 16.6 g protein per day and this would stimulate growth rate by 46 g/day. Alternatively, if a BV of 0.80 was used, the lamb was assessed to be absorbing adequate protein and would therefore not respond to a protein supplement. Thus, precise knowledge of either BV or the tissue amino acid requirements of ruminants is clearly required when assessing the practical significance of various feeding strategies.

V. REFERENCES