MODEL FOR ESTIMATION OF AMINO ACID UTILIZATION AND ITS
REQUIREMENTS IN GROWING ANIMALS

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Summary

The model is based on a mathematical description of the pattern of nitrogen balance in
growing animals, depending on nitrogen intake and feed protein quality, according to an
exponential equation (Gebhardt 1966): \( y = PD_{\text{max}}T \left( 1 - e^{-bt} \right) \).

The slope of the curve in this model (b) is directly related to protein quality. Protein
quality depends on the concentration (c) and availability of the limiting amino acid (LAA) in
the feed protein. Thus the slope is determined by the degree of utilization of the LAA (bc\textsuperscript{2}).
Maximum values for the utilization of the LAA (bc\textsuperscript{2}) have been identified and used as a
reference value to evaluate the efficiency ratio of the LAA (eLAA) in different test proteins.
In feed proteins where the amino acid under study is not an LAA, the efficiency factor can be
determined using the difference method. The concentration of utilisable amino acids in feed
proteins is calculated by multiplying the efficiency ratio of the amino acid under study with its
concentration in the feed protein. The above mentioned equation is used to calculate
requirements of limiting amino acids (x\textsubscript{LAA}) after logarithmic transformation. Thus LAA
requirements are determined depending on a selected utilization rate of PD\textsubscript{max}T and the
efficiency of utilization of the LAA.

I. INTRODUCTION

The utilization of dietary amino acids is influenced by a multitude of factors, e.g. the
dietary amino acid balance, digestion and absorption patterns, which in themselves are subject
to many influencing factors, the level of performance, dietary energy level and others. If the
efficiency of utilization for a given amino acid is unknown, rather large safety margins are
applied in feed formulation to account for differences in utilization from different ingredients.
This is the case when formulating on a total amino acid basis. There have been many
approaches in the past to overcome the shortcomings of this procedure. Formulating diets on a
true ileal digestible amino acid basis is probably the closest approach to meeting actual
requirements. However, in practice there is still some reluctance to adopt this approach for
reasons of inadequate databases or questionable techniques when assessing true ileal
digestibility. However, a general shortcoming of evaluation systems for amino acids on a
digestible basis is that metabolic utilization is not taken into account. Incomplete metabolic
utilization can be due to factors such as inevitable post-absorptive catabolism, chemical
(metabolic) unavailable amino acids or imbalances in amino acid supply. This applies
particularly when using the supplementation technique to a given basal diet with a limiting test
amino acid. There is a serious risk that the basal diet may not be fully adequate in amino acids
other than the one under test (Morris \textit{et al.} 1999). The proposed approach to evaluate the
utilization of limiting amino acids and derivation of requirements accordingly is based on a
holistic approach by using N-balance procedures. The technique applied takes advantage of
the dilution technique (Fisher and Morris, 1970; Gous and Morris, 1985).

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II. DESCRIPTION OF THE MODEL

(a) Determination of the efficiency of the limiting amino acid (eLAA)

Each animal has a genetic blueprint for its maximum protein deposition, and this is referred to as PD_max and includes nitrogen maintenance requirement (NMR). This parameter can be determined in feeding trials with subsequent carcass analysis or in N-balance trials. However, PD_max is theoretically somewhat higher for a given genetically homogenous group of animals than can be measured experimentally.

With an appropriate N-utilization model, this theoretical maximum for protein (N) retention (PD_maxT) can be identified and used further for various purposes in growth models and for determination of the efficiency of utilization of amino acid and of amino acid requirements. The model is based on a mathematical description of the pattern of nitrogen retention in growing animals, which depends on nitrogen intake and feed protein quality, according to the following equation (Gebhardt 1966):

\[
y = PD_{max}T \left( 1 - e^{-bx} \right) \quad (1)
\]

where:

- \( y \) = actual daily N-balance + NMR / LW kg\(^{0.67} \) (mg)
- \( PD_{max}T \) = max. theoretical capacity for daily N-balance + NMR / LW kg\(^{0.67} \) (mg)
- \( x \) = daily N-intake / LW kg\(^{0.67} \) (mg)
- \( b \) = slope of the curve
- \( e \) = base of natural logarithm
- NMR = nitrogen maintenance requirement, and
- LW = liveweight.

Protein quality (b) is linearly related to the concentration of the limiting amino acid (LAA) of the test protein (c). The slope of the regression depends on the efficiency of utilization of the LAA (bc\(^{-1} \)) for N-retention. As a result of many N-balance trials with mainly growing pigs of various genotypes and using complex diets, maximum values for the utilization of the LAA (bc\(^{-1} \)) have been identified (Liebert and Gebhardt, 1988b; Liebert et al., 1989). These maximum values can be used as a reference value to evaluate the efficiency ratio of the LAA (eLAA) in different test proteins according to equation (2). Figure 1 gives an example for the estimation of a lysine requirement curve in pigs with increasing performance (N-balance) compared with lysine from barley of two different varieties. Obviously there are different efficiency ratios for the utilization of lysine from the two barley varieties.

\[
eLAA = \frac{(bc^{-1}) \text{ LAA test protein}}{(bc^{-1}) \text{ LAA standard}} \quad (2)
\]

Given that barley is the sole dietary source of lysine, comparison at any given level of lysine intake shows that the efficiency of lysine utilization in barley I is higher than in barley II. Aiming for the same level of N-retention, less lysine is needed from barley I. The same approach can be applied to broilers.
Figure 1  Lysine requirement curve in pigs, relative to different efficiencies of utilization of barley-lysine from different varieties (Liebert et al., 1991).

In order to apply the model, the LAA in the test protein must be identified or set by either supplementation with amino acids or combination with other proteins. Where the amino acid under study is not limiting, the difference method can be applied (Liebert and Gebhardt, 1988b). This is important for feed formulation based on utilizable amino acids. After determining the efficiency ratio of the LAA under study, the concentration of utilizable LAA can be calculated according to equation (3).

\[ c_u = c \times e^{LAA} \quad (3) \]

(b) Calculation of LAA-requirements

Equation (1) can be adapted to describe the relation between the intake of the LAA and daily N-retention.

\[ y = PD_{max}T \left( 1 - e^{-16b/c \times LAA} \right) \quad (4) \]

\[ c \] = concentration of the limiting amino acid in the test protein (g/16 g N)

\[ (bc^{-1}) \] = efficiency of utilization of the LAA

\[ x_{LAA} \] = daily intake of LAA / LW kg \(0.67\) (mg)

After logarithmic transformation of equation (4) it can be used to calculate the requirement of the LAA depending on a selected utilization rate of PD_{max}T and on the efficiency of utilization of the LAA.

\[ X_{LAA} = \frac{In PD_{max}T - In (PD_{max}T - Y)}{16(bc^{-1})} \quad (5) \]
The term \((PD_{\text{max}}T - y)\) in equation (5) represents the actual level of performance (N-balance + NMR) in relation to the theoretical maximum capacity for daily N-balance + NMR \((PD_{\text{max}}T)\).

(c) Example for calculation of threonine requirements in growing chicken

The described model was used to evaluate the average threonine requirements of the broiler strains Cobb 500 and Ross 208. In a schematic approach, table 1 shows the calculated threonine requirements for (I) an 80% utilization rate of \(PD_{\text{max}}T\) and for (II) a distinct protein deposition rate for both genotypes within the different age periods.

Table 1. Calculated threonine requirements for Cobb 500 and Ross 208 broilers (mean values).

<table>
<thead>
<tr>
<th>Age period (days)</th>
<th>10 – 15</th>
<th>20 – 25</th>
<th>30 – 35</th>
</tr>
</thead>
<tbody>
<tr>
<td>(PD_{\text{max}}T) (mgN/d/kg(^{0.67}))</td>
<td>3753</td>
<td>3164</td>
<td>2696</td>
</tr>
<tr>
<td>Protein deposition (g/d)</td>
<td>6.8</td>
<td>11.3</td>
<td>13.8</td>
</tr>
<tr>
<td>Thr-requirement (mg/d)</td>
<td>458</td>
<td>776</td>
<td>991</td>
</tr>
</tbody>
</table>

(II) Distinct protein deposition rate

| Protein deposition (g/d) | 7.0 | 11.0 | 13.5 |
| Thr-requirement (mg/d) | 499 | 739 | 952 |
| Thr requirement (g/kg of diet)* | 8.9 | 7.4 | 6.95 |

* Approximated on NRC 1994 feed intake figures

However, the rate of utilisation of \(P_d\text{max}\) is not the same over the entire growing period. Under commercial conditions it will be lower than indicated in table 1, particularly in the first age period. The rate of utilisation that can be achieved under given conditions is, however, the important determinant of requirements.

In practice certain levels of daily protein deposition are targeted rather than certain utilization rates of \(PD_{\text{max}}T\). The differences for \(PD_{\text{max}}T\) for the entire growth period between the tested broiler genotypes were found to be negligible. Thus an average value for \(PD_{\text{max}}T\) for both genotypes can be used for calculating requirements.

The model allows the calculation of LAA requirements depending on target amounts of daily protein deposition. It circumvents difficulties arising from conventional requirement studies such as dose-response studies using the supplementation technique. However, in future, feed related bioavailability differences of the LAA should be taken into account. The present data for threonine requirements are based on the bioavailability of threonine in soybean meal. More information about threonine bioavailability in other feed ingredients and its variation can be determined with the model. Based on these data, performance-dependent amino acid requirements can be expressed in terms of utilizable amino acids and considered in feed formulation.

REFERENCES