3 Amino acids and crude protein

3.1 Introduction

So far recommendations concerning supply of crude protein and lysine (Lys) were expressed on the basis of the respective dietary gross concentrations (GrE 1987). In the meantime a considerable gain of knowledge has to be recognized in the literature which allows taking into account precaecal digestibility of individual amino acids (AA). From this a higher degree of precision can be expected in deriving AA supply, if methodologically caused influences relevant for determination of pcDigestibility are standardized. The Committee of requirement standards has elaborated methodological recommendations (GrE 2002) the application of which is to safeguard standardization in future experiments. In order to widen the basis of data for individual feeds the Committee has also evaluated the relevant literature following certain criteria which to a large extent meet the methodological standards (GrE 2005b). In Table 9.4 data concerning pcDigestibility are compiled for selected feeds. This Table is to be completed currently. In this booklet recommendations concerning supply are presented as precaecally digestible (pcD) AA. Introduction of pcDigestibility takes into account a substantial part of the feed-specific influence on overall utilization of AA.

The factorial approach is the basis of yield related supply of lysine. This requires knowledge of maintenance requirement as well as a precise description as precise as possible of all parts of the production process. Among these are composition and level of protein accretion during growth in different growth periods, reproduction with intrauterine and maternal accretion of protein as well as milk yield in combination with mobilization of body material. In this context the amino acids essential for the pig (EAA) are of interest: histidine (His), isoleucine (Ile), Leucine (Leu), lysine (Lys), methionine (Met), phenylalanine (Phe), threonine (Thr), tryptophan (Trp) and valine (Val), further the amino acids cyst(e)ine (Cys) and tyrosine (Tyr) which can partially be utilized for covering requirements of sulphur-containing amino acids and of phenylalanine, respectively. On the basis of the different processes participating in total production the necessary supply of pcDLys is derived, taking into account a specific factor for intermediary utilization:
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\[
\text{pcDLys} = \text{maintenance requirement (g/d)} + \frac{\text{Lys}_{LP} \times \text{product of performance (g/d)}}{\text{intermediary utilization of pcDLys}}
\]

Where: \(\text{Lys}_{LP}\) = lysine content (g/100 g protein) in product of performance

Product of performance (LP) = protein accretion or amount of milk protein (g/d)

\[
\text{Intermediary utilization of pcDLys} = \frac{\text{Lys}_{LP} \times \text{product of performance}}{\text{Intake of pcDLys only for performance (g/d)}}
\]

Generally it has to be noted that information concerning the utilization of AA other than Lys is not existing or insufficient (see Table 9.3) which excludes a consequent application of the factorial approach for all other AA for the time being. Therefore, constant relations of each of the individual EAA to lysine are assumed for deriving recommendations (see chapter 3.3.3).

Supply of NEAA is covered by recommendations of pcD crude protein (pcD-CP). So far approaches were based on N content in the respective product plus maintenance requirement of N taking into account the efficiency of utilization of dietary protein (NPU) (GrE 1987). As the basic alternative here all documented EAA are taken into account and it is assumed that together they represent 40% of the sum of all amino acids present in body (Table 3.2) and milk protein. Thus the minimum quantity of pcDCP is equivalent to the 2.5-fold of the sum of recommended EAA. The relation between EAA and NEAA for maintenance being 17:83 (FULLER et al. 1989) differs from that for growth; at high growth rates, however, this deviation is negligible with regard to the sum of pcDCP recommended. Nevertheless, during pregnancy this is relevant due to the high contribution of maintenance requirements. Therefore, in the calculation of minimum pcDCP the sum of pcDEAA for maintenance and for pregnancy are multiplied by 5.9 and by 2.5, respectively.

3.2 Requirements for maintenance

Requirement for maintenance is defined as all necessary expense of N compounds which allow the organism to achieve equilibrium in N balance. This in particular implies compensation for continuously occurring losses due to protein turnover and of endogenous faecal and urinary excretions caused by feed intake. Derivation of maintenance requirements is difficult in growing animals. As a consequence it is often carried out in adult animals and is normally related to metabolic body size (kg LW\(^{0.75}\)). More recent results of studies using varying designs are summarized in Table 3.1. The values presented comprise only partly
3.2 Requirements for maintenance

the higher endogenous AA losses caused by high feed intake. As, however, so far it has not been possible to experimentally quantify this influence on maintenance requirements, taking into account of this and possibly other influences is not possible in derivation of recommendations.

The feeding standards refer to pcDAA. Values used by the Committee for AA maintenance requirements (column 'AFBN') are based on a weighing of individual data and not only on averaging. A value for maintenance requirement of pcD total N is not applied. In this context it is necessary to consider on one hand the methodological problems of determining endogenous N losses (Niachoti et al. 1997, Souffrant et al. 1997) and on the other hand that the statements given here about minimum supply of pcDCP are derived from the sum of pcDEAA extrapolated by NEAA (see chapter 3.1).

Table 3.1:
Statements referring to daily requirements pcDEAA for maintaining N equilibrium in growing and in adult pigs (mg/kg LW$^{0.75}$)

<table>
<thead>
<tr>
<th>Categorie</th>
<th>Literature</th>
<th>Growing pigs $^{1}$</th>
<th>Sows $^{2}$</th>
<th>AFBN</th>
<th>Relation (Lys=100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>His</td>
<td>–</td>
<td>14</td>
<td>–</td>
<td>14</td>
<td>37</td>
</tr>
<tr>
<td>Ile</td>
<td>16</td>
<td>18</td>
<td>20</td>
<td>18</td>
<td>47</td>
</tr>
<tr>
<td>Leu</td>
<td>23</td>
<td>33</td>
<td>24</td>
<td>25</td>
<td>66</td>
</tr>
<tr>
<td>Lys</td>
<td>36</td>
<td>39</td>
<td>38</td>
<td>38</td>
<td>100</td>
</tr>
<tr>
<td>Met</td>
<td>9</td>
<td>–</td>
<td>–</td>
<td>10</td>
<td>26</td>
</tr>
<tr>
<td>Met+Cys</td>
<td>49</td>
<td>46</td>
<td>37</td>
<td>45</td>
<td>118</td>
</tr>
<tr>
<td>Phe</td>
<td>18</td>
<td>–</td>
<td>17</td>
<td>18</td>
<td>47</td>
</tr>
<tr>
<td>Phe+Tyr</td>
<td>37</td>
<td>43</td>
<td>44</td>
<td>41</td>
<td>108</td>
</tr>
<tr>
<td>Thr</td>
<td>53</td>
<td>49</td>
<td>40</td>
<td>50</td>
<td>132</td>
</tr>
<tr>
<td>Trp</td>
<td>11</td>
<td>16</td>
<td>11</td>
<td>15</td>
<td>39</td>
</tr>
<tr>
<td>Val</td>
<td>20</td>
<td>23</td>
<td>23</td>
<td>23</td>
<td>61</td>
</tr>
</tbody>
</table>

$^{1}$ Fuller et al. (1989); $^{2}$ Heger et al. (2002, 2003); $^{3}$ Roth et al. (2003)
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3.3 Requirements for growth

3.3.1 Accretion of protein and amino acids

In rearing piglets and especially in growing/fattening pigs high rates of weight gain in combination with highest possible rates of protein accretion are desired for economical reasons as well as for meeting the demands of standard carcass quality. Results of total body analyses of pigs of different LW are quoted as the basis for deriving the accretion of protein and AA during growth (see 2.3.2.1). Changes in protein concentration of LW gain are described there for rearing piglets as well as for growing/fattening pigs. Starting from this, accretion of individual amino acids depending on intensity of growth (LW gain) is calculated taking into account the pattern of AA.

At present it is not possible to model different developments of individual tissues and organs with justifiable precision and to take into account the differences in turnover of protein in different tissues. This does not exclude the possibility of describing and using growth curves for individual well described ranges, i.e. foetal development. Besides differences in the development of individual tissues some remarkable differences exist as regards their respective AA patterns (Oslage and Schulz 1977, Wünsche et al. 1983, Kirchgeessner et al. 1989, Mahan and Shields 1998). This, however, has little relevance with regard to average AA pattern of total body protein.

Principally it is to be referred to the fact that a certain potential of errors exists in the different methodological designs for deriving accretion of protein and AA (survey 3.1). Thus, losses of protein during growth (i.e. scaling off of skin, bristles, claws, loss of saliva) are weaknesses of total body analysis as well as the reference to other animals of lower live weight for calculating the deposition of nutrients during certain ranges of growth. On the other hand, total body analysis has the great advantage that it is possible to derive recommendations concerning the supply of protein, energy and minerals from identical original data. A further advantage is the fact that unlike metabolism trials, experimental animals are kept without restriction of movements or limitation of time. Concentration on total body analyses in the derivation of recommendations does not exclude using results of balance experiments, as thus nutritional influences can be identified more clearly within a narrow range of weight. Within this derivation they are, however, used not only for demonstrating quantitative correlations but also for answering basic questions such as relations between amino acid intake and accretion of protein or optimum dietary amino acid pattern. They are also used for checking the plausibility of recommendations derived by the factorial approach.
3.3 Requirements for growth

Survey 3.1: Comparison between total body analysis and measuring N-balances

<table>
<thead>
<tr>
<th>Comparative total body analysis</th>
<th>Measuring N-balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>• loss of saliva, scales, bristles during growth and possibly parts of tissue during slaughter</td>
<td>• indirect determination of N retention</td>
</tr>
<tr>
<td>• differential calculation of protein accretion comprises reference to other animals of lower weight</td>
<td>• accretion of AA not measurable</td>
</tr>
<tr>
<td>• number of experimental variables limited</td>
<td>• gaseous losses of N from faeces and urine</td>
</tr>
<tr>
<td></td>
<td>• result often representative only for short periods of time or weight</td>
</tr>
<tr>
<td></td>
<td>• feed intake pre-determined</td>
</tr>
</tbody>
</table>

Consequences

<table>
<thead>
<tr>
<th>Comparative total body analysis</th>
<th>Measuring N-balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>• generally slight underestimation of N retention, in individual cases over as well as underestimation possible when reference animals are not adequate, this especially with small scaling of weights</td>
<td>• generally overestimation of N retention which may be substantial depending on the experimental procedure</td>
</tr>
</tbody>
</table>

Starting from daily protein retention, accretion of individual EAA is calculated according to the AA pattern derived from Table 3.2. From this Table it can be seen that concentrations of most AA in body protein do not change remarkably during the period of rearing (5 – 30 kg LW). Only for Lys, Leu and glutamic acid (Glx) an increase occurs, varying in size, whereas a reduction is to be stated for Ile, Val, aspartic acid (Asp) serine (Ser) and Tyr. The change in Lys concentration of body protein from 6.3 to 6.8 and then to 7.1 g/16 g N requires a concentration of 7.2 g Lys per 100 g protein deposited. This Lys concentration is being used for further derivations as well for rearing piglets as for growing/fattening pigs.
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Table 3.2: Amino acid concentrations in empty body masses (g/16 g N)

<table>
<thead>
<tr>
<th>LW period</th>
<th>5–15 kg</th>
<th>15–25 kg</th>
<th>25–60 kg</th>
<th>60–115 kg</th>
</tr>
</thead>
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<tr>
<td>Literature</td>
<td>1. 5. 10. 15</td>
<td>1. 4. 6. 10. 16</td>
<td>2.3.6.7.8.9.10.11.16</td>
<td>4.6.7.10.12.16</td>
</tr>
<tr>
<td>Arg</td>
<td>6.5</td>
<td>6.5</td>
<td>6.4</td>
<td>6.4</td>
</tr>
<tr>
<td>His</td>
<td>2.6</td>
<td>2.6</td>
<td>3.0</td>
<td>3.2</td>
</tr>
<tr>
<td>Ile</td>
<td>3.7</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Leu</td>
<td>6.8</td>
<td>7.1</td>
<td>7.1</td>
<td>7.4</td>
</tr>
<tr>
<td>Lys</td>
<td>6.3</td>
<td>6.8</td>
<td>7.0</td>
<td>7.1</td>
</tr>
<tr>
<td>Met</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.2</td>
</tr>
<tr>
<td>Phe</td>
<td>3.7</td>
<td>3.7</td>
<td>3.8</td>
<td>3.7</td>
</tr>
<tr>
<td>Thr</td>
<td>3.7</td>
<td>3.7</td>
<td>3.7</td>
<td>3.7</td>
</tr>
<tr>
<td>Trp</td>
<td>1.1*</td>
<td>1.2*</td>
<td>0.9</td>
<td>1.0</td>
</tr>
<tr>
<td>Val</td>
<td>4.8</td>
<td>4.5</td>
<td>4.5</td>
<td>4.6</td>
</tr>
<tr>
<td>Ala</td>
<td>6.6</td>
<td>6.6</td>
<td>6.4</td>
<td>6.7</td>
</tr>
<tr>
<td>Asx</td>
<td>9.3</td>
<td>8.2</td>
<td>8.5</td>
<td>8.5</td>
</tr>
<tr>
<td>Cys</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.3</td>
</tr>
<tr>
<td>Glx</td>
<td>12.8</td>
<td>13.2</td>
<td>13.2</td>
<td>13.7</td>
</tr>
<tr>
<td>Gly</td>
<td>9.3</td>
<td>9.4</td>
<td>9.1</td>
<td>9.4</td>
</tr>
<tr>
<td>Pro</td>
<td>6.1</td>
<td>6.1</td>
<td>6.6</td>
<td>6.4</td>
</tr>
<tr>
<td>Pro-OH</td>
<td>3.0</td>
<td>2.9</td>
<td>2.5*</td>
<td>2.3*</td>
</tr>
<tr>
<td>Ser</td>
<td>4.1</td>
<td>3.9</td>
<td>3.9</td>
<td>3.7</td>
</tr>
<tr>
<td>Tyr</td>
<td>3.1</td>
<td>2.7</td>
<td>2.8</td>
<td>2.6</td>
</tr>
</tbody>
</table>

* only 2 to 3 results

1 AUMAIRE and DUEE (1974), 2 BATTERHAM et al. (1990a,b), 3 BIKKER et al (1994a),
4 BURACZEWSKI (1973), 5 CHUNG and BAKER (1992), 6 KEMM et al. (1990), 7 KIRCHGESSNER et al. (1989),
8 KYRIAZAKIS and EMMANS (1993), 9 LE BELLEGO and NOBLET (2002), 16 MAHAN and SHIELDS (1998),
11 OSLAGE and SCHULZ (1977), 12 SCHULZ and OSLAGE (1976), 13 STAUDACHER et al. (1984),
14 WIESEMULLER et al. (1975), 15 WILSON and LEIBHOLZ (1981), 16 WUNSCH et al. (1983)