

Physiological determinants to optimize metabolic utilization of dietary amino acids for animal protein production

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Abstract

In general, dietary amino acids are distributed between different metabolic pathways depending on availability, physiological priority and metabolic capacity. Metabolic utilization of dietary amino acids for animal protein production can be optimized by making proper use of physiological determinants. This means the development of so-called 'physiological feeding strategies'. In this paper we present an overview of recent achievements.

Keywords: amino acid utilization, protein production, N efficiency, short-term catabolic factors, physiological feeding strategy

Introduction

The level of nitrogen loss is of great importance for a sustainable animal production system. A substantial part of animal N intake (40-80%) is lost to the environment. The main question is whether or not this loss is an inherent part of the 'nutritional requirement' to attain the present level of production.

To answer this question several aspects should be addressed. In monogastrics at least, amino acid N needed for protein deposition should be available in the feed. In addition amino acids required for non-productive purposes should be supplied. Any further (i.e. excessive) supply will reduce N efficiency. Non-productive requirements are hard to define and depend on different aspects related to the actual physiological situation.

Physiological determinants of metabolic amino acid utilization

Amino acid pattern required for production

Amino acids required for net protein synthesis should be supplied with the feed. For broiler chicks we determined the carcass amino acid composition as a function of

age. Differences between the amino acid pattern of one-day-old chicks and growing chicks were found. Later on during development most amino acids only showed minor changes. After 3 weeks of age, cysteine, histidine, glycine and alanine showed a change greater than 10% of the mean. After 5 weeks of age, tryptophan content decreased by more than 10%. It was concluded that only the changes in carcass composition at 3 weeks of age would be nutritionally important. Therefore the use of two feeds adjusted to the amino acid pattern of the carcass either before or after 3 weeks was suggested to attain an optimal utilization of dietary amino acids for production (Ten Doeschate et al., 1991). Because of restricted digestibility, corrections had to be made for ileal digestibility of feedstuffs as described by Ten Doeschate et al. (1993).

A subsequent feeding trial with a commercial type of broiler chicks showed that compared with a control diet (based on corn, soybean and tapioca), a test diet based on the amino acid profile of body accretion resulted in a significant improvement of N efficiency. A similar improvement in N efficiency under practical circumstances was calculated to result in a reduction of N excretion of 11% at the same level of production (Ten Doeschate et al., 1992). This indicates that adjustment of amino acid profile of the feed to the profile of production may be an important tool to diminish environmental N pollution. Further improvement of N efficiency can be expected from additional studies on non-productive needs of the producing animals.

Non-productive amino acid requirements

Non-productive requirements are hard to define. These requirements or unavoidable losses seem to be related to actual physiological circumstances. In this respect, non-productive requirements comprise the needs for specific functions (e.g. methionine as methyl donor) and the needs to compensate unavoidable losses related to metabolic degradation of amino acids. These losses (often resulting from a perturbation of the balance between availability, physiological priority and metabolic capacity) are related to circumstances other than the composition of the diet. We lumped together different causes of short-term metabolic perturbation as 'short-term catabolic factors'. In this respect the frequency and size of meals, the presence of metabolic stress and the level of adaptive protein turnover should be considered (Schreurs & Boekholt, 1988; Schreurs, 1992). Short-term catabolic factors can be examined by *in vivo* metabolic studies using a dual $^{14}\text{CO}_2$ breath test approach with radiolabelled amino acids as substrate (Schreurs et al., 1992).

During feed intake, metabolic perturbation can be very substantial, as has been shown for rats fed large meals (Weijjs, 1993). Broiler chicks fed frequent small meals owing to a light schedule of 1L:2D (h) did not show a detectable perturbation as measured by the oxidation of tyrosine. This indicates a nutritional steady state for these chickens. In the nutritional steady state the level of tyrosine oxidation turned out to be about 25% of the labelled flux.

Recycling of N from essential amino acids

A certain level of metabolic degradation of essential amino acids is supposed to be unavoidable. The N released is normally converted to urea (mammals) or uric acid

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Table 1. Amino acids (g) in whole egg and one-day-old chick and the efficiency of their conversion (%)^a

Amino acid	Egg	Chick	Eff.	Amino acid	Egg	Chick	Eff.
GLY	0.26	0.54	209	PHE	0.42	0.33	79
HIS	0.19	0.22	116	ASP	0.79	0.62	78
PRO	0.31	0.34	111	CYS	0.26	0.20	77
ALA	0.44	0.43	97	SER	0.55	0.41	75
VAL	0.46	0.43	92	LEU	0.70	0.52	74
ARG	0.54	0.48	89	LYS	0.57	0.42	73
THR	0.34	0.30	88	ILE	0.42	0.30	70
GLU	1.01	0.88	87	TYR	0.34	0.23	68
MET	0.20	0.17	84	TRP	0.13	0.06	44

^a The efficiency of conversion is calculated for a 70 g egg with 9.2% shell and 12.4% protein (Uijttenboogaart & Van Crujningen, 1988) and a one-day-old chick weighing 43 g with 16% protein (Ten Doeschate et al., 1991), as follows: protein chick : egg = (6.88 : 7.88) · 100% = 87%.

(birds) and excreted. Several non-essential amino acids - glutamine, aspartic acid and glycine (uric acid only) - appear to be the direct precursors of these excretion products. This means that the nitrogen from degraded essential amino acids passes the stage of non-essential amino acids before excretion. In the case of net protein deposition, the N efficiency would improve substantially if these non-essential amino acids could be incorporated in the animal product.

A calculation of the efficiency for the conversion of total nitrogen and individual amino acids from whole egg protein to a one-day-old chick is shown in Table 1. The N efficiency, the mean of all amino acids, is very high (87%). As a consequence, some individual amino acids even show a higher efficiency: in the case of proline, histidine and glycine, the calculated efficiency even exceeds the 100% level. This indicates that recycling of N by *de novo* synthesis of non-essential amino acids is metabolically feasible. The metabolic limits of this approach for practical purposes have to be checked.

Conclusions

1. Several physiological determinants can be addressed to optimize metabolic utilization of dietary amino acids for animal production.
2. Limits of these determinants should be determined in relation to the limits of a sustainable production system.
3. In the case of high production levels, incorporation in the animal product of non-essential amino acids mainly obtained from *de novo* synthesis would substantially improve the N efficiency. As an additional advantage it would be less critical to meet the requirements of essential amino acids for productive and non-productive purposes. A small excess would not reduce N efficiency. Practical limits of this 'physiological feeding strategy' have to be examined.

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