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Dose-response relationships between intake and efficiency of utilisation of individual amino acids in chicken

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Dose-response relationships between intake and efficiency of utilisation of individual amino acids in chicken

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List of abbreviations

AA	amino acid
ALA	alanine
AME	Apparent metabolisable energy
ARG	arginine
ASP	aspartic acid
BW	body weight
ºC	degree Celsius
Cm	centimetre
CP	crude protein
Cys	cysteine
d	day
expt	experiment
g	gram
GLU	glutamic acid
GLY	glycine
EAA	essential amino acid
h	hour
kg	kilogram
ILEU	isoleucine
kJ	kilojoules
Lys	lysine
Met	methionine
N	number
NEAA	non-essential amino acid
NDR	net disappearance rate
PHE	phenylalanine
P	probability
PRO	proline
SAA	sulphur containing amino acid
SE	standard error
SER	serine
Trp	Tryptophan
THR	threonine
Val	Valine
TiO_2	titanium dioxide

1. Introduction

Optimising dietary amino acid supply to broiler depends on the amino acid requirement of broiler to be measured accurately. To achieve this, the knowledge of individual components of requirement and factors affecting these are needed. Modelling of quantitative amino acid requirement in growing animal requires the knowledge of maintenance need, rate of protein deposition, pattern of amino acid in the deposited protein and efficiency of amino acid utilisation. Feed efficiency and feed intake are also important when amino acid requirement is expressed as dietary concentration. The lack of data on the efficiency of utilisation of essential amino acids (EAA) is the major limitation in modelling amino acid requirement by the factorial approach (Fuller, 1994; Moughan, 2003; Moughan and Fuller, 2003).

Studies specifically aiming at determination of efficiency of amino acid utilisation are rare in growing chicken. Few studies that have been conducted were restricted to the ascending portion of the growth curve were growth appears to respond linear. Even then, protein and amino acid accretion were not measured in all of these studies. Studies on lysine (Edwards et al., 1999), methionine/sulphur containing amino acids (SAA) (Edwards and Baker, 1999), and valine (Baker et al., 1996a) in broiler in which protein and amino acid accretion were measured only cover the suboptimal level of amino acid supply. However studies in which amino acids covered both deficient and optimal supply of lysine in pigs (Gahl et al., 1994), and 9 EAA in rainbow trout (Rodehutscord et al., 1997) have indicated that non-linear relationships exist between intake and efficiency of amino acid utilisation in growing animals. Diminishing return is also apparent in the range of marginal supply from these studies. The nature of relationship observed (linear or non-linear) tends to be determined by the range of dietary amino acid supplementation and the mathematical approach. For non-linear relationship to be detected, levels covering both the sub optimal and optimal levels of amino acid are needed (Rodehutscord and Pack, 1999).

It is commonly assumed that different genotypes within the same species can utilise EAA to the same degree. This is yet to be studied systematically. Genetic selection for high growth rate and breast muscle development has been shown to alter the pattern of protein metabolism (protein synthesis and protein degradation) in growing chicken (Tesseraud et al., 2001) and may mediate these changes through modification of proportion of muscle mass, number of fibre per muscle and the diameter of fibre muscles (Simon, 1989). The implication of these changes in protein synthesis and protein degradation rates has not been examined for efficiency of utilisation of limiting EAA. Obviously higher retention of ingested EAA with increased growth rate may influence efficiency of utilisation. Equal digestibilty of amino acids from the distal ileum of different genotypes within the same species is also assumed.

The main objective of the present studies was to describe the efficiency of amino acid utilisation as a function of dietary intake, starting from a highly deficient situation (growth limiting doses) to more than adequate (maximum response) in male growing chicken. Amino acids considered were lysine, methionine and cysteine, valine, and tryptophan. Attempts were also made to derive amino acid requirements. Digestibility of amino acids from the terminal ileum was also studied. Additional and individual amino acid-related objectives are examined under the respective chapters.

Prior to the presentation of the experimental work, a brief overview about approaches to study efficiencies and requirements in relation to the relevant amino acids will be given.

2 Approaches to study efficiency and requirement

2.1 The linear slope

This method is based on the assumption of a linear relationship between the quantitative dependent or response variable y and the quantitative independent or predictor variable x. That means, the relationship between response (y) and predictor (x) can be sufficiently described with a straight line (Figure 1). This is calculated by fitting a linear regression model to a data set in which y has been plotted against x. This is usually achieved by method of least squares (Motulsky, 1999; Petrie and Watson, 1999).

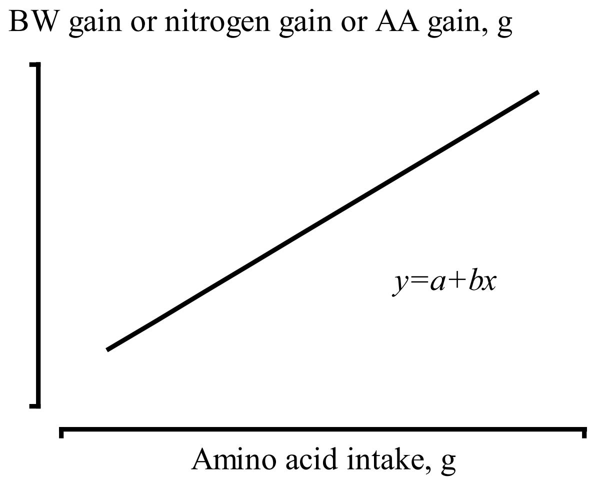

FIGURE 1. Schematic relationship between dependent variable (BW gain, nitrogen gain or amino acid gain) and the predictor variable (amino acid intake).

A simple linear equation is $y= a +bx$, where y is the dependent variable, a is the intercept i.e. the value of y at x=0, b is the slope of regression function and x is the predictor variable. With regard to calculation of efficiency of amino acid utilisation, quantitative dependent variable y may represent response in BW gain, nitrogen gain or amino acid gain expressed in grams. Estimated parameter a represents y-intercept or response to zero intake (maintenance requirement). The estimated parameter b can be interpreted as the efficiency of utilisation of the incremental amino acid intake. Predictor variable x represents the amino acid intake in grams.

The independent variable x is assumed to be measured precisely and without error, whereas the dependent variable y is assumed to be a direct consequence of x, i.e. based on the values of x, it should be possible to predict the value of y with accuracy within the scope of the data (cannot be extrapolated beyond data set), but not the other way round. Further assumptions of linear regression include homoscedasticity, Guassian distribution, and independence of data points. Details have been reviewed by Motulsky (1999) and Petrie and Watson (1999).

The use of linear regression to describe efficiency of utilisation of incremental amino acid intake is based on the assumption that efficiency of utilisation is constant within the range of amino acid supplied. This range usually covers between deficient supply and up to the range in which the amino acid requirement is met. Studies that focused on determination of efficiency of amino acid utilisation over a wide range of dietary intake for growing chicken are rare. Edwards et al. (1999) focusing on suboptimal level of lysine supply (5 to 95% requirement for maximal growth) employed a linear regression model to describe the efficiency of utilisation of lysine. 76% and 79% efficiency of lysine utilisation were reported for two strains of broilers. Han and Baker (1991) reported an efficiency of lysine utilisation for weight gain of 69% and 67% for two strains (fast and slow growing broilers). Efficiency was calculated by regressing weight gain on digestible lysine intake using a linear regression. Edwards and Baker (1999) studied the efficiency of SAA utilisation either as Met alone (with sufficient dietary Cys) or as a 1:1 mix of Met and Cys in starting male broiler chicks in a dietary range of 5 to 95% of that required for maximal growth rate. The slope of the linear regression of SAA retained depending on SAA intake declined when SAA exceeded 70% of that required for maximum growth rate for Met alone and Met and Cys. Therefore, only the dietary range between 5 and 70% of maximum growth rate was used for the calculation of efficiencies of retention. Efficiencies were reported as 68% for Met alone and 52% for Met plus Cys. Baker et al. (1996a) using a linear regression calculated an efficiency of valine retention of 73% for starting male broiler chicks fed increasing valine concentration covering the range of 5 to 95% of that required for maximal growth rate.

The slope ratio technique is an extension of the linear slope method. It is usually employed for comparisons. It is similarly based on the use of a linear regression model (Figure 2). All assumptions of a linear regression also hold for the slope ratio technique. Common intercept of the response curves (at zero amino acid intake) whose slopes are been compared can also be assumed (Littel et al., 1995). When comparing two responses, solving two linear equations in which a common intercept is assumed results in comparison of slopes i.e. $a + b_1x_1 = a + b_2x_2$ results in $x_1/x_2 = b_2/b_1$ (equation parameters for linear regression are already defined under Section 2.1) (Littel et al., 1995). The same principle is applicable to comparison of more than 2 slopes.

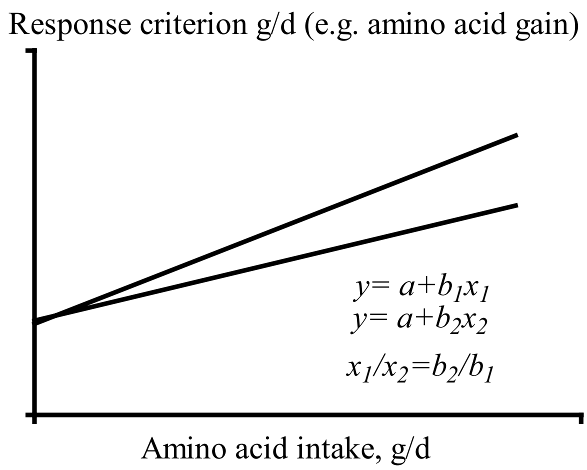

FIGURE 2. Schematic comparison of slopes of two response variables depending on amino acid intake.

This also assumes that efficiency of utilisation of incremental amino acid intake is constant up to the point where the requirement is met. Han and Baker (1991) compared efficiency of lysine utilisation for weight gain in two strains of male broiler (New Hampshire × Columbian chicks and Hubbard × Hubbard chicks) using the slope ratio technique. The fast growing (Hubbard chicks) and the slow growing (New Hampshire × Columbian chicks) had 69 and 67% lysine efficiencies for weight gain, respectively. The slope of regression did not differ significantly between the two strains. Rodehutscord et al. (2000b) in a range of sub optimal dietary lysine supply compared the efficiency of lysine utilisation from L-lysine·HCl (H) and L-lysine sulphate (S) for BW gain and lysine gain in growing rainbow trout. Differences in slopes for BW gain (30 (H) vs. 29% (S)) and lysine gains (70 (H) vs. 66% (S)) between the two lysine sources were insignificant. Rodehutscord et al. (2000a) compared the efficiency of lysine utilisation in suboptimal lysine supply for rainbow trout at two dietary levels of crude protein. The difference of slopes of lysine gain was not significant and efficiency of lysine utilisation was 71% at high crude protein (550 g/kg) and 55% at low crude protein (350 g/kg), respectively.

2.2 Non-linear models and marginal efficiency

Marginal efficiency based on non-linear regression models assumes that the efficiency of utilisation of incremental intake of an amino acid is not constant even in the ascending portion of the response curve below the requirement. This is achieved by plotting the dependent variable y against the predictor variable x. The relationship between response variable y