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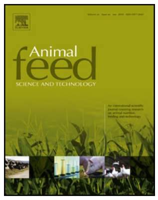

Basal endogenous losses of amino acids in protein nutrition research for swine and poultry

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ABSTRACT

In this review, the definition and terminology of amino acid (AA) digestibility and ileal endogenous losses of AA (IAA_{end}) in poultry and swine nutrition are discussed. Compared with apparent (AID) and true (TID) ileal digestibility, standardised ileal digestibility (SID) of AA is recommended for the expression of digestible AA contents of feed ingredients and for describing nutritional requirements of poultry and swine. To determine the SID of AA, total ileal flow of AA should be corrected for basal IAA_{end}. Therefore, the measurement of basal IAA_{end} is of great importance for the accuracy of the SID estimation in feed ingredients. The techniques for measuring basal IAA_{end} in poultry and swine include the use of a nitrogen-free diet (NFD), a highly digestible or enzyme hydrolyzed protein diet, and the regression method. The classic method for basal IAA_{end} determination involves the feeding of a NFD to experimental animals and measuring the ileal AA flow. This IAA_{end} output is considered as basal IAA_{end}, and it is assumed that the excretion of basal IAA_{end} depends only on DM intake, regardless of dietary composition. There are criticisms with the NFD method about the abnormal physiological state induced by severe AA deficiency. Although this AA deficiency may affect the estimate of basal IAA_{end} for dispensable AA, especially proline and glycine because of the degradation of body protein, the NFD method is still the most widely used method for basal IAA_{end} measurements. According to the definition of basal IAA_{end}, the NFD should be the preferred methodology in SID determination, because the basal IAA_{end} should be only related to dry matter intake. Additionally, the SID coefficients in feed ingredients generated by NFD method are considered to be additive in a complete diet. However, the results generated from NFD method can vary among studies due to the variance in the experimental animals and diet composition. To improve the accuracy of estimating the SID of AA in feed ingredients, it is suggested that a mandatory NFD be included in individual studies to generate basal IAA_{end} for correcting total ileal amino acid flow in determining SID of AA. In addition, research is needed to investigate the standard diet formulation of NFD.

Abbreviations: AA, amino acid; AID, apparentand ileal digestibility; AIA, acid-insoluble ash; IAA_{end}, ileal endogenous losses of AA; NFD, nitrogen-free diet; SID, standardized ileal digestibility; TID, true ileal digestibility.

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1. Introduction

Accurate determination of amino acid (AA) digestibility in feed ingredients is the cornerstone for estimation of AA requirements and formulating diets for animals. For poultry and swine, it has been well demonstrated that the small intestine is the main site for AA transport because the net absorption of AA in large intestine is negligible and the microbial activity in hind gut can modify the profile of AA in the digesta (Laplace et al., 1985; Nyachoti et al., 1997a; Ravindran et al., 1999). Therefore, accurate evaluation of AA digestibility requires collection of digesta sample from the end of ileum, rather than over the total tract. The ileal AA digestibility of AA in feed ingredients for poultry and swine has been an important research topic in the last few decades (Stein et al., 2007). Among the methods for collecting ileal digesta, collection from the ileum after animals are euthanised is the most common method in poultry, and through surgically fitted simple T-cannula in pigs (Kadim and Moughan, 1997; Stein et al., 2007). There are other methods for collecting ileal digesta from animals, such as through the use of caecectomised rooster and ileorectal anastomosis in pigs, which are well documented in previous studies and reviews (Payne et al., 1971; Sauer et al., 2001).

The basic equation for apparent ileal digestibility (AID) estimation is:

$$\text{AID, \%} = [(\text{AA intake} - \text{ileal AA output})/\text{AA intake}] \times 100. \quad (1)$$

However, for some of the ileal digesta collection methods mentioned above, the quantity of ileal AA output has to be estimated by an index marker, because in some studies, total collection of ileal digesta is not possible. Thus, the equation for AID calculation is:

$$\text{AID, \%} = [1 - (M_{\text{diet}}/M_{\text{ileal}}) \times (AA_{\text{ileal}}/AA_{\text{diet}})] \times 100. \quad (2)$$

Where M_{diet} and M_{ileal} are the concentrations of index marker (g/kg, DM basis) in diet and ileal digesta, respectively; AA_{ileal} and AA_{diet} represent AA (g/kg, DM basis) concentrations in diet and ileal digesta, respectively.

The digesta collected from the ileum may contain both dietary undigested materials and endogenous protein and AA (Laplace et al., 1985). Thus, the ileal digestibility of AA calculated without considering endogenous AA losses is defined as AID. The AID of AA is not accurate in formulating diets, because the endogenous AA flow in the ileal digesta can lead to an underestimation of AA digestibility and lack of additivity in diets containing multiple protein sources (Fan et al., 1994), especially for ingredients with low protein content (Stein et al., 2005; Xue et al., 2014). Therefore, in order to accurately measure the ileal digestibility of AA for diet formulation, accurate determination of ileal endogenous AA losses (IAA_{end}) is necessary (Stein et al., 2007).

2. Basal endogenous AA losses and standardised ileal digestibility of AA

The main sources of endogenous AA losses in animals are the proteins that are synthesised and secreted in the lumen of the digestive tract in animal but not reabsorbed (e.g., digestive enzymes, mucin protein, and serum albumin), sloughed intestinal epithelial cells, and bacterial protein from hind gut (Nyachoti et al., 1997a). The IAA_{end} can be divided into two parts, basal (non-specific, or diet-independent) and specific endogenous losses (McDonald et al., 2011). As shown in Fig. 1, the basal IAA_{end} is defined as the inevitable loss of AA in the digestive tract of animals, which is related to the amount of DM intake but otherwise unrelated to dietary composition (McDonald et al., 2011).

The specific endogenous loss is considered as the portion of endogenous AA flow, which is over and above basal IAA_{end} induced by the ingestion of diets of specific composition, such as protein level, fibre type, and anti-nutritional factors (Cowieson and Ravindran, 2007; Stein et al., 2007). The inclusion of high a concentration of protein in the diet can increase the specific endogenous loss of AA, because secretion of digestive enzymes in the digestive tract will be elevated in response to the high protein intake (Nyachoti et al., 1997b; Hodgkinson et al., 2000; Adedokun et al., 2008b). Likewise, fibre content and type can also affect the specific endogenous loss by changing the viscosity and passage rate of digesta in the small intestine, which can impact the secretion of mucin and epithelial cell turnover (Parsons et al., 1983; Mosenthin and Sauer, 1991). Anti-nutritional factors can also increase specific endogenous losses of AA. Cowieson and Ravindran (2007) reported that phytic acid can induce the secretion of specific endogenous losses of AA, and this increase of IAA_{end} can be ameliorated by the addition of phytase into the diet. This phenomenon can partly explain the effect of phytase in improving AID of AA in feed ingredients. Ileal digestibility that is adjusted for IAA_{end} can be termed either as true ileal digestibility (TID), when the total IAA_{end} is corrected for in the calculation; or standardised ileal digestibility (SID), if corrected for basal IAA_{end} (Stein et al., 2007). For common feed ingredients such as corn, SBM, DDGS, and canola meal, SID of AA is additive in complete diets (Stein et al., 2005; Xue et al., 2014). The TID and SID calculation are:

$$\text{TID, \%} = [(\text{AA intake} - (\text{ileal AA output} - IAA_{\text{end}}))/\text{AA intake}] \times 100; \quad (3)$$

$$\text{SID, \%} = [(\text{AA intake} - (\text{ileal AA output} - \text{basal } IAA_{\text{end}}))/\text{AA intake}] \times 100. \quad (4)$$

If the AID is already estimated, the equations become:

$$\text{TID, \%} = \text{AID} + (IAA_{\text{end}}/AA_{\text{diet}}) \times 100; \quad (5)$$

$$\text{SID, \%} = \text{AID} + (\text{basal } IAA_{\text{end}}/AA_{\text{diet}}) \times 100. \quad (6)$$