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BIOAVAILABILITY: AMINO ACIDS

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INTRODUCTION

The main goal in formulating animal feeds is to supply nutrients in amounts and relative proportions that optimize performance. This is particularly important with respect to amino acids (**AA**), as the feed ingredients used to supply AA are often expensive. Furthermore, any AA supplied in excess is deaminated and the resulting nitrogen excreted, thus posing a potential environmental problem. Because animals do not store excess AA in the body, the exact needs for protein synthesis need to be supplied each day. Therefore, the AA requirements of the animal and the dietary concentration of AA need to be known. However, availability of AA in many feedstuffs is not known, and thus, digestibility measurements are used as reasonable estimates of availability. The current contribution covers aspects of bioavailability of AA in feed ingredients with particular emphasis on pig nutrition. The determination of AA digestibility coefficients and the application to estimate bioavailability is discussed.

DIETARY SUPPLY OF AMINO ACIDS

Bound protein in feedstuffs and pure forms of crystalline AA supplies AA in pig diets. Crystalline AA are assumed to be completely absorbed from the gut and utilized by the animal. In contrast, animals are only able to utilize a portion of the AA contained in bound protein for metabolic functions. Therefore, the total amount of AA in a diet is not equal to the amount of AA that are available to the animal for metabolic functions. As a consequence, estimates of bioavailability of dietary AA are used in formulating swine diets to match the supply with requirements.

The Concept of Bioavailability

The bioavailability of an AA refers to the proportion of that AA that is in a form that can be digested, absorbed, and used for metabolic functions (1). Bioavailability coefficients of AA in feedstuffs are determined in slope ratio growth assays. These assays are laborious and time consuming and only allow determination of the bioavailability of a single AA at a time, which is costly. Consequently, there are only a limited number of ingredients and AA for which bioavailability coefficients have been determined and such coefficients of AA are not routinely used in feed formulation.

The use of bioavailability coefficients is important for heat-processed or long-stored ingredients because of the negative impact of these treatments on the bioavailability of the AA lysine. Lysine is rendered biologically unavailable by complexing with reducing compounds in the feed.

There are considerable efforts to develop simpler methods for estimating AA bioavailability in feedstuffs. A method known as the reactive lysine technique for assessing the bioavailability of lysine in feedstuffs that have undergone heat processing or that have been stored for a long time under conditions that might compromise lysine availability has been proposed (2). A method for determining the so-called metabolic availability of AA in feed ingredients has also been developed (3). Thus far, this method has been used to estimate the metabolic availability (i.e. the proportion that is used for body protein synthesis) of lysine in a small number of ingredients and there are still several questions that must be addressed before it can find use in routine assessment of AA bioavailability in feedstuffs.

The Concept of Digestibility

Digestibility is a measure of the disappearance of a nutrient from the digestive tract and is assumed to equate the degree of absorption of the nutrient from the gut lumen. Digestibility measurements do not provide any indication of the fate of the absorbed nutrient, but they are used as a reasonable estimate of AA availability (4).

Amino acid digestibility

Ileal AA digestibility coefficients provide better estimates of AA availability in swine feed ingredients than faecal digestibility coefficients (4) because AA that disappear from the hindgut are not available to the animal. The measurement of ileal AA digestibility coefficients requires sampling of digesta at the distal ileum. Techniques used for this purpose have been reviewed in detail (5). The techniques can be grouped into three main categories, namely those that involve cannulation, isolation of the large bowl, and slaughter of the animal (Table 1). Each of these techniques has limitations that create specific challenges in their use as discussed elsewhere (5).

Estimating Bioavailable Amino Acid Content in Feedstuffs

Apparent ileal digestibility coefficients

In conventional digestibility studies, it is not possible to distinguish between non-digested dietary AA and non-reabsorbed endogenous AA that are present in the digesta captured at the distal ileum. Calculated digestibility coefficients are, therefore, referred to as apparent digestibility coefficients.

However, apparent ileal digestibility coefficients of AA in a mixed diet may underestimate the amount of AA that are actually available to the pig. This is particularly true if low-protein feed ingredients such as cereal grains are included in the diet (6). The reason for this underestimation is that apparent ileal digestibility coefficients may not be additive in a mixture of feed ingredients, thus creating challenges in accurately formulating diets to supply the desired amount of AA in the diet (Figure 1). The use of digestibility coefficients to estimate bioavailability is improved considerably when apparent ileal digestibility coefficients are corrected for endogenous gut AA losses. For a complete review of endogenous gut AA losses in pigs and the methods used for their estimation, please refer to Nyachoti et al. (5) and Boisen and Moughan (7). Endogenous gut AA losses can be divided into two categories, namely, basal (diet-independent) losses and diet-specific (additional) losses. Basal endogenous AA losses are obligatory losses closely associated with the metabolic functions of the animal and are independent of the type of diet fed. Specific endogenous AA losses are dependent on the composition of the diet.

Standardized ileal amino acid digestibility coefficients

Standardized ileal AA digestibility coefficients, which are sometimes, incorrectly, referred to as true ileal digestibility coefficients are derived by correcting apparent ileal digestibility coefficients for basal endogenous AA losses (8). Compared with apparent digestibility coefficients, standardized ileal digestibility coefficients are believed to provide a better estimate of AA bioavailability in pig feeds. It is important, however, to recognize that estimates of basal endogenous AA losses vary widely among studies and that there is no general agreement on the best estimate of basal endogenous AA losses (7).

True ileal amino acid digestibility coefficients

True ileal AA digestibility coefficients are estimated when the recovery of specific endogenous AA in the ileal digesta is determined and used to correct apparent digestibility coefficients. This requires that the specific endogenous gut AA losses in ileal digesta be quantified. The required techniques are relatively tedious, thus making it more difficult to generate true ileal digestibility coefficients for routine feed formulation. However, when the goal is to understand how different feed ingredients or dietary components influence AA utilization in pigs, true ileal digestibility coefficients should be determined.

Effects of gut microbes on estimation of amino acid digestibility

Although the majority of the gut microflora in monogastric animals reside in the hindgut, a large microbial population also inhabits the upper gut (i.e. small intestine). Gut microbes may deaminate dietary AA or synthesis new AA. This will influence the digestibility measurements. The significance of such an effect on determining ileal AA digestibility coefficients is not known yet and deserves further attention.

Conclusion

Formulating pig diets to closely match the supply of AA with the AA requirements of the animals present a significant economic benefit and helps minimize nitrogen excretion in pig

manure, thus reducing the environmental impact of livestock production on the environment. To achieve this goal, knowledge of the bioavailability of AA in pig feed ingredients is required. Due to the difficulties involved in determining the content of bioavailable AA in feedstuffs on a routine basis, ileal digestible AA are used. To this end, it is recommended to use standardized ileal digestible AA coefficients as estimates of bioavailable AA. Such values should be determined for the specific feeding situation. Continued efforts to develop and/or refine current methods for determining bioavailability of AA for routine application are warranted.

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Table 1. Techniques used in collecting ileal digesta from pigs.

Cannulation techniques
Simple-T-cannula
Post-valve T-cannula (PVTC)
Steered ileal-caecal valve cannula
Re-entrant cannula
Isolation of the large bowl
Ileo-rectal anastomosis
Ileostomy
Slaughter and ileal dissection

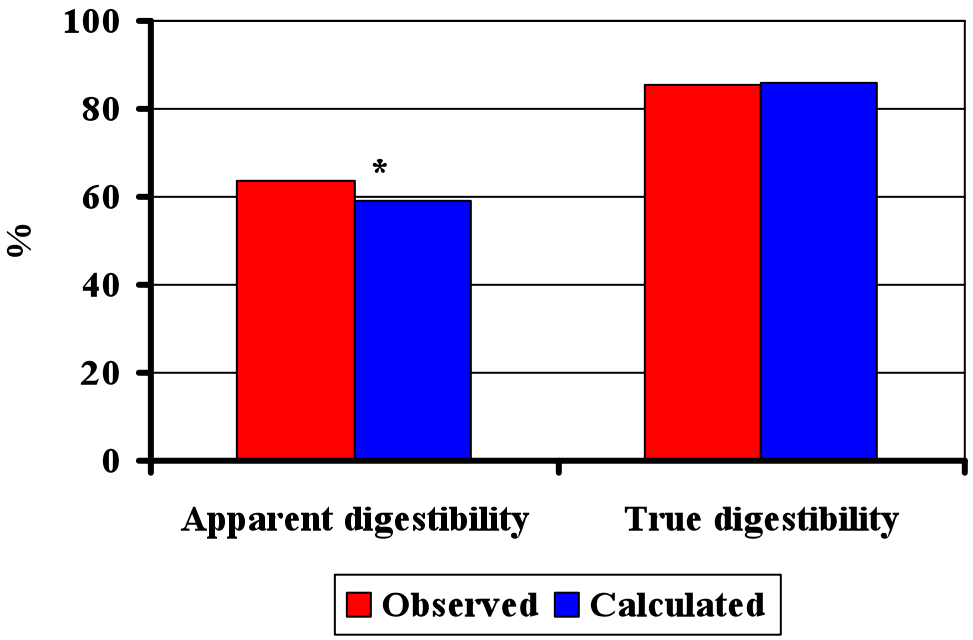

Figure 1. Observed and calculated apparent and true ileal lysine digestibilities in a barley-canola meal-based diet fed to growing pigs. Adapted from Nyachoti et al. (9)