

- BPEX, Warwickshire, England.
- BPEX (2011b) *20:20 Pig Health and Welfare, A Vision for 2020*. BPEX, Warwickshire, England.
- BPEX (2010) *Research into Action 5; Lighting for pig units*. BPEX, Warwickshire, England.
- FAO (2006) *Livestock's Long Shadow – environmental issues and options*. Food and Agriculture Organisation, Rome.
- Godfray, H.C.J., et al. (2011) *Foresight. The Future of Food and Farming (2011)*. Final Project Report. The Government Office for Science, London.
- Greenhouse Gas Action Plan (2011) *Meeting the Challenge: agricultural industry GHG Action Plan*. 2011.
- Topp, C.F.E., Houdijk, J.G. M., Tarsitano, D., Tolkamp, B.J. and Kyriazakis, I. (2012) Quantifying the environmental benefits of using home grown protein sources as alternatives to soyabean meal in pig production through life cycle assessment. *Advances in Animal Biosciences*, **3**, 15.
- Taylor, N. (2010) *Lighting for Pig Units*. BPEX, Warwickshire, England.
- Union of Concerned Scientists (2011) *The Root of the Problem – what's driving tropical deforestation today*. Union of Concerned Scientists, Cambridge, MA, USA.
- WWF (2011). *Soya and the Cerrado: Brazil's forgotten jewel*. WWF-UK, Goldaming, UK.

ASPECTS OF AMINO ACID DIGESTIBILITY IN FEED INGREDIENTS FED TO PIGS

F. N. ALMEIDA AND H. H. STEIN

Department of Animal Sciences, University of Illinois, Urbana, Illinois, USA

Introduction

Knowledge about the nutritional quality of feed ingredients is imperative for success in nutrition of pigs. For the protein fraction, it is generally agreed that the most accurate estimate of the quality of a feed ingredient is described by the digestibility of protein and amino acids in the ingredient. The objective of this chapter is to review digestion and absorption of protein and amino acids in pigs, to provide information about factors that influence protein and amino acid digestibilities in feed ingredients fed to pigs, and to discuss factors that may negatively impact protein and amino acid digestibility by pigs.

Digestion and absorption of protein and amino acids

Protein digestion in pigs starts in the stomach where pepsinogen, which is secreted by the Chief cells in the Fundic region, is activated to pepsin by H ions. In this stage, between 15 and 50% of all peptide bonds in proteins are hydrolyzed by pepsin, thus forming small oligopeptides. Activation of pepsinogen is best achieved at pH 2, and this may be a challenge for young pigs because HCl secretion is limited compared with that in older pigs. Therefore, activation of pepsinogen in young pigs may be limited and digestion of proteins may not be as effective as in older pigs, but there are limited data to demonstrate the extent to which protein digestion is impaired in young pigs. After gastric digestion, small and larger oligopeptides proceed to the small intestines where pancreatic enzymes (i.e., trypsin, chymotrypsin, elastase, and carboxypeptidase) and aminopeptidase,

which is secreted from the small intestinal brush border, hydrolyze most of the peptide bonds in the oligopeptides. The resulting free amino acids, di-peptides, and tri-peptides are subsequently absorbed into the enterocytes using four different active transport systems. After absorption, di-peptides and tri-peptides are broken down to free amino acids in the enterocytes by the action of di-peptidases and tri-peptidases, respectively. The majority of the free amino acids then leave the enterocytes via the basolateral membrane and are subsequently taken up by the hepatic portal vein and transported to the liver. These amino acids are used for synthesis of proteins that may be used for maintenance or for production by the animal. Excess amino acids are not stored in the body. Instead, excess amino acids are deaminated and metabolized, and the N is excreted in the urine in the form of urea. The carbon skeletons are used for ketogenesis or gluconeogenesis and thus provide energy for the animal.

Amino acid digestibility

Absorption of amino acids takes place only in the small intestine. Amino acids that pass the last portion of the small intestine (the ileum) into the large intestine can no longer be absorbed by the animal and may be metabolized by microorganisms in the large intestine and subsequently excreted as microbial protein in the feces. Thus, determination of amino acid digestibility is believed to be more accurate if determined at the end of the ileum than in the faeces (Stein et al., 2007). Amino acid digestibility is generally expressed as apparent ileal digestibility (AID), true ileal digestibility (TID), or standardized ileal digestibility (SID; Stein et al., 2007; Urbaityte et al., 2009).

APPARENT ILEAL DIGESTIBILITY

Values for AID of amino acids are used to describe the net disappearance of protein and amino acids from the digestive tract proximal to the distal ileum (Stein et al., 2007). To determine AID values, pigs are surgically fitted with a T-cannula in the distal ileum from which ileal digesta are collected using standard procedures (Almeida et al., 2011). The concentration of protein and amino acids in the ileal digesta is then subtracted from the concentration of protein and amino acids in the diet, and the difference is divided by the concentration of protein and amino acids in the diet (Stein et al., 2007). Values for the AID of protein and amino acids, however, are not to be additive in mixed diets because they do not account for the

endogenous losses of protein and amino acids, which is the main disadvantage of the use of values for AID (Stein et al., 2005). This issue, however, may be overcome by correction for endogenous protein and amino acid losses.

ENDOGENOUS PROTEIN AND AMINO ACID LOSSES

Endogenous protein and amino acid losses are composed of protein and amino acids resulting from mucoproteins, sloughed cells, digestive enzymes, microbial protein, amides, and ingested hair (Souffrant, 1991; Nyachoti et al., 1997). Endogenous protein and amino acid losses may be divided into 2 categories: 1) basal endogenous losses, which relates to the physical flow of feed dry matter through the gastrointestinal tract and represent the minimum amount of protein and amino acids inevitably lost by the pig; and 2) specific endogenous losses, which is stimulated by specific characteristics of feed ingredients such as fibre and antinutritional factors, and represent the losses above the basal endogenous losses (Schulze et al., 1995; Stein et al., 2007).

Methods used to determine basal endogenous losses of protein and amino acids include feeding a protein-free diet, the regression procedure, and the peptide alimentation procedure (Fuller, 1991; Jansman et al., 2002; Moughan, 2003). Use of the N-free diet is the simplest and easiest of these procedures and is, therefore, the most commonly used procedure. However, it is recognized that the N-free procedure may overestimate endogenous losses of proline and glycine (Stein et al., 2007).

Total endogenous losses of protein and amino acids, which include basal plus specific losses, may be estimated using the homoarginine method or the isotope tracer technique (Krawielitzki et al., 1977; Hagemester and Ebersdobler, 1985). Both of these procedures are expensive and tedious to use and only estimate the loss of one or a few amino acids and they are, therefore, not commonly used in practical feed ingredient evaluation (Stein et al., 2007).

TRUE ILEAL DIGESTIBILITY

Values for the TID of amino acids are determined by correcting AID values for total endogenous losses of protein and amino acids. True ileal digestibility values, therefore, represent the amount of dietary protein and amino acids that disappear from the gastrointestinal tract proximal to the distal ileum (Stein et al., 2007). However, because of the difficulties in determining the total endogenous losses,

