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Combination of digestibility marker and fiber affect energy and nitrogen digestibility in growing pigs

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ABSTRACT

This study was conducted to investigate if (i) the coefficient of ileal apparent digestibility (CIAD) of gross energy (GE) or nitrogen (N) was influenced by the type of digestibility marker (DMr) and dietary fiber, and (ii) the coefficient of total tract apparent digestibility (CTTAD) of GE or N was influenced by the type of method (i.e. total collection (TC) and DMr) and dietary fiber. Eighteen barrows fitted with a T-cannula at the end of the ileum were used in a 2-period randomized complete block design. Three corn-soybean meal-based diets were formulated with corn starch, corn bran or oat bran at 100 g/kg. All 3 diets contained 3 DMr, which were chromic oxide (Cr), titanium dioxide (Ti), and acid-insoluble ash (AIA). The ileal digesta were collected for 3 days, and the CIAD of GE and N were determined by measuring Cr, Ti or AIA. The feces were collected by using TC method, and the CTTAD of GE and N were determined by using Cr, Ti, AIA, or TC method. There were interactions between diet and DMr ($P < 0.001$) for CIAD of GE and N and DMr recovery ($P < 0.001$), and between diet and method for CTTAD of GE and N ($P < 0.001$). The DMr had similar effect on CIAD of GE and N within each diet, but different effects among the 3 diets. For corn starch and corn bran, the greatest CIAD of GE or N was determined by Ti, while for oat bran, the greatest CIAD was determined by AIA. However, the CTTAD of GE or N of corn starch and the CTTAD of N of corn bran determined by the 3 DMr were not different. The greatest CTTAD of GE of corn bran was determined by Ti or AIA, while the greatest CTTAD of GE or N of oat bran was determined by Cr or AIA. For all 3 diets, the CTTAD of GE and N determined by the TC method was greater ($P < 0.001$) than those determined by using DMr. The recovery of Ti in feces of pigs fed the oat bran was 78.3%, which was the least among all the 3 diets ($P < 0.05$). In conclusion, the CIAD of GE or N was more influenced by the choice of DMr compared with CTTAD, and the Ti recovery of pigs fed oat bran was less than corn starch or corn bran.

1. Introduction

Coefficient of ileal apparent digestibility (CIAD) and coefficient of total tract apparent digestibility (CTTAD) of gross energy (GE) and nitrogen (N) are commonly used to evaluate digestibility of feed nutrients and energy. The most common method used to determine CIAD is to include digestibility marker (DMr) in the diet, and spot-sample ileal digesta from pigs fitted with simple T-cannulas (Köhler et al., 1990). For the determination of CTTAD, either the total collection (TC) method or the DMr method can be

Abbreviations: AIA, acid-insoluble ash; CIAD, coefficient of ileal apparent digestibility; Cr, chromic oxide; CTTAD, coefficient of total tract apparent digestibility; DM, dry matter; DMr, digestibility marker; GE, gross energy; N, nitrogen; SED, standard error of difference; TC, total collection; Ti, titanium dioxide; TP, time period

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used (Kong and Adeola, 2014). Chromic oxide (Cr), titanium dioxide (Ti) and acid-insoluble ash (AIA) are the most common DMr used in pigs to determine CIAD and CTTAD (McCarthy et al., 1974; Jagger et al., 1992). Total collection method determined similar energy digestibility with Cr in corn or with Ti in wheat based complete diet, while greater values than using Cr in triticale diet (Adeola et al., 1986; Thompson and Wiseman, 1998).

Previous studies have indicated that the choice of DMr could affect the determination of CIAD and CTTAD of nutrients (Jagger et al., 1992; Yin et al., 2000; Kavanagh et al., 2001; Favero et al., 2014). What's more, the effects of dietary fiber on nutrient digestibility have been investigated in pigs (Köhler et al., 1990) and broiler chickens (Smeets et al., 2015), however, the interaction between DMr and dietary fiber types have not been reported. Oat bran is rich in water-soluble fiber and low in cellulose and lignin (Jacobs, 1983), but the major components of corn bran are cellulose and hemicellulose which are nearly completely insoluble in water (Rose et al., 2010). The hypothesis of this study was that there is interaction between diet and DMr for CIAD, and method (i.e. TC and DMr) for CTTAD. Therefore, the objective of the current study was to determine the effect of diet and DMr (or method) on CIAD (or CTTAD) of GE and N in growing pigs.

2. Materials and methods

All animal procedures used in this study were approved by the Purdue Animal Care and Use Committee.

2.1. Animals and diets

Three corn-soybean meal-based diets containing 100 g/kg corn starch, corn bran or oat bran, and identical in other components (Table 1) were prepared. All 3 diets contained 3 DMr, which were 5 g/kg Cr, 5 g/kg Ti, and 20 g/kg diatomaceous earth (AIA, Perma-Guard, Inc., Bountiful, UT).

Eighteen Hampshire × Duroc × Yorkshire × Landrace barrows were surgically fitted with a simple T-cannula at the distal ileum as described by Dilger et al. (2004). All pigs were housed individually in stainless steel metabolism crates (1.22 × 1.22 m) during the entire experimental period. Metabolism crates were equipped with a feeder and a nipple drinker and placed in a room with a 24-h lighting program. In the first period, 18 pigs were grouped into 6 blocks based on body weight (24.2 ± 0.3 kg) and were randomly allotted to 3 diets. In the second period, the same 18 pigs were grouped into 6 new blocks based on body weight (26.9 ± 0.5 kg) and went through the same procedure except that pigs consumed diets different from the first period, providing 12 observations per diet in total.

2.2. Sample collection

At the beginning of the experimental period, daily feed allowance was set as 4% of body weight and pigs were fed at 08:00 and 16:00 h in 2 equal meals. Water was provided to the pigs via nipple drinkers at 3 L/kg feed intake. Each period consisted of a 7-d adjustment period followed by a 3-d total fecal collection period and a 3-d ileal digesta collection period. Feces were collected using the TC method and collection was initiated and ended with the appearance of ferric oxide in feces as described by Akinmusire and Adeola (2009). The ileal digesta were collected every 3 h between 09:00 to 21:00 h with 4 time period (TP) where TP 1 = 09:00 to 12:00 h, TP 2 = 12:00 to 15:00 h, TP 3 = 15:00 to 18:00 h, and TP 4 = 18:00 to 21:00 h on ileal digesta collection days by attaching a Whirlpak® bag (NASCO, Fort Atkinson, WI) to the cannula with a rubber O-ring. The ileal digesta collection procedure used in this study was used to investigate the effects of TP and ileal collection day on DMr concentration (Wang and Adeola, 2017).

2.3. Analytical method and calculations

Ileal digesta from each pig at each TP within each ileal digesta collection day and feces samples for each pig within each period were pooled, subsampled, forced-air dried at 55 °C to constant weight and ground to pass through a 0.5-mm screen before analysis. The dry matter (DM) contents of ileal and fecal samples were determined by drying at 105 °C in a forced-air oven (Precision Scientific Co., Chicago, IL; method 934.01; AOAC, 2006) for 24 h. Chromium content was analyzed according to the method described by Saha and Gilbreath (1991) with modification of temperature and measured by spectrophotometer at 450 nm of absorption (Spectronic 21D; Milton Roy Co., Rochester, NY). Titanium content was analyzed as described by Favero et al. (2014). Acid-insoluble ash content was determined as described by McCarthy et al. (1974). Gross energy content was determined by isoperibol bomb calorimetry using a Parr 1261 calorimeter (PARR Instrument Co., Moline, IL). Nitrogen content was analyzed with the combustion method using a LECO Model TruMac nitrogen analyzer (LECO Corp., St. Joseph, MI; method 990.03; AOAC, 2000). Acid detergent fiber was expressed inclusive of residual ash (method 973.18 (AD); AOAC, 2006) and neutral detergent fiber was assayed with a heat stable amylase and expressed inclusive of residual ash (Van Soest et al., 1991) and both were analyzed by the ANKOM 200 Fiber Analyzer (ANKOM Technology, Macedon, NY).

The CIAD and CTTAD of N were calculated using the following equations (Adedokun and Adeola, 2005):

$$\text{CIAD of N} = [1 - (M_{diet}/M_{digesta}) \times (N_{digesta}/N_{diet})];$$

$$\text{CTTAD of N} = [1 - (M_{diet}/M_{feces}) \times (N_{feces}/N_{diet})],$$