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Comparative ileal amino acid digestibility of distillers' grains for growing pigs[☆]Olayiwola Adeola^{a, *}, Darryl Ragland^b^a Department of Animal Sciences, Purdue University, West Lafayette 47907, USA^b Department of Veterinary Clinical Sciences, Purdue University, West Lafayette 42054, USA

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ABSTRACT

The objective of the experiment reported here was to investigate and compare the amino acid (AA) digestibility of distillers' dried grains (DDG), distillers' dried grains with solubles (DDGS), high protein distillers' dried grains (HP-DDG), and high protein distillers' dried grains with solubles (HP-DDGS) in growing pigs. Five semi-purified diets consisting of DDG, DDGS, HP-DDG, HP-DDGS, and nitrogen-free diet (NFD) were fed to pigs fitted with simple T-cannula for 5 observations per diet. Endogenous losses of AA at the terminal ileum of pigs that received the NFD were used to calculate standardized ileal digestibility (SID) of AA from apparent ileal digestibility (AID) of AA. The AID of Lys in DDGS was lower ($P < 0.05$) than that in DDG, which was also lower ($P < 0.05$) than that in HP-DDG. There were no differences in AID of Met among DDG, DDGS and HP-DDGS, but was greater ($P < 0.05$) in HP-DDG than in DDG or DDGS. The AID of Thr in HP-DDG was greater ($P < 0.05$) than that in DDGS but not different from that in DDG or HP-DDGS. The branched-chain AA Ile and Leu had greater ($P < 0.05$) AID in HP-DDG than in DDG, DDGS or HP-DDGS, and there was no difference among DDG, DDGS, and HP-DDGS. The AID of Trp in DDG and DDGS or HP-DDG and HP-DDGS were not different, but the AID of Trp in HP-DDGS was greater ($P < 0.05$) than that of DDGS. The greatest SID of the indispensable AA was in HP-DDG. Except for Arg and Lys in which DDG had greater ($P < 0.05$) digestibility, there was no difference between DDG and DDGS in the SID of the indispensable AA. The SID of Lys in DDG was greater ($P < 0.05$) than that of DDGS but there was no difference between that of DDG and HP-DDGS. Only His, Ile, and Met had lower ($P < 0.05$) SID in HP-DDGS than HP-DDG within the indispensable AA. The SID of Ala, Asp, Cys, Glu, Gly, Ser and Tyr were lower ($P < 0.05$) in DDGS than in HP-DDG. There SID of dispensable AA in DDG was not different from that of HP-DDGS. The current study provided apparent and standardized ileal amino acids digestibility values for traditional and high-protein corn distillers' dried grains coproducts for use in formulating swine diets. Amino acid digestibility was generally higher in HP-DDG than in other tested co-products of the dry grind processing of corn for ethanol.

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1. Introduction

Corn distillers' dried grains (DDG) is a co-product of the dry grind processing of corn for ethanol production (Adeola et al., 2010; Kingsly et al., 2010). As ethanol producers implement new processes that more efficiently utilize starch from grain cereals, new co-products are being made available for use in swine feed formulation. Appropriate use of any new co-product in diets requires information on nutrient utilization and profile. Two fractionation processes have been implemented by the industry that can separate components of corn kernels to be further processed into discrete components. A back-end fractionation process takes post-fermentation DDG and separates fractions into protein and

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fiber subunits. The other process is a front-end or pre-fermentation fractionation process wherein individual corn kernels are divided into 3 segments: the endosperm, the pericarp, and the germ (Zhao et al., 2010). The high-fiber fragment, the pericarp, is processed into a human food product, animal feed or biomass fuel substrate. The portion which is relatively high in oil, the germ, is segregated to extract the oil with the remainder being processed into corn germ meal. The endosperm is high in starch and protein and is the fragment used within the ethanol plant as substrate for microbes to produce ethanol. Following the fermentation process, the remaining co-product is the eventual high-protein distillers' dried grains (HP-DDG; Jacela et al., 2010). When the HP-DDG or DDG is combined with condensed distillers' solubles, the resulting product is high-protein distillers' dried grains with solubles (HP-DDGS) or distillers' dried grains with solubles (DDGS).

Because of a dearth of information on the SID and AID of amino acids (AA) in HP-DDG and HP-DDGS, the experiment reported here was conducted to investigate and compare digestibility of AA in DDG, DDGS, HP-DDG, and HP-DDGS when fed to growing pigs.

2. Materials and methods

2.1. Pigs, test ingredients, and diets

Crossbred Hampshire × Duroc × Yorkshire × Landrace barrows, obtained from the Purdue University Animal Research Farm, were used in the study. Pig surgery with simple T-cannula and animal care protocols were approved by the Purdue University Animal Care and Use Committee. The procedures were similar to those recently described by Zhai and Adeola (2011) and Cotten et al. (2016). Pigs were allowed at least 14 days to recover from surgery before initiation of the study. Average body weights of pigs at the beginning and end of the study were 50.2 kg (SD 4.5) and 54 kg (SD 5.2), respectively. Analyzed chemical composition of the test ingredients, DDG, DDGS, HP-DDG, and HP-DDGS, supplied by Mor Technology LLC (Metropolis, Illinois, USA), are presented in Table 1 and ingredient and chemical composition of the 5 diets used in the study are presented in Table 2. The nitrogen-free diet (NFD) was used to estimate basal endogenous losses of AA. Feed allowance for each pig was based on approximately 4% of body weight in 2 equal daily meals at 08:00 and 20:00. Each period lasted 7 d consisting of 5 d for the pigs to adapt to the experimental diets, followed by a 2 d collection period of ileal digesta during which a plastic tubular bag was attached to the externalized T-cannula on d 6 and 7. To reduce proliferation of bacteria in the ileal samples, each bag contained 10 mL of 5% formic acid, and ileal contents were stored at −20°C between collections. Chromic oxide was added as an indigestible marker calculation of ileal nutrient digestibility by the index method.

2.2. Analyses

Diets and freeze-dried ileal digesta were ground through a 0.5-mm screen prior to analyses. Samples were dried at 100°C for 24 h to determine the dry matter (AOAC, 2006). Chromium (Cr) concentration was determined by the inductively coupled plasma atomic emission spectroscopy method following wet ash digestion with nitric and perchloric acid. Nitrogen (N; AOAC, 2006) was determined by the combustion method (model FP2000, LECO Corp., St. Joseph, MI, USA) using EDTA as a standard. Analyses of AA (AOAC, 2006) were conducted at the Experimental Station Chemical Laboratory, University of Missouri, Columbia, MO, USA. Sample hydrolysis used 6 mol/L HCl at 100°C for 24 h under N atmosphere. For the sulfur AA (Met and Cys), performic acid oxidation occurred prior to acid hydrolysis. Barium hydroxide was used to hydrolyze

Table 1

Analyzed dry matter, nitrogen (N), and amino acid (AA) composition of distillers' dried grains (DDG), distillers' dried grains with solubles (DDGS), high protein distillers' dried grains (HP-DDG) and high protein distillers' dried grains with solubles (HP-DDGS) on an as-fed basis.

Item	DDG	DDGS	HP-DDG	HP-DDGS
Dry matter, g/kg	936.3	888.4	961.5	878.1
Crude protein (N × 6.25), g/kg	315	277	579	481
Crude fat, g/kg	89	11	19	27
Crude fiber, g/kg	91	74	47	36
Neutral detergent fiber, g/kg	496	371	417	279
Acid detergent fiber, g/kg	179	108	263	160
Ca, g/kg	0.2	2.0	0.2	0.5
Total P, g/kg	4.8	7.7	1.8	2.5
Indispensable AA, g/kg				
Arg	12.9	13.5	18.4	15.5
His	8.8	8.5	15.4	13.7
Ile	12.9	10.6	24.0	19.2
Leu	43.6	32.7	89.6	67.5
Lys	9.3	10.5	9.8	10.6
Met	6.7	5.4	13.9	9.8
Phe	17.2	13.1	34.6	24.7
Thr	11.6	10.3	20.1	16.8
Trp	2.0	2.1	2.8	2.5
Val	17.2	15.1	28.8	25.0
Dispensable AA, g/kg				
Ala	25.0	20.5	48.9	39.1
Asp	20.1	17.6	34.8	26.2
Cys	6.0	5.2	10.9	8.1
Glu	52.2	37.9	105.0	64.4
Gly	11.7	11.7	17.7	15.2
Pro	25.7	20.4	52.4	37.0
Ser	13.2	11.5	24.0	19.9
Tyr	13.1	9.9	27.6	19.3

tryptophan during analysis. High pressure liquid chromatography (HPLC) after post-column derivatization was used to determine AA concentrations in hydrolyzate.

The apparent ileal digestibility (AID) of AA was calculated as: $AID (\%) = 100 \times [1 - (Cr \text{ in diet}/Cr \text{ in digesta}) \times (AA \text{ in digesta}/AA \text{ in diet})]$; Ileal endogenous loss (IEL) of AA in mg AA per kg of dry matter intake (DMI) was calculated as: $IEL = (Cr \text{ in diet} - Cr \text{ in digesta})/Cr \text{ in diet} \times DMI$; standardized ileal digestibility (SID) of AA was calculated as: $SID (\%) = AID (\%) + [(IEL/AA \text{ in diet}) \times 100]$. Data was analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC, USA) for a Latin square design, with pig serving as the experimental unit. The model included the fixed effects of the diet, with block, period, and pig as random effects. The LSMEANS statement in SAS was used to generate means, which were separated using the possible difference option in SAS and a probability level of 5% was considered significant.

3. Results

Table 3 shows the comparative AID of AA in DDG, DDGS, HP-DDG, and HP-DDGS. The AID of Lys in DDGS was lower ($P < 0.05$) than that in DDG, which was also lower ($P < 0.05$) than that in HP-DDG. There were neither differences in AID of Lys between HP-DDGS and DDGS nor between HP-DDGS and DDG. Other cationic AA, Arg and His, followed similar trends as Lys relative to differences among ingredients but the digestibility of those AA were much greater than that of Lys (Table 3). The AID of Met was not different among DDG, DDGS and HP-DDGS, but was greater ($P < 0.05$) in HP-DDG than in DDG or DDGS. The AID of Thr in HP-DDG was greater ($P < 0.05$) than that in DDGS but not different from that in DDG or HP-DDGS. The branched-chain AA, Ile and Leu, had greater ($P < 0.05$) AID in HP-DDG than DDG, DDGS or HP-DDGS, and there was no difference among DDG, DDGS, and HP-DDGS. The AID

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