Title: Ileal and total tract apparent and true digestibility of fat in distillers dried grains with solubles and other corn oil products fed to growing pigs. National Pork Board Project Identification – **NPB #08-115.**

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INDUSTRY SUMMARY

The objective of this research was to test the hypothesis that oil in distillers dried grains with solubles (**DDGS**) and other co-products from the ethanol industry such as high protein distillers dried grains (**HP DDG**) and corn germ have different nutritional properties in swine diets than liquid extracted corn oil and intact oil in corn. We, therefore, hypothesized that it is not possible to predict the effects of the oil in distillers co-products on carcass quality of pigs simply by measuring the concentration of oil in the co-products, but if the digestibility of oil in the feed ingredients are measured, then diets may be formulated based on the concentration of digestible fat in the diets. The specific objective of the present experiment was, therefore to measure the true ileal digestibility and the true total tract digestibility of fat in extracted corn oil, intact corn oil from high oil corn, DDGS, HP DDG, and corn germ and to compare these values to the digestibility of fat in soybean oil.

The experiment was conducted using 19 barrows with an initial BW of 52.2 kg. All pigs were surgically prepared with a T-cannula in the distal ileum. Diets based on extracted corn oil, high oil corn, DDGS, corn

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germ, HP DDG, and full fat soybeans were formulated and fed to the pigs for 7 days. Fecal samples were collected from the pigs on d 5 of each feeding period and ileal samples were collected on d 6 and 7 of each period. A total of 11 samples were obtained for each diet. All diets and all ileal and fecal samples were analyzed for fat and the digestibility of fat in each ingredient were calculated.

Results showed that the digestibility of fat was greater in extracted corn oil and full fat soybeans than in the other ingredients. However, HP DDG and DDGS had greater digestibility of fat than high oil corn and corn germ, which indicates that the fermentation process in the ethanol plants increases fat digestibility. It is concluded that the digestibility of fat varies greatly among feed ingredients. As a result, it is not possible to predict the impact of a specific feed ingredient on quality of pork fat just by measuring the concentration of fat in that ingredient. Instead, it is necessary to formulate diets based on the digestible concentration of fat in the diets. The present research provides for the first time, digestibility values for fat in distillers co-products and other feed ingredients. Using these data, it is now possible to formulate diets fed to growing and finishing pigs based on concentrations of digestible fat, which in turn allows producers to predict the effects of a specific diet on the quality of the fat in pigs fed that diet.

SCIENTIFIC ABSTRACT

An experiment was conducted to measure the true ileal digestibility (TID) and the true total tract digestibility (TTTD) of acid-hydrolyzed ether extract (AEE) in extracted corn oil, high-oil corn, distillers dried grains with solubles (DDGS), corn germ, high-protein distillers dried grains (HP DDG), and full-fat soybeans. Nineteen barrows with an initial BW of 52.2 kg (SD = 3.81) were fitted with a T-cannula in the distal ileum and allotted to a 19 × 11 Youden square design with 19 diets and 11 periods. A basal diet based on cornstarch, casein, sucrose, and corn bran was formulated. Eighteen additional diets were formulated by adding 3 levels of extracted corn oil, high-oil corn, DDGS, corn germ, HP DDG, or full-fat soybeans to the basal diet. The apparent ileal and the apparent total tract digestibility of AEE were calculated for each diet. The endogenous flow of AEE associated with each ingredient and values for TID and TTTD were calculated using the regression procedure. Result showed that digested AEE in ileal digesta and feces linearly increased as AEE intake increased regardless of ingredient ($P < 0.001$) and the regression of ileal and fecal AEE output against AEE intake was significant ($P < 0.001$; $r^2 > 0.77$) for all ingredients. However, the ileal and fecal endogenous losses of AEE were different ($P < 0.05$) from zero only for extracted corn oil, HP DDG, and full-fat soybeans. The TID of AEE was greater ($P < 0.05$) for extracted corn oil (95.4%) than for the other oil sources. The TID of AEE in HP DDG was greater ($P < 0.05$) than in high-oil corn and corn germ (76.5 vs. 53.0 and 50.1%). The TID of AEE in DDGS (62.1%) was not different from that in high-oil corn, corn germ, or HP DDG. Full-fat soybeans had greater AEE TID (85.2%) than high-oil corn, DDGS, and corn germ. The TTTD of AEE was greater ($P < 0.05$) for extracted corn oil (94.3%) than for the other ingredients. The TTTD of AEE in HP DDG was greater ($P < 0.05$) than in high-oil corn, DDGS, and corn germ (70.2 vs. 41.4, 51.9, and 43.9%). The TTTD of AEE in DDGS was not different from that in high-oil corn or corn germ. Full-fat soybeans had greater TTTD of AEE (79.7%) than high-oil corn, DDGS, and corn germ. In conclusion, the AEE in HP DDG is more digestible than in high-oil corn, DDGS, or corn germ, but less digestible than that in extracted corn oil.

Key words: acid hydrolyzed ether extract, pigs, true ileal digestibility, true total tract digestibility

INTRODUCTION

Fat is an important nutrient in swine diets because of its high energy value (Stahly and Cromwell, 1979) as well as its direct reflection on pork fat quality (Warnants et al., 1999; Averette Gatlin et al., 2002; Weber et al., 2006). As the ethanol industry increases the production of co-products, such as corn distillers dried grains with solubles (**DDGS**), corn germ and high-protein distillers dried grains (**HP DDG**), these co-products are increasingly used in swine diets (Widmer et al., 2007, 2008; Stein and Shurson, 2009; Kim et al., 2009). However, pork fat quality may be compromised as these co-products are used due to the relatively large proportion of unsaturated fatty acids in corn oil (Whitney et al., 2006; Widmer et al., 2008).

To prevent the deterioration of pork fat quality, it may become necessary to formulate diets based on concentrations of digestible fat, but the digestibility of fat varies among corn and corn co-products. The intact form of oil is less digestible than the free (extracted) form (Adams and Jensen, 1984; Kill et al., 2007), but there is no information on the digestibility of fat in co-products from the ethanol industry. Such information is, however, needed to predict the effects of ethanol co-products on pork fat quality.

The objective of this experiment, therefore, was to determine the true ileal digestibility (**TID**) and true total tract digestibility (**TTTD**) of acid-hydrolyzed ether extract (**AEE**) in high-oil corn, DDGS, corn germ, and HP DDG and to compare these values to TID and TTTD values for extracted corn oil and intact soybean oil.

STATED OBJECTIVES FROM ORIGINAL PROPOSAL

The objective of this research was to test the hypothesis that oil in distillers dried grains with solubles (DDGS) has different chemical and nutritional properties in swine diets than liquid extracted (free) corn oil and intact oil in corn. Specific aims are: (1) To compare the apparent ileal (AID) and apparent total tract (ATTD) digestibility of fat in DDGS and corn oil in a free or an intact form. (2) To estimate the endogenous losses of fat in pigs fed different forms of oils. (3) To compare the true ileal (TID) and the true total tract digestibility (TTTD) of fat in DDGS and corn oil in a free or an intact form.

MATERIALS AND METHODS

The experiment was conducted in an environmentally controlled room at the University of Illinois at Urbana-Champaign. The protocol for the experiment was reviewed and approved by the Institutional Animal Care and Use Committee at the University of Illinois. All pigs used in this experiment were the offspring of line 337 boars that were mated to C22 females (Pig Improvement Company, Hendersonville, TN).

Animals, Experimental Design, and Housing

Nineteen growing barrows with an initial BW of 52.2 ± 3.81 kg were used in the experiment. Pigs were equipped with a T-cannula in the distal ileum using procedures adapted from Stein et al. (1998). Pigs were allotted to a 19 × 11 Youden square design with 19 diets and 11 periods. Pigs were individually housed in pens equipped with a feeder and a nipple drinker.

Diets and Feeding

Nineteen experimental diets were prepared (Tables 1 and 2). A basal diet (1.32% AEE) based on cornstarch, casein, sucrose, and corn bran was formulated. Eighteen additional diets were formulated by adding 3 levels of extracted corn oil (2, 4, or 6%), high-oil corn (24, 48, or 72%), DDGS (17, 34, or 51%), corn germ (11, 22, or 33%), HP DDG (16, 32, or 48%), or full-fat soybeans (9.34, 18.68, or 28.02%) to the basal diet at the expense of corn starch, casein, and corn bran. The concentration of corn bran was adjusted to minimize the potential effects of fiber on the digestibility of AEE. The concentration of dietary AEE increased with the increasing levels of each feed ingredient. All diets contained 0.5% chromic oxide as an indigestible marker, and vitamins and minerals were included in all diets to meet or exceed nutrient requirement estimates (NRC, 1998).

Feed was provided at daily levels of 2.5 times the estimated maintenance requirement for energy (i.e., 106 kcal of ME/kg $BW^{0.75}$) and equal meals were provided at 0800 and 1600. The feed allowance was adjusted at the beginning of each period when BW were recorded. Animals had free access to water through a nipple drinker.

Sample Collection

Each period lasted 7 d. The initial 4 d were an adaptation period to the diet. Fecal samples were collected on d 5. Ileal digesta samples were collected for 8 h on d 6 and 8 h on d 7. A plastic bag was attached to the cannula barrel using a cable tie and digesta flowing into the bag were collected. Bags were removed whenever they were filled with digesta, or at least once every 30 min. Fecal and ileal samples were stored at -20°C immediately after collection.

Chemical Analysis

At the conclusion of the experiment, fecal samples were dried at 55°C in a forced-air oven. Frozen ileal samples were allowed to thaw at room temperature, mixed within animal and diet, and a sub-sample was collected and lyophilized. Fecal and ileal samples were finely ground prior to chemical analysis.

Diets, fecal samples, and ileal samples were analyzed for DM and AEE (method 930.15 and method 954.02, respectively; AOAC, 2005). All diets were also analyzed for GE using bomb calorimetry (Parr 6300 calorimeter, Parr Instruments Co., Moline, IL). The Cr concentration of the samples was determined using graphite furnace atomic absorption spectrometry. All diets were also analyzed for NDF (Holst, 1973) and ADF (method 973.18; AOAC, 2005).

Calculation

The ileal and total tract output of AEE and the digested AEE (g/kg DMI) in ileal digesta and in feces from each diet were calculated. The apparent ileal digestibility (**AID**) and the apparent total tract digestibility (**ATTD**) of AEE were calculated for each diet according to Stein et al. (2007). The true digestibility of AEE and the ileal and total tract endogenous AEE excretion were estimated using regression analyses according to the following equation:

$$AEE_D = -AEE_{EL} + (AEE_{TD} \times AEE_{IN}),$$

where AEE_D = digested AEE (g/kg of DMI); AEE_{EL} = endogenous AEE loss (g/kg of DMI); AEE_{TD} = true digestibility of AEE, %; and AEE_{IN} = AEE intake (g/kg of DMI).

Statistical Analysis

Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). The initial model included diet as a fixed variable and period and animal as random variables. No effects of random variables were detected and the final model, thus, included only the fixed variable. Outliers were detected using the UNIVARIATE procedure. Orthogonal polynomial contrasts were used to determine the effects of increasing dietary AEE concentration from each ingredient. Appropriate coefficients for unequally spaced AEE intake were obtained using the interactive matrix language procedure. The REG procedure was used to estimate the endogenous AEE loss in ileal digesta and in feces. Estimates of true digestibility values (slope of the regression line) were compared based on confidence intervals. The pig was the experimental unit and the alpha level used for determination of differences among means was 0.05.

RESULTS

As pigs consumed increasing concentrations of AEE from extracted corn oil, ileal output of AEE calculated as g/kg of DMI linearly increased ($P < 0.05$; Table 3). When high-oil corn, DDGS, corn germ, HP DDG, or full-fat soybeans was used as a source of additional oil, both ileal and fecal output linearly increased with increasing dietary concentrations of AEE ($P < 0.001$). Digested AEE in ileal digesta and in feces linearly increased as AEE intake increased regardless of feed ingredient ($P < 0.001$). The AID of AEE increased (linear and quadratic; $P < 0.01$) with increasing AEE intake from extracted corn oil or full-fat soybeans. A linear increase in the AID of AEE was observed in pigs fed oil from HP DDG ($P < 0.001$) and a tendency ($P = 0.10$) for a linear increase in AID of AEE was observed for DDGS. The ATTD of AEE also increased (linear and quadratic; $P < 0.05$) as the concentration of extracted corn oil, HP DDG, or full-fat soybeans increased in the diet.

The regression of ileal AEE output against AEE intake was significant ($P < 0.001$; $r^2 > 0.77$) for all ingredients (Table 4). However, the y-intercept, which represents the endogenous loss of AEE was different from zero only for extracted corn oil, HP DDG, and full-fat soybeans (6.11, 4.20, and 4.85 g/kg DMI, respectively; $P < 0.01$). The TID of AEE that were calculated as the slopes of the regression lines were greater ($P < 0.05$) for extracted corn oil (95.4%) than for the other ingredients. The TID of AEE in HP DDG was greater ($P < 0.05$) than in high-oil corn and corn germ (76.5 vs. 53.0 and 50.1%). The TID of AEE in DDGS (62.1%) was not different from that in high-oil corn, corn germ, or HP DDG. Full-fat soybeans had greater TID of AEE (85.2%) than high-oil corn, DDGS, and corn germ.

The regression of fecal output of AEE against the intake of AEE was also significant ($P < 0.001$; $r^2 > 0.77$) for all ingredients. However, the y-intercept was different from zero only for extracted corn oil, HP DDG, and full-fat soybeans (6.51, 2.62, and 4.85 g/kg DMI, respectively; $P < 0.05$). The TTTD of AEE were greater ($P < 0.05$) for extracted corn oil (94.3%) than for the other ingredients. The TTTD of AEE in HP DDG was greater ($P < 0.05$) than in high-oil corn, DDGS, and corn germ (70.2 vs. 41.4, 51.9, and 43.9%), but the TTTD of AEE in DDGS was not different from that in high-oil corn or corn germ. Full-fat soybeans had greater TTTD of AEE (79.7%) than high-oil corn, DDGS, and corn germ.

DISCUSSION

The concentration and source of dietary fiber have been reported to affect the digestibility of fat (Just et al., 1980; Hansen et al., 2006). In the present experiment, corn bran was included in the diet to minimize the potential influence of dietary fiber on fat digestibility. Although the concentration of NDF in the diets varied from 12.3 to 21.5%, most values were within a narrow range.

As anticipated, increasing levels of AEE intake from extracted corn oil resulted in a linear and quadratic increase in the AID and ATTD of AEE (Table 3). This observation agrees with previous research with extracted oils such as animal fat (Just et al., 1980), soybean oil (Jørgensen et al., 1993), and corn oil (Kil et al., 2007). The reason for this curvilinear response is that the endogenous loss of AEE contributes a relatively larger proportion to the total AEE output in diets with low AEE concentration than in diets with greater AEE concentration (Kil et al., 2007). The AID and ATTD of AEE from full-fat soybeans also had a linear and quadratic response. However, the digestibility values for AEE from high-oil corn, DDGS, or corn germ were unaffected by the level of AEE intake. The reason for this observation may be that these diets had a greater AEE output in the digesta and feces because of the low AEE digestibility than diets containing extracted corn oil or full fat soybeans. The contribution of endogenous AEE to the AEE output was, therefore, much lower in pigs fed these diets. The estimates of endogenous AEE loss in pigs fed diets containing high oil corn, DDGS, or corn germ also had greater variation than the estimates for pigs fed corn oil or full-fat soybeans. The ATTD of AEE in DDGS in this study ranged from 51.3 to 60.6%. However, the ATTD of ether extract in DDGS has ranged from 66.7 to 77.1% in a previous report (Stein et al., 2009).

Extracted corn oil had a greater TID of AEE compared with oil in high-oil corn, which is in agreement with previous research (Adams and Jensen, 1984; Agunbiade et al., 1992; Kil et al., 2007). This may be attributed to insufficient digestive capacity of pigs to liberate all oil from the intact forms of oil, because some of the oil may be trapped in fiber compounds in the ingredients. The TID of AEE in extracted corn oil that was measured in the present experiment is comparable to the TID recently reported for extracted corn oil (Kil et al., 2007).

The TID of AEE in high-oil corn was not different from that in corn germ. The germ contains over 90% of the total amount of oil in corn. Thus, the similar digestibility values for AEE in high-oil corn and corn germ were expected. The relatively low TID of AEE in corn germ explains why the total DE in corn germ is not greater than in corn despite the high concentration of oil in corn germ (Widmer et al., 2007). The TID of AEE in DDGS was numerically greater than in high-oil corn and corn germ. This may be attributed to the fermentation in the ethanol production process, which may have liberated some of the oil or made it slightly more digestible. The TID of AEE in HP DDG was greater than in high-oil corn and corn germ. Because HP DDG is produced from fermentation of endosperm, which is left after removal of bran and germ from the corn grain (Widmer et al., 2007), most of the fat in HP DDG is from the fermentation process and, thus, is more digestible than the intact corn oil in high-oil corn and corn germ.

In conclusion, the AEE in extracted corn oil is more digestible than in intact forms of oil sources, and the AEE in HP DDG is more digestible than in high-oil corn, DDGS, or corn germ. However, the digestibility of AEE in high oil corn, corn germ, and DDGS is relatively low.

The present experiment provides for the first time estimates of the TID and TTTD of AEE in distillers co-products.

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X. Tables

Table 1. Ingredient composition of experimental diets, as-fed basis

Oil source:		Corn oil			High-oil corn			DDGS[1]			Corn germ			HP DDG[1]			Full-fat soybeans		
Added oil, level:	-	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Ingredient, %																			
Corn starch	56.00	54.00	52.00	50.00	37.71	18.60	2.00	38.53	31.57	23.80	40.46	34.08	27.43	43.08	37.95	28.62	51.22	45.48	39.73
Casein	11.50	11.50	11.50	11.50	9.80	8.70	4.50	9.00	5.20	2.10	10.60	9.90	9.40	4.90	-	-	8.30	5.80	3.30
Sucrose	10.00	10.00	10.00	10.00	10.00	10.00	10.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	10.00	10.00	10.00
Corn bran	19.60	19.60	19.60	19.60	15.75	11.90	8.10	13.10	6.60	0.13	15.65	11.70	7.80	13.05	6.50	-	18.45	17.35	16.25
Corn oil	-	2.00	4.00	6.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
High-oil corn	-	-	-	-	24.00	48.00	72.00	-	-	-	-	-	-	-	-	-	-	-	-
DDGS	-	-	-	-	-	-	-	17.00	34.00	51.00	-	-	-	-	-	-	-	-	-
Corn germ	-	-	-	-	-	-	-	-	-	-	11.00	22.00	33.00	-	-	-	-	-	-
HP DDG	-	-	-	-	-	-	-	-	-	-	-	-	-	16.00	32.00	48.00	-	-	-
Full-fat soybeans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.34	18.68	28.02

L-Lys·HCl	-	-	-	-	-	-	0.29	-	0.13	0.32	-	-	-	0.22	0.54	0.40	-	-	-
L-Thr	-	-	-	-	-	-	0.10	-	0.02	0.04	-	-	-	0.05	0.06	-	-	-	-
L-Trp	-	-	-	-	-	-	0.04	-	0.03	0.04	-	-	-	0.04	0.07	0.05	-	-	-
Dicalcium phosphate	0.48	0.48	0.48	0.48	0.52	0.54	0.68	0.15	0.00	-	0.08	-	-	0.69	0.82	0.74	0.56	0.60	0.65
Ground limestone	0.70	0.70	0.70	0.70	0.75	0.79	0.82	1.00	1.23	1.35	0.99	1.10	1.15	0.75	0.84	0.97	0.66	0.62	0.58
Potassium carbonate	0.40	0.40	0.40	0.40	0.20	0.20	0.20	-	-	-	-	-	-	-	-	-	0.20	0.20	0.20
Magnesium oxide	0.10	0.10	0.10	0.10	0.05	0.05	0.05	-	-	-	-	-	-	-	-	-	0.05	0.05	0.05
Chromic oxide	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Salt	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Vitamin-mineral premix[2]	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Santoquin[3]	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

[1]DDGS = distillers dried grains with solubles; HP DDG = high-protein distillers dried grains.

[2]Supplied per kg of complete diet: vitamin A, 11,128 IU; vitamin D_3, 2,204 IU; vitamin E, 66 IU; vitamin K, 1.42 mg; thiamin, 0.24 mg; riboflavin, 6.58 mg; pyridoxine, 0.24 mg; vitamin B_{12}, 0.03 mg; D-pantothenic acid, 23.5 mg; niacin, 44

mg; folic acid, 1.58 mg; biotin, 0.44 mg; Cu, 10 mg as copper sulfate; Fe, 125 mg as iron sulfate; I, 1.26 mg as potassium iodate; Mn, 60 mg as manganese sulfate; Se, 0.3 mg as sodium selenite; and Zn, 100 mg as zinc oxide.

[3]Supplied 130 mg of ethoxyquin per kg of complete diet.

Table 2. Analyzed nutrient composition of experimental diets, as-fed basis

Oil source:		Corn oil			High-oil corn			DDGS[1]			Corn germ			HP DDG[1]			Full-fat soybeans		
Added oil, level:	-	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Composition[2]																			
DM, %	91.0	91.0	91.4	91.0	90.0	89.2	89.6	92.0	91.8	91.7	91.7	92.1	92.0	92.5	93.0	93.4	91.4	91.8	92.1
AEE,[2] %	1.32	4.26	6.45	7.39	2.80	3.61	5.58	3.37	4.71	6.48	3.28	5.14	6.19	3.10	4.09	5.27	3.38	5.60	7.88
AEE, % of DM	1.46	4.68	7.06	8.12	3.11	4.04	6.23	3.67	5.13	7.06	3.58	5.57	6.72	3.35	4.40	5.64	3.70	6.10	8.56
GE, kcal/kg	3,868	3,967	4,106	4,180	3,908	4,013	3,993	3,999	4,056	4,173	3,992	4,072	4,164	3,973	4,034	4,229	3,970	4,101	4,245
NDF, %	15.83	14.55	13.82	12.29	19.11	15.23	14.78	16.27	20.14	21.44	15.24	15.20	15.90	15.39	19.88	21.53	14.64	14.67	14.80
ADF, %	3.76	3.13	3.24	3.25	3.37	3.56	3.56	4.36	5.86	6.32	3.80	3.88	4.51	4.74	5.87	6.56	3.90	4.11	4.34

[1]DDGS = distillers dried grains with solubles; HP DDG = high-protein distillers dried grains.

[2]AEE = acid hydrolyzed ether extract.

Table 3. Apparent ileal digestibilty (AID) and apparent total tract digestibility (ATTD) of acid hydrolyzed ether extract (AEE) in corn oil, high-oil corn, distillers dried grains with solubles, high-protein distillers dried grains, and full-fat soybeans fed to growing pigs[1]

		Added oil				*P*-value	
Item	Basal	Level 1	Level 2	Level 3	SEM	Linear	Quadratic
Corn oil							
AEE ileal output, g/kg DMI	7.1	7.9	9.3	10.0	1.01	0.021	0.567
AEE ileal digested, g/kg DMI	7.5	38.9	61.3	71.2	1.01	< 0.001	0.598
AID of AEE, %	51.5	83.2	86.8	87.7	3.08	< 0.001	< 0.001
AEE fecal output, g/kg DMI	7.4	9.7	8.6	12.3	1.54	0.059	0.705
AEE total tract digested, g/kg DMI	7.2	37.1	62.0	68.9	1.54	< 0.001	0.727
ATTD of AEE, %	49.3	79.3	87.8	84.9	3.54	< 0.001	0.001
High-oil corn							
AEE ileal output, g/kg DMI	7.1	16.6	23.8	29.8	1.83	< 0.001	0.074
AEE ileal digested, g/kg DMI	7.5	14.5	16.7	32.4	1.83	< 0.001	0.088
AID of AEE, %	51.5	46.6	41.2	52.1	4.59	0.939	0.072
AEE fecal output, g/kg DMI	7.4	17.7	26.7	35.4	1.46	< 0.001	0.068
AEE total tract digested, g/kg DMI	7.2	13.4	13.8	26.9	1.46	< 0.001	0.085
ATTD of AEE, %	49.3	43.1	34.1	43.2	3.99	0.200	0.034
Distillers dried grains with solubles							
AEE ileal output, g/kg DMI	7.1	14.9	20.7	28.2	1.71	< 0.001	0.774

AEE ileal digested, g/kg DMI	7.5	21.8	30.6	42.4	1.71	< 0.001	0.851
AID of AEE, %	51.5	59.5	59.7	60.1	3.95	0.100	0.309
AEE fecal output, g/kg DMI	7.4	14.4	25.0	33.2	1.36	< 0.001	0.248
AEE total tract digested, g/kg DMI	7.2	22.2	26.3	37.4	1.36	< 0.001	0.301
ATTD of AEE, %	49.3	60.6	51.3	53.0	3.37	0.721	0.097
Corn germ							
AEE ileal output, g/kg DMI	7.1	18.7	22.5	35.7	2.05	< 0.001	0.258
AEE ileal digested, g/kg DMI	7.5	17.1	33.2	31.6	2.05	< 0.001	0.265
AID of AEE, %	51.5	47.9	59.6	47.0	5.16	0.918	0.606
AEE fecal output, g/kg DMI	7.4	18.2	29.3	37.0	1.50	< 0.001	0.387
AEE total tract digested, g/kg DMI	7.2	17.6	26.4	30.2	1.50	< 0.001	0.399
ATTD of AEE, %	49.3	49.1	47.4	44.9	4.18	0.417	0.676
High-protein distillers dried grains							
AEE ileal output, g/kg DMI	7.1	11.5	17.1	16.3	1.05	< 0.001	0.112
AEE ileal digested, g/kg DMI	7.5	22.0	26.9	40.1	1.05	< 0.001	0.135
AID of AEE, %	51.5	65.7	61.1	71.1	3.52	0.001	0.658
AEE fecal output, g/kg DMI	7.4	11.6	16.0	19.5	0.98	< 0.001	0.470
AEE total tract digested, g/kg DMI	7.2	21.8	28.0	36.9	0.98	< 0.001	0.409
ATTD of AEE, %	49.3	65.2	63.5	65.3	3.28	0.001	0.047
Full-fat soybeans							
AEE ileal output, g/kg DMI	7.1	11.2	11.7	18.5	1.30	< 0.001	0.337
AEE ileal digested, g/kg DMI	7.5	25.8	49.2	67.1	1.30	< 0.001	0.275

AID of AEE, %	51.5	69.7	80.8	78.4	3.51	< 0.001	0.003
AEE fecal output, g/kg DMI	7.4	13.0	16.9	22.2	1.03	< 0.001	0.715
AEE total tract digested, g/kg DMI	7.2	24.0	44.1	63.3	1.03	< 0.001	0.846
ATTD of AEE, %	49.3	64.9	72.3	74.0	3.20	< 0.001	0.019

[1]Each least squares mean represents 11 observations.

Table 4. Endogenous loss and the true digestibility of acid hydrolyzed ether extract (AEE) in corn oil, high-oil corn, distillers dried grains with solubles (DDGS), high-protein distillers dried grains (HP DDG), and full-fat soybeans fed to growing pigs

				Endogenous AEE loss, g/kg DMI			True digestibility of AEE, %		
Item	n	Regression equation[1]	r^2	Estimate	SE	*P*-value	Estimate	SE	*P*-value
Ileal basis									
Corn oil	37	y = –6.11 + 0.954x	0.988	6.11	1.085	< 0.001	95.4[a]	1.76	< 0.001
High-oil corn	33	y = –1.77 + 0.530x	0.787	1.77	2.120	0.411	53.0[d]	4.96	< 0.001
DDGS	37	y = –1.27 + 0.621x	0.893	1.27	1.836	0.492	62.1[cd]	3.63	< 0.001
Corn germ	30	y = 0.29 + 0.501x	0.775	-0.29	2.429	0.907	50.1[d]	5.11	< 0.001
HP DDG	33	y = –4.20 + 0.765x	0.940	4.20	1.480	0.008	76.5[bc]	3.48	< 0.001
Full-fat soybeans	33	y = –4.85 + 0.852x	0.977	4.85	1.368	0.001	85.2[b]	2.38	< 0.001
Total tract basis									
Corn oil	37	y = –6.51 + 0.943x	0.970	6.51	1.725	< 0.001	94.3[a]	2.80	< 0.001
High-oil corn	33	y = 0.11 + 0.414x	0.771	-0.11	1.732	0.948	41.4[c]	4.05	< 0.001
DDGS	37	y = 0.87 + 0.519x	0.887	-0.87	1.587	0.589	51.9[c]	3.14	< 0.001

Corn germ	30	y = 1.33 + 0.439x	0.863	-1.33	1.572	0.407	43.9^{c}	3.31	< 0.001
HP DDG	33	y = –2.62 + 0.702x	0.951	2.62	1.222	0.040	70.2^{b}	2.87	< 0.001
Full-fat soybeans	33	y = –4.85 + 0.797x	0.985	4.85	1.020	< 0.001	79.7^{b}	1.77	< 0.001

20 [a,b,c,d]Means within a column and site of collection lacking a common superscript letter are different ($P < 0.05$).