Comparison of two diet types in the determination of metabolizable energy content of corn distillers dried grains with solubles for broiler chickens by the regression method[1]

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ABSTRACT The objective of this study was to compare 2 diet types, practical and semi-purified, in the determination of ME and ME_n contents of corn distillers dried grains with solubles (CDDGS) for broiler chickens by the regression method. Two hundred eighty-eight 14-d-old Ross 308 broiler chickens were assigned to 6 diets consisting of 2 factors in a 2 × 3 factorial arrangement: diet type (practical corn-soybean meal or semi-purified nitrogen-free diet) and CDDGS (0, 300, or 600 g/kg). The birds were fed for 7 d, and there were 6 birds per cage and 8 replicate cages per diet in a randomized complete block design. The CDDGS sample used in the present experiment contained (by analysis) 895 g/kg of DM, 4.811 kcal/g of gross energy, 265.7 g/kg of CP, 107.6 g/kg of crude fat, 61.3 g/kg of crude fiber, and 41.8 g/kg of ash. There was the expected interaction ($P < 0.001$) between diet type and CDDGS level in nitrogen retention response of the birds with a decrease as CDDGS level in the practical diet increased but an increase in the semi-purified diet. There were interactions ($P < 0.001$) between diet type and CDDGS level in energy retention response, ME, and ME_n. Energy retention linearly decreased ($P < 0.0001$) from 78.6 to 58.6% as CDDGS increased from 0 to 600 g/kg in the practical diets, whereas the decrease was from 86.8 to 75.4% in the semi-purified diet. The ME and ME_n (kcal/g) contents of the diets linearly decreased ($P < 0.0001$) from 3.615 and 3.414 to 2.753 and 2.642, respectively, as CDDGS increased from 0 to 600 g/kg in the practical diets. Corresponding linear decrease ($P < 0.0001$) values for semi-purified diets were 3.210 and 3.227 to 2.732 and 2.697, respectively. Regression of CDDGS-associated ME intake in kilocalories against grams of CDDGS intake generated the following equations for practical and semi-purified diets respectively: $Y = 2.904X + 52$, $r^2 = 0.987$ and $Y = 3.013X + 67$, $r^2 = 0.983$. The regression equations for CDDGS-associated ME_n intake in kilocalories against grams of CDDGS intake were $Y = 2.787X + 46$, $r^2 = 0.989$ and $Y = 2.963X + 66$, $r^2 = 0.983$ for practical and semi-purified diets, respectively. Comparison using ANOVA procedures indicated the slope for semi-purified diet type was greater ($P < 0.05$) than that for the practical diet type. These data indicate that the respective ME and ME_n values (kcal/g) of the CDDGS sample evaluated were 3.013 and 2.963 when semi-purified nitrogen-free diet was used as the basal diet; and 2.904 and 2.787 when practical corn-soybean meal diet was used as the basal diet. These differences imply that broiler chicken nutritionists should exercise due caution regarding the source of data for ME values of CDDGS when formulating diets containing CDDGS.

Key words: broiler chick, corn distillers dried grains with solubles, metabolizable energy, practical diet, semi-purified diet

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INTRODUCTION

A co-product of the dry grind processing of corn for ethanol production is corn distillers dried grains with solubles (**CDDGS**). During dry-grind ethanol processing, CDDGS is obtained by drying 2 product streams, namely the wet distillers grains and the condensed distillers solubles, in a ratio that varies from plant to plant. Because ethanol production in the United States is increasing and corn is currently the primary feedstock used in the dry-grind process, the quantity of CDDGS available for use in livestock diets will increase. In view of the potential of using CDDGS in diets, and because CDDGS is a potential source of energy, protein, and phosphorus, it is important to determine the energy and nutrients available in this co-product for broiler

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Table 1. Ingredient composition of starter diet fed from d 0 to 14

Item	
Ingredient, g/kg	
Corn	548.5
Soybean meal	360
Soybean oil	50
Dicalcium phosphate	20
Limestone (38% Ca)	12
NaCl	4
Vitamin-mineral premix[1]	3
DL-Methionine	2.5
Total	1,000
Calculated nutrient content	
Protein, g/kg	221.2
ME, kcal/kg	3,202
Ca, g/kg	9.6
P, g/kg	7.5
Ca:P	1.3
Nonphytate P, g/kg	4.9
Total indispensable amino acids, g/kg	
Arginine	14.6
Histidine	5.9
Isoleucine	9.2
Leucine	18.9
Lysine	12.1
Methionine	5.9
Methionine + cysteine	9.5
Phenyalanine	10.5
Phenylalanine + tyrosine	19.2
Threonine	8.3
Tryptophan	3
Valine	10.2

[1]Supplied the following per kilogram of diet: vitamin A, 5,484 IU; vitamin D_3, 2,643 ICU; vitamin E, 11 IU; menadione sodium bisulfite, 4.38 mg; riboflavin, 5.49 mg; D-pantothenic acid, 11 mg; niacin, 44.1 mg; choline chloride, 771 mg; vitamin B_{12}, 13.2 µg; biotin, 55.2 µg; thiamine mononitrate, 2.2 mg; folic acid, 990 µg; pyridoxine hydrochloride, 3.3 mg; I, 1.11 mg; Mn, 66.06 mg; Cu, 4.44 mg; Fe, 44.1 mg; Zn, 44.1 mg; Se, 300 µg.

chickens. However, energy and nutrient utilization must be known to fully evaluate the significance of energy and nutrient concentration because energy and nutrient utilization measurements depend upon the changes in amounts between feed and excreta in poultry.

Using the rooster assay, TME of several CDDGS samples have been reported to be between 2.484 and 3.234 kcal/g [Lumpkins et al., 2004 (cecectomized rooster); Fastinger et al., 2006 (cecectomized rooster); Kim et al., 2008 (intact rooster)]. There are no reports in which the ME of CDDGS has been determined in broiler chickens. Such determination of ME require the difference method that uses a substitution approach in which CDDGS is substituted for the energy-yielding ingredients in a basal diet. In this regard, the diet may be a practical diet or a semi-purified diet, which is more commonly used in amino acid utilization assay. Information on whether practical and semi-purified diets provide similar estimates of ME value is essential so energy and amino acid utilization assays could be efficiently performed in the same experiment. The current experiment was conducted with the intent of contributing to the sparse pool of knowledge related to the energy value of CDDGS for broiler chickens. The objective of this study was to compare 2 diet types (practical and semi-purified diet) in the determination of ME content of CDDGS for broiler chickens by the regression method.

MATERIALS AND METHODS

Birds and Diets

Male broiler chicks (Ross 308) were obtained from a local hatchery, tagged with identification numbers, and fed a standard broiler starter diet (Table 1) from d 0 to 14 posthatch. The birds were reared in electrically heated battery brooders maintained at temperatures of 35°C from d 1 to 7 posthatch and 32°C from d 8 to 14 posthatch. On d 14, the birds were weighed individually, 288 birds were sorted by BW, and assigned to 8 cages per diet with 6 birds per cage in such a way that the average initial weight was similar across diets. Cages were divided into 8 blocks of 6 diets and diets were randomly assigned to cages within each block. Birds were provided ad libitum access to water and dietary treatments from d 14 to 21, and battery cage temperature was maintained at 27°C. Bird management and handling procedures used in this study were approved by the Purdue University Animal Care and Use Committee.

The chemical characteristics of the CDDGS used in this experiment are presented in Table 2. Experimental treatments consisted of 2 factors including diet type at 2 levels (a practical corn-soybean meal diet or a semi-purified nitrogen-free diet) and CDDGS at 3 levels (0, 300, or 600 g/kg) in a 2 × 3 factorial arrangement. Corn, soybean meal, and soy oil were replaced by CDDGS in such a way as to maintain the same ratio of corn, soybean meal, and soy oil across the practical experimental diets. In the semi-purified diet, CDDGS replaced the dextrose, corn starch, soy oil, and Solka Floc (a purified functional cellulose, International Fiber Corp., North Tonawanda, NY) in such a way as to maintain the same ratio across the 3 semi-purified experimental diets. This substitution method is important due to energy contribution of basal ingredients and CDDGS to the experimental assay diets when using regression method in the determination of ME. Ingredient composition of the 6 diets is shown in Table 3.

Chemical Analysis

Samples of excreta and diets were analyzed for gross energy to determine the ME. Samples were dried at 105°C in a drying oven (Precision Scientific Co., Chicago, IL) for 24 h for DM determination. Gross energy was determined in bomb calorimeter (Parr 1261 bomb calorimeter, Parr Instruments Co., Moline, IL) using benzoic acid as a calibration standard. Chromium concentration in the diets and excreta samples was determined using the method of Fenton and Fenton (1979). Nitrogen was determined using combustion method (Leco FP analyzer Model 602600, Leco Corp.,

Table 2. Characteristics (analyzed) of the corn distillers grains with solubles used in the study[1]

Item	
DM, g/kg	894.8
Gross energy, kcal/g	4.811
CP (N × 6.25), g/kg	265.7
Crude fat, g/kg	107.6
Crude fiber, g/kg	61.3
Neutral detergent fiber, g/kg	253
Acid detergent fiber, g/kg	99
Ash, g/kg	41.8
Calcium, g/kg	0.3
Phosphorus, g/kg	6.3
Indispensable amino acid, g/kg	
Arginine	11.2
Histidine	7.0
Isoleucine	9.8
Leucine	30.7
Lysine	7.5
Methionine	5.3
Phenylalanine	13.0
Threonine	10.3
Tryptophan	2.0
Valine	13.1
Dispensable amino acid, g/kg	
Alanine	18.8
Aspartate	17.7
Cysteine	5.1
Glutamate	42.3
Glycine	9.9
Proline	20.2
Serine	11.4
Tyrosine	9.8

[1]Values presented are from 1 replicate analysis for amino acids and means of duplicate analyses for the other nutrients.

St. Joseph, MI) using EDTA as a calibration standard. Dry matter, gross energy, and nitrogen in CDDGS were determined as described above. Proximate analyses [AOAC Official Methods 990.03 (for nitrogen); 942.05 (for ash); 920.39 (for crude fat); 978.10 (for crude fiber); 934.01 (for moisture)]; neutral detergent fiber, acid detergent fiber [AOAC Official Method 973.18 (A-D)], Ca, P [AOAC Official Method 985.01 (A, B, D)], and amino acid [AOAC Official Method 982.30 E (a,b,c)] analyses (AOAC International, 2000) of the CDDGS were conducted at the University of Missouri Experiment Station Chemical Laboratories, Columbia.

Calculations

Metabolizable energy coefficient (**MEc**) was calculated as follows:

$$\text{MEc} = 1 - [(\text{Cd}/\text{Ce}) \times (\text{Ee}/\text{Ed})],$$

where Cd is the concentration of chromium in the diet; Ce is the concentration of chromium in the excreta; Ee is the concentration of energy in the excreta; and Ed is the concentration of energy in the feed.

The ME (kcal/g) of the diet was calculated as the product of MEc and the gross energy (kcal/g) concentration of the diet. The energy-yielding ingredients contributed 959 and 925 g/kg of diet to the gross energy concentration of the practical and semi-purified diets,

Table 3. Ingredient composition of experimental diets

	Dietary corn distillers grains with solubles (CDDGS), g/kg					
	Practical diets			Semi-purified diets		
Item	0	300	600	0	300	600
Ingredient, g/kg						
Corn	523.5	355.3	187.0	0.0	0.0	0.0
Soybean meal	360.0	244.3	128.6	0.0	0.0	0.0
Soybean oil	50.0	33.9	17.9	50.0	33.3	16.7
Dicalcium phosphate	20.0	20.0	20.0	20.0	20.0	20.0
Limestone	12.0	12.0	12.0	12.0	12.0	12.0
NaCl	4.0	4.0	4.0	4.0	4.0	4.0
Chromium oxide premix[1]	25.0	25.0	25.0	25.0	25.0	25.0
Vitamin-mineral premix[2]	3.0	3.0	3.0	5.0	5.0	5.0
DL-Methionine	2.5	2.5	2.5	0.0	0.0	0.0
Corn starch	0.0	0.0	0.0	200.0	133.3	66.7
Dextrose	0.0	0.0	0.0	600.0	400.0	200.0
Solka Floc[3]	0.0	0.0	0.0	50.0	33.3	16.7
$NaHCO_3$	0.0	0.0	0.0	20.0	20.0	20.0
K_2HPO_4	0.0	0.0	0.0	12.0	12.0	12.0
MgO	0.0	0.0	0.0	2.0	2.0	2.0
CDDGS	0.0	300.0	600.0	0.0	300.0	600.0
Total	1,000.0	1,000.0	1,000.0	1,000.0	1,000.0	1,000.0
Analyzed composition[4]						
DM, g/kg	916.4	960.4	951.3	928.6	950.7	952.4
Gross energy, kcal/g	4.599	4.576	4.701	3.698	4.198	4.410
CP (N × 6.25), g/kg	215.0	230.1	238.9	2.4	95.6	154.5

[1]Prepared as 1 g of chromic oxide mixed with 4 g of corn starch.

[2]Supplied the following per kilogram of diet: vitamin A, 5,484 IU; vitamin D_3, 2,643 ICU; vitamin E, 11 IU; menadione sodium bisulfite, 4.38 mg; riboflavin, 5.49 mg; D-pantothenic acid, 11 mg; niacin, 44.1 mg; choline chloride, 771 mg; vitamin B_{12}, 13.2 μg; biotin, 55.2 μg; thiamine mononitrate, 2.2 mg; folic acid, 990 μg; pyridoxine hydrochloride, 3.3 mg; I, 1.11 mg; Mn, 66.06 mg; Cu, 4.44 mg; Fe, 44.1 mg; Zn, 44.1 mg; Se, 300 μg.

[3]Solka Floc, International Fiber Corp., North Tonawanda, NY.

[4]Values are means of duplicate analyses.

respectively. Energy was corrected for nonenergy-yielding ingredients, and substitution rate was corrected for the energy contributions of basal ingredients and CDDGS to the total dietary energy. The product of CDDGS energy contribution-corrected substitution rate and dietary ME content is the CDDGS-associated ME intake. Because catabolic compounds in excreted nitrogen can contribute to energy loss, ME was corrected to zero nitrogen retention using a factor of 8.22 kcal/g (Hill and Anderson, 1958).

Statistical Analysis

Energy, nitrogen, and DM utilization data were analyzed as a 2 × 3 factorial of diet type (practical corn-soybean meal or semi-purified diet) and CDDGS (0, 300, or 600 g/kg) in a randomized complete block design using the general linear model procedures of SAS (2006). The CDDGS-associated ME or ME_n intake in kilocalories was regressed against grams of CDDGS intake for cage of birds, and the solutions option was used to generate the intercept and slope using the general linear models procedures of SAS (2006). Because there were 3 cages of 0, 300, or 600 g of CDDGS substitution/kg in each block and 8 blocks per diet type (practical or semi-purified diet), ME or ME_n intake in kilocalories was regressed against grams of CDDGS intake for each block to generate intercepts and slopes for each of the 8 blocks per diet type. The intercept and slope data were analyzed as a one-way ANOVA in a completely randomized design using intercept or slope as the dependent variable and diet type as the independent variable with 1 df for diet type and 14 df for the error term. In this analysis, a block of 3 cages served as the experimental unit. Statistical significance was determined at an α level of 0.05.

RESULTS

The CDDGS used in the current study contained 4.811 kcal of gross energy/g and 265.7 g of CP/kg (Table 2). There were interactions ($P < 0.001$) between diet type and CDDGS level in DM, nitrogen, and energy retention responses, as well as in ME and ME_n (Table 4). There were linear ($P < 0.0001$) and quadratic ($P < 0.05$) decreases in DM retention from 73.16 to 50.29% as CDDGS increased from 0 to 600 g/kg in the practical diets, whereas for birds fed the semi-purified diets, there was a linear decrease ($P < 0.0001$) from 84.21 to 53.28% as CDDGS increased from 0 to 600 g/kg. Nitrogen retention expressed as a percentage of nitrogen intake or DM intake increased ($P <$ 0.0001) as CDDGS substitution into the semi-purified diet increased from 0 to 600 g/kg, whereas there was a decrease in these response criteria for birds fed the practical diets (Table 4). As CDDGS substitution into the semi-purified diets increased from 0 to 600 g/kg, there was a linear decrease ($P < 0.0001$) in energy retention for birds fed the semi-purified diets. The retention of energy linearly decreased ($P < 0.0001$) from 78.61 to 58.57% as CDDGS increased from 0 to 600 g/kg in the practical diets. As observed for DM retention, birds fed the semi-purified diet retained more of the dietary energy than those fed the practical diet. There was a linear decrease ($P < 0.0001$) in dietary ME from 3.615 to 2.753 kcal/g as CDDGS substitution into the practical diet increased from 0 to 600 g/kg. Likewise, dietary ME_n linearly decreased ($P < 0.0001$) from 3.414 to 2.642 kcal/g as CDDGS substitution into the practical diet increased from 0 to 600 g/kg. For birds fed the semi-purified diets, there were linear and quadratic ($P < 0.0001$) decreases in dietary ME and ME_n from 3.210 and 3.227 to 2.732 and 2.687 kcal/g, respectively, as CDDGS substitution into diets increased from 0 to 600 g/kg (Table 4). The increase from 3.210 to 3.227 kcal/g when ME was corrected for nitrogen retention in the semi-purified diet resulted from the birds being in a negative nitrogen balance.

The regression of ME intake associated with CDDGS intake against the intake of CDDGS of birds fed practical corn-soybean meal diets and semi-purified diet diets is depicted in Figure 1. Regression equation for the practical diet was $Y = 52 + 2.904X$, $r^2 = 0.987$, which connotes a ME value of 2.904 kcal/g for the CDDGS. For the semi-purified diets, the regression equation was $Y = 67 + 3.013X$, $r^2 = 0.983$, which signifies a ME value of 3.013 kcal/g. Figure 2 describes the regression of ME_n intake associated with CDDGS intake against the intake of CDDGS of birds fed practical corn-soybean meal diets or semi-purified diets. Regression equation for the practical diet was $Y = 46 + 2.787X$, $r^2 = 0.989$, which indicates a ME_n value of 2.787 kcal/g. The regression equation was $Y = 66 + 2.963X$, $r^2 = 0.983$ for the semi-purified diets, which implies a ME_n value of 2.963 kcal/g for the CDDGS sample used in the current study.

The intercepts for both ME and ME_n regressions were greater ($P < 0.01$) for the semi-purified than for the practical diets (Table 5). Likewise, the slopes were greater ($P < 0.01$) for the semi-purified diets than for the practical diets. The implication of this is that ME and ME_n values determined using semi-purified diets are greater than those determined using practical diets.

DISCUSSION

The current experiment was conducted to contribute to the sparse pool of knowledge on the ME value of CDDGS for broiler chickens and compare 2 diet types (practical and semi-purified diet) in the determination of ME content of CDDGS for broiler chickens by the regression method. We used a CDDGS that contained 4.811 kcal of gross energy/g and 265.7 g of CP/kg, which can be considered typical because the gross energy and CP content are within the range of 4.705 to 4.984 kcal of gross energy/g and 246 to 291 g of CP/kg reported by Stein et al. (2006). Because the study was designed to determine the ME content of DDGS using the regression method, incorporation of DDGS at a relatively high level into diets is essential for generating a reliable energy value. Thus, during the relatively short period of feeding the experimental diets to attain the objective of determining the ME value of DDGS, we expected that diets containing 60% DDGS would depress growth performance and energy and nutrient utilization of birds.

The birds retained 73% of the DM in the practical corn-soybean meal diet that contained no CDDGS. Using 21-d-old birds, Onyango et al. (2004, 2005) reported 72 and 75% DM retention in birds fed a corn-soybean meal diet that is similar to that fed in the current study. In another study, Adedokun et al. (2004) observed a 74% DM retention in 21-d-old birds. The 65% nitrogen retention of birds fed the practical corn-soybean meal diet is similar to previous observations of 66, 64, and 65% (Fernández-Fígares et al., 2002; Adedokun et al., 2004; Onyango et al., 2005). Retention of energy was 79% of the energy intake of birds fed the practical corn-soybean meal diet. Similar energy retentions (79, 79, and 81%) have been observed for 21-d-old birds fed a corn-soybean meal diet (Adedokun et al., 2004; Onyango et al., 2004, 2005). Dry matter and energy retention in birds fed the nitrogen-free diet were 84 and 87%, respectively. We are not aware of published information related to retention of DM and energy by broiler chickens fed a nitrogen-free diet. In unpublished data from this lab, we have observed between 84 and 86% DM retention and between 85 and 90% energy retention in broiler chickens fed nitrogen-free diet. Observations in the current study are consistent with the notion that retention of DM and energy will be higher for a semi-purified nitrogen-free diet than that for a practical corn-soybean meal diet. As CDDGS substitution increased from 0 to 600 g/kg, DM retention decreased from 73 to 50% for the practical diets and from 84 to 53% for birds fed the semi-purified diets. Similarly, the retention of energy decreased from 79 to 59% for the practical diets and from 87 to 62% for

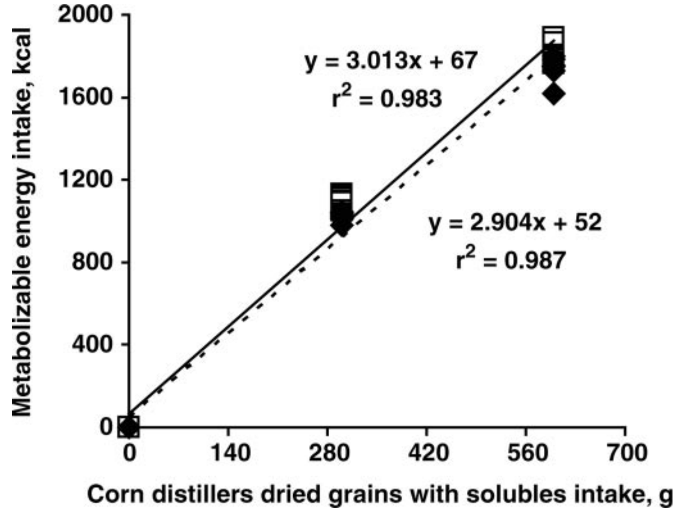

Figure 1. Regression of ME intake (Y, kcal) associated with corn distillers grains with solubles intake against the intake of corn distillers grains with solubles (X, g) of birds fed either semi-purified diets (open squares, solid line) or practical corn-soybean meal diets (solid diamonds, dashed line) from d 14 to 21 posthatch. Regression equations were $Y = 67 + 3.013X$, $r^2 = 0.983$ for semi-purified diets (open squares, solid line) and $Y = 52 + 2.904X$, $r^2 = 0.987$ for practical corn-soybean meal diets (solid diamonds, dashed line).

Table 4. Dry matter, energy, and nitrogen utilization of broilers fed the experimental diets containing corn distillers grains with solubles (CDDGS) levels at 0, 300, or 600 g/kg

	Practical diets			Semi-purified diets				*P*-value[2]						
Item	0	300	600	0	300	600	SEM[1]	Diet type	CDDGS level	Diet type × CDDGS level	L[3]	Q[3]	L[4]	Q[4]
DM retention, % of DMI	73.16	63.85	50.29	84.21	69.16	53.28	0.689	<0.0001	<0.0001	<0.0001	<0.0001	0.0164	<0.0001	0.6243
Nitrogen retention, % of nitrogen intake	65.15	51.12	33.60	−515.93	37.99	21.49	32.079	<0.0001	<0.0001	<0.0001	0.4914	0.965	<0.0001	<0.0001
Nitrogen retention, mg/g of DMI	24.46	19.59	13.50	−2.15	6.11	5.58	0.379	<0.0001	<0.0001	<0.0001	<0.0001	0.1964	<0.0001	<0.0001
Energy retention, % of energy intake	78.61	69.35	58.57	86.79	75.43	61.96	0.591	<0.0001	<0.0001	0.0012	<0.0001	0.2293	<0.0001	0.1545
ME, kcal/g of DM	3.615	3.173	2.753	3.210	3.166	2.732	0.0251	<0.0001	<0.0001	<0.0001	<0.0001	0.7272	<0.0001	<0.0001
ME_n, kcal/g of DM	3.414	3.012	2.642	3.227	3.116	2.687	0.0230	<0.0001	<0.0001	<0.0001	<0.0001	0.5777	<0.0001	<0.0001

[1]Values are means of 8 replicate cages with 6 birds per cage; DMI is DM intake.

[2]Probability values of the main effects of diet type and CDDGS, interaction of diet type and CDDGS level, and linear (L) and quadratic (Q) contrasts.

[3]Linear (L) and quadratic (Q) contrasts for the practical diets.

[4]Linear (L) and quadratic (Q) contrasts for the semi-purified diets.

the semi-purified diets as CDDGS increased from 0 to 600 g/kg. The respective 23 vs. 31 percentage point and 20 vs. 25 percentage point decrease in DM and energy retention suggest that CDDGS has a greater influence on utilization of these diet components in semi-purified diets than in the practical diets.

For the reason that energy utilization is affected by age, species, and protein quality of a feed, ME should be corrected for nitrogen retention that occurs during the assay period. This correction in the current study resulted in a between 4 and 6% reduction in ME content of the practical diets and a 4% decrease in the ME value of CDDGS when practical corn-soybean meal diet was used as the basal diet. In ME studies using cockerels, correction for nitrogen retention resulted in between 2 and 4% reduction in energy values (McNab and Blair, 1988). In duck studies, Adeola et al. (1997, 2007) and Hong et al. (2002) reported between 2 and 5%, 4 and 6%, and 7 and 10% reductions in energy values, respectively. Presumably, protein quality of these diets is contributory, in part, to the differences in nitrogen-corrected reductions in ME. Due to the negative nitrogen retention in birds fed the semi-purified nitrogen-free diet, correction of ME for nitrogen retention resulted in a 0.5% increase in ME of the diet. The negative nitrogen retention is the result of the diet lacking nitrogen, which predisposed the birds to catabolizing their body protein to meet needs for essential and nonessential nitrogen for the support of vital body functions and the resultant loss of excretion of unused nitrogen as uric acid in the excreta. Substitution of CDDGS into the diet at 300 or 600 g/kg resulted in positive nitrogen retention in the birds and a 1.6% reduction in energy value when corrected for nitrogen retention. Because diets with added CDDGS contained nitrogen that supplied part of the bird's need for protein, there was reduced catabolism of body protein, relative to the nitrogen-free diet, and hence a positive, albeit small, nitrogen retention.

The TME_n content of CDDGS from the beverage industry for poultry published by NRC (1994) is 3.097 kcal/g. Lumpkins et al. (2004) reported TME_n of 2.905 kcal/g of DDGS derived from the dry-grind ethanol extraction process. Nitrogen-corrected TME values of 2.48, 2.815, 2.994, 3.014, and 3.047 kcal/g for 5 samples of DDGS from the dry-grind ethanol industry were obtained in a study by Fastinger et al. (2006). Recently, Kim et al. (2008) reported TME of 3.266 kcal/g of DDGS, from the dry-grind ethanol extraction process, for birds. In the current study with broilers, the ME_n for CDDGS was 2.787 or 2.963 kcal/g for practical or semi-purified diets, respectively. Important distinctions between the current study and those cited above are the use of 14- to 21-d-old broiler chickens vs. roosters [cecectomized in Lumpkins et al. (2004) and Fastinger et al. (2006), but intact in Kim et al. (2008)], substitution of CDDGS into a basal diet vs. direct intubation of CDDGS into the crop of fasted roosters, and correction for endogenous energy loss. Thus, bird age and

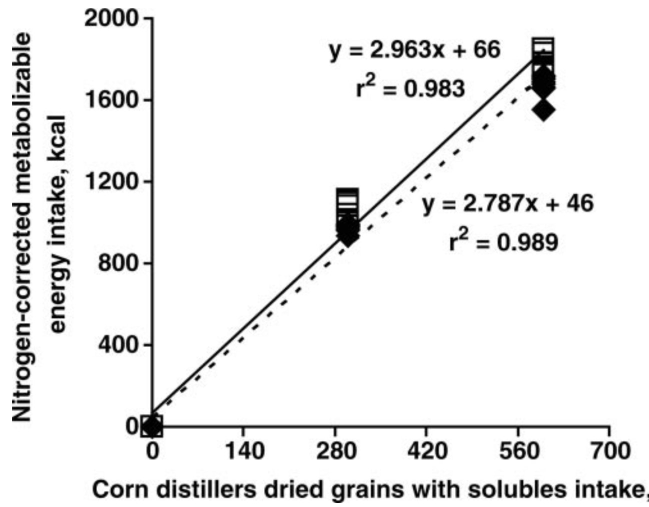

Figure 2. Regression of ME_n intake (Y, kcal) associated with corn distillers grains with solubles intake against the intake of corn distillers grains with solubles (X, g) of birds fed semi-purified diets (open squares, solid line) or practical corn-soybean meal diets (solid diamonds, dashed line) from d 14 to 21 posthatch. Regression equations were $Y = 66 + 2.963X$, $r^2 = 0.983$ for semi-purified diets (open squares, solid line) and $Y = 46 + 2.787X$, $r^2 = 0.989$ for practical corn-soybean meal diets (solid diamonds, dashed line).

assay method may perhaps contribute to the differences in ME values. The TME_n contents of corn for poultry published by NRC (1994), Ertl and Dale (1997), and Song et al. (2003) are 3.470, 3.523, and 3.524 kcal/g, respectively, which is higher than that of CDDGS. Considering that starch, the substrate for the dry-grind processing of corn to ethanol, is reduced from approximately 630 g/kg in the corn to 70 g/kg in the CDDGS and crude fiber is increased from 24 to 60 g/kg, corn is expected to have a higher ME than CDDGS.

The ME and ME_n values of the CDDGS sample evaluated when practical corn-soybean meal diet was used as the basal diet (2.904 and 2.787 kcal/g) were lower than those when semi-purified nitrogen-free diet was used as the basal diet (3.013 and 2.963 kcal/g). Presumably, the greater proportional utilization of dietary energy in the semi-purified diets contributed to associative effects that enhanced the utilization of energy in CDDGS. When the ME of a feed ingredient cannot be determined by feeding the ingredient as the only

Table 5. Comparison of diet types (practical and semi-purified) for intercepts and slopes of the regressions in the determination of ME and ME_n of corn distillers grains with solubles

Item	Intercept, kcal	Slope, kcal/g
ME		
Practical diets	51.63	2.904
Semi-purified diets	66.59	3.013
SEM	3.478	0.0305
P-value	0.008	0.0238
ME_n, kcal/g		
Practical diets	45.98	2.787
Semi-purified diets	65.80	2.963
SEM	3.204	0.0283
P-value	0.0006	0.0006

source of dietary energy, 2 or more diets consisting of a basal diet and one or more test diets in which the energy-yielding ingredients of the basal diet are substituted with the test ingredient must be used. Basal diets composed of practical feed ingredients are preferable to semi-purified diets. However, in situation where ileal amino acid digestibility is also of interest, the capability of using the same basal diet for concurrent determination of energy and amino acid utilization would be efficient and desirable. Thus, one of the objectives of this study was to compare practical and semi-purified diets in the determination of ME content of CDDGS for broiler chickens by the regression method. The experimental design we employed allowed the generation of ME for each block of 3 cages that used 0, 300, or 600 g of CDDGS substitution/kg for each practical or semi-purified diets. Metabolizable energy values from each of 8 blocks were subsequently compared by ANOVA procedures as described in the Materials and Methods section. A greater proportional utilization of dietary energy in the semi-purified diets contributed to associative effects that enhanced the utilization of energy in CDDGS and thus the greater ME value of CDDGS when assessed using semi-purified diets.

In summary, the ME value of CDDGS determined using the substitution method is affected by the basal diet used in the bioassay, being greater with a semi-purified nitrogen-free diet than with a practical corn-soybean meal diet. The ME of CDDGS was 3.013 kcal/g with semi-purified nitrogen-free diet as the basal diet and 2.904 kcal/g with practical corn-soybean meal diet as the basal diet. Nitrogen-corrected ME of CDDGS was 2.963 kcal/g with semi-purified nitrogen-free diet as the basal diet and 2.787 kcal/g with practical corn-soybean meal diet as the basal diet. The implication of the results of this research is that the assay diet affects the derived ME value of CDDGS, and therefore nutritionists should be cautious of the source of data for CDDGS ME values when formulating diets.

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