Evaluation of corn distillers dried grains with solubles as an alternative ingredient for broilers

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ABSTRACT The effects of graded levels of corn distillers dried grains with solubles (DDGS) were investigated as a partial replacement for sources of protein, energy, and other nutrients for broilers when the digestible amino acid balance was maintained. Zero, 8, 16, and 24% DDGS were incorporated into isonutritive diets at the expense of corn, soybean meal, and DL-Met. Poultry oil, L-Lys, and L-Thr additions increased with increasing levels of DDGS. Diets were each fed to 36 Cobb 500 straight-run broilers in 6 floor pens in 2 experiments. In experiment 1, broilers fed ≥8% DDGS showed increased BW gain compared with those fed the control diet during the 0- to 18-d starter period ($P = 0.0164$) but were almost identical in BW at 42 d ($P = 0.9395$). The only difference at 42 d was in the carcass fat composition of female broilers: percentage of fat pad decreased with increasing DDGS level ($P = 0.0133$). Corn DDGS reduced the pellet durability index. However, the pellet durability index was not related to growth or feed utilization. In experiment 2 at 42 d, broilers fed all levels of DDGS showed increased BW gain compared with those fed the control diet. Broilers may perform well when fed properly balanced feeds containing up to 24% DDGS despite reduced pellet quality.

Key words: corn distillers dried grains with solubles, broiler, pellet durability

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INTRODUCTION

Distillers dried grains with solubles (**DDGS**), whether from corn or other cereals, can be a good feed ingredient for all classes of poultry based on its nutrient profile. Estimates of how much corn DDGS can be effectively fed to poultry vary: Waldroup et al. (1981) concluded that 25% DDGS could be fed to broilers without harmful effects when supplementing their corn- and soybean meal (**SBM**)-based diets with only Met. In sharp contrast, Parsons et al. (1983) demonstrated that only 8% DDGS could be fed to broilers when Met and Lys were supplemented. Lumpkins et al. (2004) concluded that broiler starter diets should not contain more than 12% DDGS and that grower-finisher diets could contain 12 or 15% DDGS. However, their data also suggest that broilers perform well with 15% DDGS in the starter diet with adequate energy, and with 18% in the grower-finisher period. More recently, Wang et al. (2007) fed DDGS at 5% increments from 0 to 25% of the diet and concluded that good-quality DDGS could be used in broiler diets at levels of 15 to 20% with little adverse effect on live performance. However, it might result in some loss of dressing percentage or breast meat yield.

The inclusion of DDGS in corn- and SBM-based feeds is known to impair pellet quality (Behnke, 2007; Srinivasan et al., 2009). The objectives of this study were 1) to investigate the effects of graded levels of DDGS on broiler performance when the digestible amino acid (**AA**) balance was maintained by setting minima on 8 essential AA, and 2) to measure the pellet durability index of the feeds.

MATERIALS AND METHODS

Experiments 1 and 2 were conducted in a broiler house with space heaters and evaporative cooling. Target temperatures were 30, 29, 27, 26, 24, 23, and 21°C for d 0 to 3, d 4 to 6, d 7 to 12, d 13 to 15, d 16 to 22, d 23 to 35, and d 36 to 42, respectively. High and low temperatures were recorded daily and did not vary from targets by more than 2°C. Stirring fans maintained uniform temperatures within the room of 24 pens with separate heating and cooling systems. The broiler house was completely enclosed, and lighting was provided by fluorescent bulbs. Photoperiods were 23L:1D in both experiments.

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For each experiment, 864 male Cobb × Cobb 500 broiler chicks were randomly allocated, 36 per pen, to 24 floor pens (119 × 300 cm) covered with pine shavings. Each pen was considered a replicate. There were 4 dietary feeding regimens (treatments), with each regimen consisting of a starter diet from 0 to 18 d, a grower diet from 19 to 35 d, and a finisher diet from 36 to 42 d in experiment 1 and a starter diet from 0 to 18 d, a grower diet from 19 to 28 d, and a finisher diet from 29 to 35 d in experiment 2. The nutrient profile of the ingredients used in formulating the diets is shown in Table 1. The basal (0% DDGS) and summit (24% DDGS) diets (Table 2) were mixed and blended to form the diets with intermediate levels of DDGS (8 and 16% DDGS). Locally purchased ingredients were used for the diets. The DDGS used was supplied by Keystone Foods (Huntsville, AL). Diets were formulated on a digestible AA basis, to meet the levels in Table 3, by using coefficients for corn, SBM, and meat and bone meal from Ajinomoto Heartland LLC (2004). Amino acid digestibility coefficients for DDGS were based on values reported by Batal and Dale (2006) and Fiene et al. (2006). Starter diets were fed as crumbles, and grower and finisher diets were fed as 5-mm pellets. Feed and water were provided ad libitum. Feed and average pen weights were recorded at the beginning of the study and at the end of the starter, grower, and finisher phases for determination of BW gain and adjusted feed conversion ratio.

The durability of the pellets produced by a California pellet mill (1973, California Pellet Mill Co., Crawfordsville, IN) was determined according to American Society of Agricultural Engineers standard method S269.4 (American Society of Agricultural and Biological Engineers, 2007). The pellets were made at 65.6 to 68.3°C and cooled to room temperature (22°C) and approximately 500 g was used for each test. Prior to testing, the pellets were sieved using round-hole sieves with screen sizes of 4.0 and 4.8 mm corresponding to the pellets made using die diameters 4.8 and 5.2 mm, respectively. The pellets were tumbled inside a pellet durability tester for 10 min. The pellets were sieved after tumbling, and the pellet durability index was calculated as the ratio of the mass of pellets remaining on a sieve after tumbling to the initial mass before tumbling.

In both trials, birds were handled according to the University of Georgia Animal Use and Care Guidelines. In experiment 1 only, before placement on d 1, chicks were separated by sex. Six birds of each sex were randomly selected from each pen and tagged for processing. The first 4 tagged birds randomly caught on d 42 were processed on d 43. These birds were taken off feed approximately 12 h before slaughter and placed in pens with birds from all 4 treatments. Birds were cooped (water withdrawal) approximately 2 h before slaughter. The birds were stunned with 14 V, 60 Hz AC for 9 s by a commercial stunner (Simmons model SF-7001, Simons Engineering Co., Dallas, GA) and then killed by manually cutting the carotid artery and jugular vein on the side of the neck. After exsanguination, the birds were scalded at 54°C for 120 s and picked for 30 s. The scalder (Cantrell Model SS300CF, Cantrell Machine Co. Inc., Gainesville, GA), picker (Cantrell Model CPF-60, Cantrell Machine Co. Inc.), and eviscerator

Table 1. Nutritional composition of feed ingredients used for formulating the diets[1]

Item	AME_n	CP	Lys	dLys	Met	dMet	TSAA	dTSAA	Thr	dThr
Ingredient[2]	kcal/g	%								
Corn	3.37	7.5	0.26	0.21	0.17	0.15	0.37	0.31	0.32	0.26
SBM	2.46	48.3	3.06	2.73	0.66	0.60	1.45	1.25	1.92	1.66
DDGS	2.81	26.5	0.70	0.46	0.53	0.45	1.09	0.89	0.94	0.67
Meat and bone meal	1.98	44.7	2.14	1.78	0.61	0.53	0.93	0.70	1.47	1.20
Poultry fat	7.94									
L-Lys·HCl	3.99	94.4	78.80	78.80						
DL-Met	4.63	57.5			99.00	99.00	99.00	99.00		
L-Thr	3.48	72.4							98.50	98.50
Chemical analysis of DDGS[3]		27.56	0.85		0.50		0.99		1.00	

Item	Trp	dTrp	Ile	dIle	Val	dVal	Arg	dArg	Ca	aP
Ingredient[2]	%									
Corn	0.07	0.05	0.29	0.25	0.40	0.34	0.38	0.34	0.01	0.09
SBM	0.65	0.56	2.17	1.96	2.25	2.02	3.62	3.31	0.20	0.21
DDGS	0.21	0.17	0.95	0.76	1.27	1.02	1.05	0.87	0.10	0.49
Meat and bone meal	0.27	0.21	1.32	1.12	2.27	1.91	3.09	2.69	13.86	6.49
Poultry fat										
L-Lys·HCl										
DL-Met										
L-Thr										
Chemical analysis of DDGS[3]	0.22		0.97		1.30		1.25			

[1]d- = digestible amino acid contents; aP = available phosphorus. Digestible amino acid contents were calculated for DDGS based on values reported by Batal and Dale (2006) and Fiene et al. (2006).

[2]SBM = soybean meal; DDGS = distillers dried grains with solubles.

[3]Ajinomoto Heartland LLC (Chicago, IL).

Table 2. Ingredient composition and nutritive value (%) of basal diets

Item	Starter phase, d 0 to 18				Grower phase, d 19 to 35				Finisher phase, d 36 to 42			
Ingredient[1] (%)												
Corn	57.22	51.56	45.91	40.27	63.19	58.11	52.34	46.31	68.63	62.80	56.77	50.08
DDGS	0	8	16	24	0	8	16	24	0	8	16	24
SBM	34.87	32.21	29.56	26.90	28.07	24.90	22.33	20.02	22.50	19.97	17.64	15.90
Meat and bone meal[2]	0.00	0.00	0.00	0.00	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50
Poultry fat	3.48	3.85	4.23	4.60	2.76	3.03	3.42	3.86	3.00	3.40	3.84	4.40
L-Lys·HCl	0.17	0.20	0.29	0.35	0.17	0.24	0.30	0.35	0.19	0.25	0.30	0.33
DL-Met	0.28	0.26	0.23	0.21	0.26	0.24	0.22	0.20	0.24	0.22	0.19	0.16
L-Thr	0.09	0.10	0.10	0.11	0.07	0.08	0.09	0.09	0.07	0.07	0.07	0.06
Limestone	1.13	1.21	1.29	1.37	0.57	0.65	0.73	0.81	0.56	0.64	0.72	0.79
Defluorinated P	1.76	1.63	1.46	1.31	0.51	0.36	0.21	0.06	0.44	0.29	0.14	0.00
Sodium chloride	0.51	0.48	0.44	0.41	0.44	0.40	0.37	0.33	0.42	0.38	0.35	0.31
Vitamin premix[3]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Mineral premix[4]	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Choline chloride, 70%	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cupric sulfate[5]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.03	0.03	0.03	0.03
Bacitracin methylene disalicylate	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Monensin premix[6]	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Calculated composition[7]												
ME (kcal/g)	3.09	3.09	3.09	3.09	3.13	3.13	3.13	3.13	3.20	3.20	3.20	3.20
CP	21.52	21.98	22.44	22.90	20.22	20.50	20.99	21.57	17.95	18.45	19.03	19.81
Ca	0.92	0.92	0.92	0.92	0.90	0.90	0.90	0.90	0.87	0.87	0.87	0.87
Available P	0.46	0.46	0.46	0.46	0.44	0.44	0.44	0.44	0.42	0.42	0.42	0.42

[1]DDGS = distillers dried grains with solubles; SBM = soybean meal (CP content of SBM: 48.3%).

[2]CP content of meat and bone meal: 44.7%.

[3]Vitamin mix provided the following (per kilogram of diet): thiamine mononitrate, 2.4 mg; nicotinic acid, 44 mg; riboflavin, 4.4 mg; D-Ca pantothenate, 12 mg; vitamin B_{12} (cobalamin), 12.0 µg; pyridoxine-HCl, 2.7 mg; D-biotin, 0.11 mg; folic acid, 0.55 mg; menadione sodium bisulfate complex, 3.34 mg; choline chloride, 220 mg; cholecalciferol, 1,100 IU; *trans*-retinyl acetate, 5,500 IU; all-*rac*-tocopherol acetate, 11 IU; ethoxyquin, 150 mg.

[4]Trace mineral mix provides the following (per kilogram of diet): manganese ($MnSO_4{\cdot}H_2O$), 101 mg; iron ($FeSO_4{\cdot}7H_2O$), 20 mg; zinc (ZnO), 80 mg; copper ($CuSO_4{\cdot}5H_2O$), 3 mg; iodine (ethylene diamine dihydroiodide), 0.75 mg; magnesium (MgO), 20 mg; selenium (sodium selenite), 0.3 mg.

[5]Supplied 67.4, 67.4, and 40.5 mg of Cu/kg of starter, grower, and finisher diets, respectively, as a growth promoter.

[6]Premix = 59.5 mg of monensin/kg of diet added.

[7]Calculated from NRC (1994).

Table 3. Digestible amino acid composition of basal and summit diets[1]

Amino acid (%)	Starter phase, d 0 to 18		Grower phase, d 19 to 35		Finisher phase, d 36 to 42	
	Basal	Summit	Basal	Summit	Basal	Summit
dLys	1.20	1.20	1.09	1.09	0.97	0.97
dMet	0.57	0.54	0.54	0.51	0.50	0.46
dCys	0.33	0.36	0.31	0.34	0.28	0.32
dTSAA	0.89	0.88	0.83	0.83	0.76	0.76
dThr	0.82	0.82	0.74	0.74	0.66	0.66
dVal	0.90	0.93	0.85	0.87	0.76	0.80
dIle	0.83	0.81	0.75	0.73	0.65	0.66
dTrp	0.22	0.21	0.20	0.18	0.17	0.16
dArg	1.35	1.24	1.24	1.12	1.07	1.00

[1]d- = digestible amino acid contents. Digestible amino acid contents were calculated for distillers dried grains with solubles (DDGS) based on values reported by Batal and Dale (2006) and Fiene et al. (2006). Basal diet = 0% DDGS; summit diet = 24% DDGS.

Table 4. Comparison of the best performances in experiments 1 and 2 and contemporary Cobb 500 Breeder Management Guide[1] performance expectations

Age (d)	Experiment 1		Experiment 2		Breeder Management Guide	
	BW (kg)	FCR[2]	BW (kg)	FCR	BW (kg)	FCR
18	0.723	1.319	0.716	1.251	0.727	1.176
28			1.500	1.430	1.468	1.446
35	2.090	1.549	1.974	1.571	2.050	1.611
42	2.496	1.686			2.636	1.760

[1]Cobb-Vantress Inc. (Siloam Springs, AR; http://www.cobb-vantress.com).

[2]FCR = feed conversion ratio (weight of feed consumed/BW).

Table 5. Treatment effects on production measurements (experiment 1)[1]

Item (%)	BW gain (kg)	FC[2] (kg)	AFCR[3] (kg of feed/ kg of BW gain)	Mortality (%)
Starter phase (0 to 18 d)				
DDGS[4]				
0	0.688 ± 0.007[b]	0.923 ± 0.012	1.343 ± 0.008	0.953 ± 0.603
8	0.710 ± 0.002[ab]	0.928 ± 0.007	1.308 ± 0.011	0
16	0.723 ± 0.012[a]	0.952 ± 0.011	1.319 ± 0.013	0.477 ± 0.477
24	0.719 ± 0.006[a]	0.955 ± 0.016	1.330 ± 0.019	0.952 ± 0.952
$P > F$	0.0164	0.1640	0.3389	0.6503
Grower phase (19 to 35 d)				
DDGS				
0	1.357 ± 0.015	2.238 ± 0.016	1.651 ± 0.012	2.382 ± 0.878
8	1.340 ± 0.026	2.261 ± 0.049	1.689 ± 0.032	1.428 ± 1.428
16	1.327 ± 0.014	2.231 ± 0.041	1.681 ± 0.018	2.855 ± 1.277
24	1.330 ± 0.014	2.241 ± 0.029	1.685 ± 0.014	3.332 ± 1.146
$P > F$	0.6566	0.9428	0.5410	0.7141
Finisher phase (36 to 42 d)				
DDGS				
0	0.454 ± 0.026	1.069 ± 0.011	2.398 ± 0.154	1.903 ± 0.953
8	0.440 ± 0.023	1.085 ± 0.020	2.497 ± 0.124	2.382 ± 0.878
16	0.422 ± 0.023	1.071 ± 0.016	2.569 ± 0.120	0.953 ± 0.953
24	0.448 ± 0.029	1.079 ± 0.026	2.448 ± 0.119	0.477 ± 0.477
$P > F$	0.8223	0.9220	0.8144	0.3827
Overall (0 to 42 d)				
DDGS				
0	2.496 ± 0.036	4.205 ± 0.024	1.686 ± 0.022	5.238 ± 1.363
8	2.487 ± 0.038	4.264 ± 0.070	1.715 ± 0.024	3.810 ± 1.756
16	2.469 ± 0.023	4.235 ± 0.066	1.715 ± 0.019	4.285 ± 1.769
24	2.494 ± 0.036	4.268 ± 0.059	1.711 ± 0.011	4.760 ± 1.204
$P > F$	0.9395	0.8473	0.7042	0.9229

[a,b]Means in a column without a common superscript are significantly different ($P < 0.05$).

[1]Main effect means ± SE of 6 pens of 36 birds.

[2]FC = feed consumption.

[3]AFCR = feed conversion ratio adjusted for mortality.

[4]DDGS = distillers dried grains with solubles.

Table 6. Treatment effects on processing measurements (experiment 1)[1]

Item	BW (kg)	Fat pad		Chill carcass wt		Breast meat		Legs		Wings	
		kg	%	kg	%	kg	%	kg	%	kg	%
Pooled data											
DDGS[2]											
0	2.52 ± 0.04	0.05 ± 0.01	2.03 ± 0.10	1.94 ± 0.03	76.94 ± 0.30	0.53 ± 0.01	27.22 ± 0.25	0.59 ± 0.01	30.45 ± 0.22	0.20 ± 0.01	10.33 ± 0.12
8	2.54 ± 0.02	0.05 ± 0.01	2.05 ± 0.03	1.95 ± 0.02	76.57 ± 0.11	0.53 ± 0.01	26.95 ± 0.15	0.60 ± 0.01	30.69 ± 0.21	0.20 ± 0.01	10.28 ± 0.05
16	2.50 ± 0.04	0.05 ± 0.01	0.92 ± 0.06	1.91 ± 0.03	76.29 ± 0.32	0.52 ± 0.03	26.99 ± 0.37	0.58 ± 0.01	30.35 ± 0.42	0.20 ± 0.01	10.29 ± 0.11
24	2.51 ± 0.02	0.05 ± 0.01	1.90 ± 0.07	1.94 ± 0.01	76.98 ± 0.11	0.54 ± 0.01	27.61 ± 0.42	0.58 ± 0.01	29.85 ± 0.45	0.20 ± 0.01	10.15 ± 0.13
$P > F$	0.8483	0.4974	0.3646	0.7235	0.1495	0.6642	0.4462	0.1791	0.3872	0.7359	0.6816
Males											
DDGS											
0	2.74 ± 0.05	0.04 ± 0.01^{c}	1.55 ± 0.14^{c}	2.11 ± 0.04	77.09 ± 0.56	0.59 ± 0.01	27.75 ± 0.27	0.65 ± 0.01	30.64 ± 0.34	0.22 ± 0.01	10.39 ± 0.17
8	2.75 ± 0.04	0.05 ± 0.01^{b}	1.78 ± 0.06^{bc}	2.10 ± 0.03	76.31 ± 0.11	0.56 ± 0.01	26.83 ± 0.23	0.65 ± 0.01	31.01 ± 0.29	0.22 ± 0.01	10.37 ± 0.13
16	2.73 ± 0.05	0.05 ± 0.01^{b}	1.73 ± 0.14^{bc}	2.09 ± 0.04	76.46 ± 0.44	0.57 ± 0.02	27.09 ± 0.40	0.64 ± 0.01	30.56 ± 0.43	0.22 ± 0.01	10.44 ± 0.19
24	2.73 ± 0.03	0.05 ± 0.01^{b}	1.75 ± 0.07^{bc}	2.11 ± 0.02	77.15 ± 0.22	0.58 ± 0.02	27.60 ± 0.67	0.63 ± 0.01	29.98 ± 0.55	0.22 ± 0.01	10.21 ± 0.09
$P > F$	0.9848	0.5142	0.4707	0.9659	0.3010	0.6170	0.5618	0.8627	0.4056	0.3832	0.7314
Females											
DDGS											
0	2.31 ± 0.05	0.06 ± 0.01^{a}	2.49 ± 0.10^{a}	1.77 ± 0.03	76.79 ± 0.33	0.48 ± 0.01	26.70 ± 0.33	0.54 ± 0.01	30.27 ± 0.39	0.18 ± 0.01	10.26 ± 0.16
8	2.34 ± 0.05	0.05 ± 0.01^{b}	2.32 ± 0.04^{a}	1.80 ± 0.04	76.83 ± 0.18	0.49 ± 0.01	27.06 ± 0.18	0.55 ± 0.02	30.36 ± 0.29	0.18 ± 0.01	10.18 ± 0.10
16	2.28 ± 0.05	0.05 ± 0.01^{b}	2.12 ± 0.12^{a}	1.73 ± 0.05	76.13 ± 0.95	0.47 ± 0.03	26.90 ± 0.67	0.52 ± 0.01	30.14 ± 0.49	0.18 ± 0.01	10.14 ± 0.12
24	2.30 ± 0.02	0.05 ± 0.01^{b}	2.05 ± 0.10^{ab}	1.77 ± 0.02	76.82 ± 0.35	0.49 ± 0.01	27.62 ± 0.50	0.53 ± 0.01	29.72 ± 0.46	0.18 ± 0.01	10.10 ± 0.22
$P > F$	0.8031	0.0220	0.0133	0.7062	0.7480	0.7443	0.5309	0.5230	0.7068	0.6569	0.8870
Source, $P > F$						*P*-value					
Diet	0.8256	0.5102	0.4000	0.7370	0.4054	0.6496	0.4279	0.2570	0.2397	0.6717	0.6946
Sex	<0.0001	0.0117	<0.0001	<0.0001	0.7418	<0.0001	0.4308	<0.0001	0.1499	<0.0001	0.0907
Diet × sex	0.9666	0.0409	0.0157	0.9057	0.7442	0.7116	0.4940	0.9697	0.9721	0.7998	0.9290

[a–c]Means in a column without a common superscript are significantly different ($P < 0.05$).

[1]Main effect means ± SE of 6 pens of 36 birds.

[2]DDGS = distillers dried grains with solubles.

Table 7. Pellet durability test based on different levels of distillers dried grains with solubles (DDGS) and fat (experiment 1)[1]

	Actual durability		Relative durability	
Item	Grower	Finisher	Grower	Finisher
DDGS (%)				
0	80.74 ± 0.21[a]	74.20 ± 1.33[a]	100.00	100.00
8	74.78 ± 1.47[b]	69.51 ± 1.08[a]	92.62	93.68
16	70.14 ± 0.81[b]	60.18 ± 1.45[b]	86.87	81.11
24	60.98 ± 2.29[c]	49.66 ± 2.49[c]	75.53	66.93
$P > F$	<0.0001	<0.0001		

[a–c]Means in a column without a common superscript are significantly different ($P < 0.05$).

[1]Main effect means ± SE of 3 samples.

(Cantrell Model Mark 4, Cantrell Machine Co. Inc.) in the automated line system used imposed most of the physical stresses normally encountered under commercial processing conditions with the exception that the warm eviscerated carcasses were static-chilled in slush-ice for 4 h rather than by convective agitation. Carcasses were then chilled and individually wrapped in plastic bags and placed in a cool room (5°C) until they were dissected on d 44. Carcasses were suspended on cones and the breast skin was removed and breast meat was cut from the carcass along with the wings. The wings were subsequently removed from the breast meat. Both femurs were dislocated to remove the thighs from the frame.

Statistical Analysis

Analysis of variance was performed on all data for both experiments using the GLM procedure of SAS (SAS Institute, 2006) appropriate for a one-way design. Treatment means were compared using Duncan's new multiple range test (Duncan, 1955) at $\alpha = 0.05$.

RESULTS AND DISCUSSION

The feeds containing higher levels of DDGS contained higher levels of CP (Table 2) because they were formulated to maintain minimum digestible AA levels (Table 3). A total of 7 AA (Met, TSAA, Thr, Val, Ile, Trp, and Arg) were set as minima relative to digestible Lys. The fourth limiting AA, as determined by the targeted minimum ratios (Val in the 0% DDGS diet and Arg in the 24% DDGS diet) became the constraint that dictated the minimum level of CP. In all phases, the broilers performed very well, similar to the performance expectations of the breeder (Table 4).

Broilers fed the diets containing the higher levels of DDGS had greater BW gain than broilers fed 0% DDGS during the starter phase in experiment 1 (Table 5). That was the only performance difference detected. At 42 d, a difference of only 2 g/bird was found in birds fed 0 vs. 24% DDGS. Processing measurement results were similar for birds fed the diets with different levels of DDGS (Table 6). The only significant difference in carcass measurements among treatments was observed for kilograms and percentage of fat in the female carcasses, which increased with increased levels of DDGS ($P < 0.05$). Because there was no apparent biological reason for this difference, we considered that it was declared significant by chance alone. Taken with the opposite trends noted for fat pad measurements for male and female broilers, little evidence exists to support the hypothesis that any negative changes occurred in carcass measurements from feeding DDGS in this experiment. If there were any changes from feeding DDGS, the effect was small and positive. It would not be surprising if female broilers had reduced carcass fat because of the slightly higher protein levels in the higher DDGS diets (Donaldson et al., 1956).

Pellet durability was negatively related to the proportion of DDGS in the feeds (Table 7). Two factors probably contributed to reduced pellet quality when DDGS was included in the feeds: higher DDGS levels and higher poultry fat levels. An explanation is lacking for why broilers fed DDGS performed very well despite the reduced pellet quality. Therefore, the reduced pellet quality observed when feeding DDGS should not be regarded as negative.

Broilers fed DDGS in experiment 2 had increased BW gains compared with those fed the basal diet (Table 8). Lumpkins et al. (2004) evaluated DDGS as a feed ingredient for broilers and concluded that DDGS can be safely used at 6% of the diet in the starter phase and at 12 to 15% in the grower and finisher periods. However, Lumpkins et al. (2004) speculated that when they fed DDGS, the high level of dietary protein of corn origin and the corresponding decrease in soybean protein may have contributed to the depressed performance because of a marginal Lys deficiency. This could have occurred as their diets were formulated to maintain minimum CP levels and on a total AA basis balanced for Met, TSAA, and Lys only. In experiments 1 and 2, minimum digestible AA were adjusted for constant ME levels. Even chicks fed 24% DDGS had excellent growth performance with an adequate digestible AA balance.

Variation exists in raw ingredients and processing methods and samples (Batal and Dale, 2003, 2006; Fastinger and Mahan, 2006; Fiene et al., 2006; Martinez-Amezcua et al., 2007). Differences in processing methods and DDGS origin may explain the improved

Table 8. Treatment effects on production measurements (experiment 2)[1]

Item	BW gain (kg)	FC[2] (kg)	AFCR[3] (kg of feed/ kg of BW gain)	Mortality (%)
Starter phase (0 to 18 d)				
DDGS[4] (%)				
0	0.585 ± 0.011[b]	0.826 ± 0.024	1.414 ± 0.043	4.168 ± 1.720
8	0.711 ± 0.008[a]	0.896 ± 0.043	1.262 ± 0.065	0.927 ± 0.585
16	0.704 ± 0.007[a]	0.911 ± 0.028	1.295 ± 0.041	0.463 ± 0.463
24	0.716 ± 0.008[a]	0.969 ± 0.068	1.651 ± 0.041	3.242 ± 1.817
$P > F$	<0.0001	0.0628	0.1625	0.1660
Grower phase (19 to 28 d)				
DDGS (%)				
0	0.728 ± 0.022	1.165 ± 0.023[b]	1.600 ± 0.026	1.250 ± 0.660
8	0.789 ± 0.019	1.238 ± 0.019[a]	1.569 ± 0.007	0.520 ± 0.520
16	0.776 ± 0.014	1.238 ± 0.017[a]	1.595 ± 0.007	1.530 ± 0.685
24	0.771 ± 0.022	1.246 ± 0.016[a]	1.616 ± 0.016	1.616 ± 1.084
$P > F$	0.1178	0.0039	0.0669	0.7305
Finisher phase (29 to 35 d)				
DDGS (%)				
0	0.522 ± 0.058[a]	0.954 ± 0.030	1.828 ± 0.137[b]	0.520 ± 0.520
8	0.474 ± 0.025[b]	0.966 ± 0.022	2.038 ± 0.074[a]	1.010 ± 0.639
16	0.449 ± 0.019[b]	0.918 ± 0.020	2.045 ± 0.084[a]	1.764 ± 0.706
24	0.456 ± 0.019[b]	0.927 ± 0.025	2.033 ± 0.039[a]	0.505 ± 0.505
$P > F$	0.0425	0.8726	0.0253	0.5521
Overall (0 to 35 d)				
DDGS (%)				
0	1.835 ± 0.041[b]	2.945 ± 0.059	1.606 ± 0.019	5.730 ± 1.617
8	1.974 ± 0.031[a]	3.100 ± 0.054	1.571 ± 0.020	2.457 ± 0.907
16	1.929 ± 0.029[ab]	3.067 ± 0.045	1.590 ± 0.017	3.757 ± 1.659
24	1.943 ± 0.032[a]	3.142 ± 0.068	1.617 ± 0.025	5.363 ± 2.317
$P > F$	0.0476	0.1171	0.4331	0.4986

[a,b]Means in a column without a common superscript are significantly different ($P < 0.05$).

[1]Main effect means ± SE of 6 pens of 36 birds.

[2]FC = feed consumption.

[3]AFCR = feed conversion ratio adjusted for mortality.

[4]DDGS = distillers dried grains with solubles.

performance at relatively high levels of DDGS in experiments 1 (starter phase only) and 2 and in earlier studies in which similar DDGS levels impaired growth (Parsons et al., 1983; Lumpkins et al., 2004). Almost all these early trials were based on using total AA values rather than digestible values, and AA constraints were often set for only Met, TSAA, and Lys. Corn DDGS processing methods and the quality and nutrient digestibility values of the DDGS are variable. Not fully adjusting for the quality and composition of the DDGS and other ingredients used may have affected the outcomes, as may have the formulation models, especially fat and AA supplementation. In early trials with DDGS, often only Met or Met and Lys were supplemented (Waldroup et al., 1981; Lumpkins et al., 2004). Using an ideal AA balance along with digestible AA values, as was done in this trial, is the best means of fully realizing the true value of a by-product ingredient such as DDGS. Failing to use these approaches could otherwise reduce the perceived value of the DDGS being tested.

Experimental power is also an important consideration that may affect conclusions between experiments. In experiment 2, a 108-g difference in 35-d BW was declared significantly different from zero. In the study by Wang et al. (2007), a 113-g decrease in 42-d BW was not significant. With a similar product at 25% of the diet, Applegate et al. (2009) observed that broilers were 70 g heavier to 42 d, but the difference was not significant at $P < 0.05$.

The research demonstrates that broilers may perform acceptably when high-quality DDGS is fed and the diets are properly balanced on a digestible AA basis. This performance may be achieved in spite of reduced pellet quality related to feeding DDGS.

REFERENCES

Ajinomoto Heartland LLC. 2004. True Digestibility of Essential Amino Acids for Poultry. Revision 7. Ajinomoto Heartland LLC, Chicago, IL. Accessed May 2007. http://www.lysine.com/new/tecpoul2.htm.

American Society of Agricultural and Biological Engineers. 2007. Cubes, pellets, and crumbles: Definitions, and methods for determining density, durability, and moisture content. Pages 624–626 in ASABE Standards. Am. Soc. Agric. Biol. Eng., St. Joseph, MI.

Applegate, T. J., C. Troche, Z. Jiang, and T. Johnson. 2009. The nutritional value of high protein corn distillers dried grains for broiler chickens and its effect on nutrient excretion. Poult. Sci. 88:354–359.

Batal, A. B., and N. M. Dale. 2003. Mineral composition of distillers dried grains with solubles. J. Appl. Poult. Res. 12:400–403.

Batal, A. B., and N. M. Dale. 2006. True metabolizable energy and amino acid digestibility of distillers dried grains with solubles. J. Appl. Poult. Res. 15:89–93.

Behnke, K. C. 2007. Feed manufacturing considerations for using DDGS in poultry and livestock diets. Pages 77–81 in Proc. 5th

Mid-Atlantic Nutr. Conf. N. G. Zimmermann, ed. University of Maryland, College Park.

Donaldson, W. E., G. F. Combs, and G. L. Romoser. 1956. Studies on energy levels in poultry rations. 1. The effect of calorie-protein ratio of the ration on growth, nutrient utilization, and body composition of chicks. Poult. Sci. 35:1100–1105.

Duncan, D. B. 1955. Multiple range and multiple F-tests. Biometrics 11:1–42.

Fastinger, N. D., and D. C. Mahan. 2006. Determination of the ileal amino acid and energy digestibilities of corn distillers dried grains with solubles using grower-finisher pigs. J. Anim. Sci. 84:1722–1728.

Fiene, S. P., T. W. York, and C. Schasteen. 2006. Correlations of DDGS IDEA^{TM} digestibility assay for poultry with cockerel true amino acid digestibility. Pages 82–89 in Proc. 4th Mid-Atlantic Nutr. Conf. N. G. Zimmermann, ed. University of Maryland, College Park.

Lumpkins, B. S., A. B. Batal, and N. M. Dale. 2004. Evaluation of distillers dried grains with soluble as a feed ingredient for broilers. Poult. Sci. 83:1891–1896.

Martinez-Amezcua, C., C. M. Parsons, V. Singh, R. Srinivasan, and G. S. Murthy. 2007. Nutritional characteristics of corn distillers dried grains with soluble as affected by the amounts of grains versus soluble and different processing techniques. Poult. Sci. 86:2624–2630.

NRC. 1994. Nutrient Requirements of Poultry. 9th ed. Natl. Acad. Press, Washington, DC.

Parsons, C. M., D. H. Baker, and J. M. Harter. 1983. Distillers dried grains with solubles as a protein-source for the chick. Poult. Sci. 62:2445–2451.

SAS Institute. 2006. SAS User's Guide: Statistics. Version 9.1.3 ed. SAS Inst. Inc., Cary, NC.

Srinivasan, R., A. Corzo, K. B. Koch, and M. T. Kidd. 2009. Effect of fractionation of distillers dried grains with solubles (DDGS) on pelleting characteristics of broiler diets. Cereal Chem. 86:393–397.

Waldroup, P. W., J. A. Owen, B. E. Ramsey, and D. L. Whelchel. 1981. The use of high-levels of distillers dried grains plus solubles in broiler diets. Poult. Sci. 60:1479–1484.

Wang, Z., S. Cerrate, C. Coto, F. Yan, and P. W. Waldroup. 2007. Utilization of distillers dried grains with solubles (DDGS) in broiler diets using a standardized nutrient matrix. Int. J. Poult. Sci. 6:470–477.