Dried distillers grains with solubles in laying hen diets[1]

M. K. Masa'deh,* S. E. Purdum,†[2] and K. J. Hanford‡

*MBA Poultry, 13151 Dovers St., Waverly, NE 68462; †Department of Animal Science, University of Nebraska, Lincoln 68583-0908; and ‡Department of Statistics, University of Nebraska, Lincoln 68583-0693

ABSTRACT A study was conducted to test the inclusion rate of corn dried distillers grains with solubles (DDGS) in laying hen diets on egg production (EP) responses for a full production cycle. A total of 288 Bovan Single Comb White Leghorn laying hens were fed diets containing 0, 5, 10, 15, 20, or 25% DDGS from 24 to 46 wk (phase 1) and 47 to 76 wk (phase 2) of age. The diets were formulated to be isocaloric at 2,775 and 2,816 kcal/kg of ME and isonitrogenous at 16.5 and 16.0% CP for phases 1 and 2, respectively. Nutrient retention of both N and P were determined by the indicator methods during phase 2. Diets were replicated with 8 pens/treatment and 6 hens/pen in an unbalanced randomized complete block design. Average daily feed intake, EP, and overall weight gain were similar ($P = 0.08$ to 0.1) among treatments during the study. Egg weight was affected ($P = 0.064$) by DDGS treatment during phase 1. Hens fed 0, 5, 10, 15, 20, or 25% DDGS had an average egg weight of 60.6, 60.4, 60.8, 60.0, 59.0, and 59.0 g, respectively; however, no differences were detected in egg weight during phase 2. During phase 1, diets were formulated based on TSAA, allowing Met to decrease as DDGS increased, but during phase 2, diets were formulated to keep Met equal across DDGS treatments, allowing TSAA to increase as a result of high Cys in DDGS. Yolk color increased with increasing DDGS level; the highest Roche score ($P = 0.001$) was 7.2 for hens fed 25% DDGS. Nitrogen and P retention was greater ($P = 0.003$) in hens fed 25% DDGS. Also, N and P excretion decreased ($P = 0.007$) linearly as DDGS increased. In summary, feeding DDGS up to 25% during EP cycles had no negative effects on feed intake, EP, Haugh units, or specific gravity, and improved yolk color at the highest levels. Increasing DDGS level beyond 15% caused a reduction in egg weight during phase 1 of egg production, though no differences were observed in egg weight during phase 2. Nitrogen and P excretion were lower at higher inclusion rate of DDGS. Hens fed 25% DDGS had the highest N and P retention.

Key words: layers fed dried distillers grains with solubles, egg production, dried distillers grains with solubles

2011 Poultry Science 90:1960–1966
doi:10.3382/ps.2010-01184

INTRODUCTION

Dried distillers grains with solubles (**DDGS**) is a corn co-product obtained during the dry-milling process of corn to produce ethanol after the fermentation of cornstarch by selected yeasts. Dried distillers grains with solubles has been available for poultry for many decades and comes primarily from the beverage industry. Dried distillers grains with solubles are a valuable source of energy, protein, and amino acids for poultry (Jensen, 1978, 1981; Parsons and Baker, 1983; Wang et al., 2007). The production and supply of ethanol DDGS continues to increase (Renewable Fuels Association, 2011), potentially increasing the use of DDGS in poultry diets.

In 2009, the US production of distiller's grains for livestock exceeded 25 million tonnes (Renewable Fuels Association, 2011). The poultry industry uses around 9% of total DDGS, whereas the swine industry uses nearly 10% of DDGS; the majority (80%) is fed to ruminants (Renewable Fuels Association, 2011). Feeding higher levels of DDGS could have a significant effect on feed costs for poultry producers because of higher availability of DDGS for livestock usage and the current price fluctuations of feed ingredients (Schilling et al., 2010).

Previous research has shown that DDGS are an acceptable ingredient in laying hen diets. Dried distillers grains with solubles can contribute as much as one-third of the protein needed in the laying hen (Roberson et al., 2005). Roberson et al. (2005), Lumpkins et al. (2005), and Świątkiewicz and Koreleski (2006) all recommend a usage rate of up of 15% DDGS in laying hen diets to maintain egg production. The objective of our

Received October 13, 2010.
Accepted April 22, 2011.
[1]A contribution of the University of Nebraska Agricultural Research Division.
[2]Corresponding author: spurdum2@unl.edu

study was to test inclusion levels of DDGS higher than 15% for laying hens and the effect of inclusion level on feed intake, BW, and egg quality for 1 full production cycle.

MATERIALS AND METHODS

Experimental Diets

Six diets were formulated for phase 1 (wk 24–46) and phase 2 (wk 47–76) of egg production according the Centurion Poultry Inc. (2009) recommendation based on 110 g/hen per day predicted feed intake and to meet the National Research Council (1994) nutrient requirement for laying hens. The diets were formulated to include 0, 5, 10, 15, 20, or 25% corn DDGS. Composition of the 6 diets for phases 1 and 2 is shown in Tables 1 and 2, respectively. The nutrient composition of DDGS (Dakota Gold BPX, Poet Nutrition, Sioux Falls, SD) used in the study was provided by the manufacturer from laboratory analysis. Dried distillers grains with solubles used for formulation contained an estimated 27% CP, 10.3% fat, 2,800 kcal/kg of ME (calculated), 0.97% Lys, and 0.51% Met. Diets were maintained isocaloric to provide 2,775 and 2,816 kcal/kg of ME and isonitrogenous to provide 16.5 and 16.0% CP for phases 1 and 2, respectively. Phase 1 diets were formulated on a total Lys and TSAA concentration for all treatments, whereas phase 2 diets were balanced for a fixed Lys and Met concentration in all treatments, allowing TSAA level to increase as a result of high DDGS Cys levels. This change in TSAA formulations was attributable to an observed decreased egg weight in phase 1 as DDGS increased and an attempt to meet minimum Met levels. Each of the diets was fed to 8 replicate pens with 6 hens/pen. Birds were provided feed (up to 115 g/hen per day) and water throughout the study. Dietary samples were collected during each phase of diet formulation and were subsequently ground using a Tecator Cyclotec grinder (1 mm screen; 1093 Sample Mill, Tecator, Höganäs, Sweden) and stored at −20°C until chemical analysis was performed. At 75 wk of age, chromic oxide (**Cr**; 0.1% of the feed) was mixed with dietary treatments as an indigestible marker and fed for 1 wk. Excreta samples from each pen were collected for N and P analysis at the end of the feeding period.

Grains (corn and soybean meal), DDGS, and feed additives prices were obtained from Iowa State University Extension (2005) and a local farmer co-op for the time period when the study was conducted. The average ingredient price ($) per kilogram for corn, soybean meal, DDGS, limestone, dicalcium phosphate, fat blend, NaCl, HCl-Lys, DL-Met, and vitamin–mineral premix was 0.149, 0.326, 0.154, 0.046, 0.507, 0.727, 0.099, 2.535, 4.917, and 7.144, respectively. The 6 diet costs were calculated based on the collective ingredient prices for both phases 1 and 2 and are presented in Tables 1 and 2, respectively.

Birds and Housing

A total of 288 Bovans White hens were used in this study and were randomly assigned to 1 of 6 dietary treatment groups varying in DDGS level. The birds were obtained from a commercial pullet farm at 18 wk of age. From 18 to 24 wk, a standard Bovan (no DDGS) corn–soybean meal prelay diet based on Centurion Poultry Inc. (2009) was fed. Hens were 24 wk of age at the beginning of the study and were fed the dietary treatments from 24 to 46 wk of age for phase 1 and from 47 to 76 wk of age for phase 2 of egg production. Birds were housed in the F-research building at the University of Nebraska–Lincoln Poultry Research Facility. Hens were maintained on a 16L:8D photoperiod throughout the study. Dimensions of cages (stacked deck cages; Big Dutchman Inc., Holland, MI) were 50 × 60 cm, equaling 3,000 cm^2 of floor space. With 6 hens/cage, each bird had approximately 500 cm^2 of floor space. Cages were supplied with 2 nipple drinkers/pen and adequate feeder space (8 cm/hen) for all hens. The study was conducted under the approval of the University of Nebraska's Animal Care Committee.

Parameters Measured

Data collected included daily hen egg production and feed intake throughout the production cycles. One day of egg production was used to measure egg weight every other week. Haugh units (Haugh, 1937) were measured on 3 eggs/pen (with similar weight) every other week to record albumen height. Both egg weight and Haugh unit were recorded using Egg Ware (Technical Services and Supplies, Dunnington, UK). Specific gravity was determined by floating collected eggs in graded salt (sodium chloride) bucket solutions ranging from 1.070 to 1.1 (0.05 intervals) every other week. Yolk color was measured every 2 wk using the Roche color fan scale (DSM Nutrition Products, Basel, Switzerland) and performed by the same person throughout the study to prevent any subjective influence. Hen weight was recorded on a monthly basis by averaging the weight of 6 hens/pen. Hen BW gain was calculated as the difference between average final hen weights and the average beginning hen weights. Hen mortality was recorded daily during both phases 1 and 2 of the study. Production responses such as feed intake and egg production were adjusted for hen mortalities for the day mortality occurred and on based on the total number of hens in the pen.

Determination of N and P Retention

Diets were mixed with Cr (0.1% of the feed) as an indigestible marker and were fed for 1 wk before fecal collection during phase 2 of egg production. Clean excreta (free from feathers and feed) were collected after a 24-h production period from the plastic manure belt

Table 1. Experimental diet composition for phase 1 (as-fed basis)

	Dried distillers grains with solubles, %					
Item, % unless noted	0	5	10	15	20	25
Ingredient						
Corn	64.07	61.80	59.51	57.25	55.03	52.79
Soybean meal[1]	24.42	21.61	18.86	16.14	13.38	10.59
Dried distiller grains with solubles	0.00	5.00	10.00	15.00	20.00	25.00
Limestone[2]	8.54	8.68	8.78	8.82	8.86	8.94
Dicalcium phosphate	1.75	1.64	1.52	1.41	1.30	1.19
Fat blend	0.60	0.64	0.69	0.74	0.79	0.84
NaCl	0.32	0.30	0.28	0.26	0.23	0.21
HCl-Lys	0.00	0.05	0.10	0.14	0.19	0.23
DL-Met	0.20	0.18	0.16	0.14	0.12	0.11
Vitamin and mineral premix[3]	0.10	0.10	0.10	0.10	0.10	0.10
Calculated nutrient composition						
ME,[4] kcal/kg	2,775	2,775	2,775	2,775	2,775	2,775
Protein	16.50	16.50	16.50	16.50	16.50	16.50
TSAA	0.75	0.75	0.75	0.75	0.75	0.75
Met	0.47	0.45	0.44	0.43	0.41	0.40
Cys	0.28	0.30	0.31	0.32	0.34	0.35
Lys	0.83	0.83	0.83	0.83	0.83	0.83
Ca	3.70	3.70	3.70	3.70	3.70	3.70
Nonphytate P	0.42	0.42	0.42	0.42	0.42	0.42
Total P	0.63	0.63	0.62	0.62	0.61	0.61
Analyzed nutrient composition[5]						
Protein	16.23	16.29	16.40	16.52	16.62	16.92
TSAA	0.73	0.79	0.75	0.78	0.70	0.73
Met	0.41	0.45	0.41	0.44	0.39	0.41
Cys	0.32	0.34	0.34	0.34	0.31	0.32
Lys	0.86	0.80	0.83	0.83	0.87	0.87
Ether extract[6]	3.22	3.75	4.13	4.45	4.83	5.26
Ca	3.57	3.57	3.46	3.71	3.24	3.25
Total P	0.67	0.66	0.64	0.59	0.69	0.66
Price,[7] $/1,000 kg	220.25	215.46	210.83	206.12	201.58	197.18

[1]High protein (48% CP) soybean meal.

[2]Limestone was 50% large particles and 50% fine particles.

[3]Provided the following per kilogram: vitamin A (retinyl acetate), 6,600 IU; vitamin D_3, 2,805 IU; vitamin E (DL-α-tocopheryl acetate), 10 IU; vitamin K_3 (menadione dimethylpyrimidinol), 2.0 mg; riboflavin, 4.4 mg; pantothenic acid, 6.6 mg; niacin, 24.2 mg; choline, 110 mg; vitamin B_7 (biotin), 8.8 mg; ethoxyquin, 1.1 mg; Mn (MnO), 88 mg; Cu ($CuSO_4$), 6.6 mg; Fe ($FeSO_4$), 8.5 mg; Zn (ZnO), 88 mg; and Se (Na_2SeO_3), 0.30 mg.

[4]Values for ingredients used in diet formulation were based on laying hen requirements in NRC (1994).

[5]Values based on total Cys and Met.

[6]Ether extract represents total fat content in the diet.

[7]Feed prices are calculated with corn, soybean meal, and dried distillers grains with solubles priced at $150, $326, and $154/tonne, respectively.

under each pen and the samples were placed in aluminum trays. Wet sample weights were recorded and samples were placed in −20°C freezer for 2 d. Subsequently, excreta were freeze dried (FTS System Inc., Stone Ridge, NY). The apparent retention of N and P was determined using equations for the indicator method described by Schneider and Flatt (1975):

$$\text{nutrient retention} = 100 - 100 \times [(\%\ Cr_{diet} \text{ in the diet} \times \%\ \text{nutrient in the feces})/(\%\ Cr_{out} \text{ in the feces} \times \%\ \text{nutrient in the diet})],$$

where Cr_{diet} is the initial Cr concentration in the diet and Cr_{out} is the concentration of Cr in the excreta. Further, the total nutrients excreted per kilogram of DM intake (**DMI**) were calculated by using the ratio of Cr intake to Cr output (Dilger and Adeola, 2006):

$$\text{nutrient output, g/kg of DMI} = NcE \times (Cr_{diet}/Cr_{out}),$$

where NcE is the concentration of the respective nutrient in the excreta, Cr_{diet} is the initial Cr concentration in the diet, and Cr_{out} is the concentration of Cr in the excreta.

Chemical Analysis

Diet samples were collected for each diet mixing during both phases 1 and 2. The samples were pooled and subsequently ground using a Tecator Cyclotec grinder (1 mm screen; 1093 Sample Mill). All diets were analyzed for Ca (method 927.02), P (method 965.17), CP (Kjeldahl method; method 988.05), and crude fat (ether extract; method 920.39) according to AOAC (1995). For amino acids analysis, diet samples were hydrolyzed for 20 h (6 *N* HCl) at 105°C with the exception of sulfur amino acid. Ion-exchange chromatography was used to separate amino acids. The HPLC analyzer contained a cation exchange column that eluted amino acids using a gradient of lithium buffers. Then, amino acids were quantitated fluorometrically using o-phthalaldehyde as

Table 2. Experimental diet composition for phase 2 (as-fed basis)

	Dried distillers grains with solubles, %					
Item, % unless noted	0	5	10	15	20	25
Ingredient						
Corn	62.81	60.36	57.89	55.44	53.00	49.10
Soybean meal[1]	23.55	20.98	18.41	15.83	13.20	10.96
Dried distiller grains with solubles	0.00	5.00	10.00	15.00	20.00	25.00
Limestone[2]	9.44	9.52	9.61	9.69	9.78	10.33
Dicalcium phosphate	1.54	1.43	1.31	1.19	1.10	1.10
Fat blend	2.00	2.03	2.07	2.11	2.15	2.74
NaCl	0.40	0.38	0.36	0.36	0.34	0.32
HCl-Lys	0.16	0.16	0.17	0.17	0.18	0.19
DL-Met	0.00	0.04	0.08	0.11	0.15	0.16
Vitamin and mineral premix[3]	0.10	0.10	0.10	0.10	0.10	0.10
Calculated nutrient composition						
ME,[4] kcal/kg	2,816	2,816	2,816	2,816	2,816	2,816
Protein	16.00	16.00	16.00	16.00	16.00	16.00
Met	0.44	0.44	0.44	0.44	0.44	0.44
Lys	0.80	0.80	0.80	0.80	0.80	0.80
Ca	3.70	3.70	3.70	3.70	3.70	3.70
Nonphytate P	0.42	0.42	0.42	0.42	0.42	0.42
Total P	0.59	0.58	0.58	0.57	0.57	0.58
Analyzed nutrient composition[5]						
Protein	15.59	15.68	15.69	16.43	16.95[6]	16.26
TSAA	0.69	0.69	0.68	0.77	1.02[6]	0.72
Met	0.40	0.42	0.43	0.45	0.68[6]	0.40
Cys	0.29	0.29	0.25	0.32	0.34	0.32
Lys	0.84	0.82	0.82	0.85	0.87	0.83
Ether extract[7]	4.13	4.59	4.93	5.31	5.93	6.37
Ca	3.84	3.52	3.59	3.24	2.88	3.53
Total P	0.61	0.67	0.57	0.54	0.60	0.57
Price,[8] $/1,000 kg	219.36	216.66	214.39	211.04	208.59	208.42

[1]High protein (48% CP) soybean meal.

[2]Limestone was 50% large particles and 50% fine particles.

[3]Provided the following per kilogram: vitamin A (retinyl acetate), 6,600 IU; vitamin D_3, 2,805 IU; vitamin E (DL-α-tocopheryl acetate), 10 IU; vitamin K_3 (menadione dimethylpyrimidinol), 2.0 mg; riboflavin, 4.4 mg; pantothenic acid, 6.6 mg; niacin, 24.2 mg; choline, 110 mg; vitamin B_7 (biotin), 8.8 mg; ethoxyquin, 1.1 mg; Mn (MnO), 88 mg; Cu ($CuSO_4$), 6.6 mg; Fe ($FeSO_4$), 8.5 mg; Zn (ZnO), 88 mg; and Se (Na_2SeO_3), 0.30 mg.

[4]Values for ingredients used in diet formulation were based on laying hen requirements in NRC (1994).

[5]Values based on total Cys and Met.

[6]Aberrant data (sampling error).

[7]Ether extract represents total fat content in the diet.

[8]Feed prices are calculated with corn, soybean meal, and dried distillers grains with solubles priced at $150, $326, and $154/tonne, respectively.

the derivatization reagent. Methionine and Cys (sulfur amino acids) were determined by ion-exchange chromatography of acid-hydrolyzate samples that had been preoxidized with performic acid [hydrogen peroxide (300 g/L):formic acid (880 g/L), 1:9, vol/vol; (AOAC, 1995; method 994.12)]. Chromic oxide in diets and feces were analyzed according to the procedure described by Williams et al. (1962) using atomic absorption spectrophotometry.

Statistical Analysis

Data were analyzed as an unbalanced randomized complete block design using the MIXED procedure of SAS (SAS Institute, 2008). Cage was the experimental unit, with 6 hens/cage. Each treatment was replicated 8 times and cages were blocked by side (north and south) and by tier level (1 through 6). Each block consisted of 8 pens, so more than 1 treatment was present in the same block more than once, causing the design to be unbalanced. Repeated measures ANOVA with the factors treatments (the error term being cage within treatment), time (the residual error being the error term), and treatment by time interaction were carried out on all production data, except BW gain was not a repeated measure. Appropriate covariance structures were chosen based on Akaike information criterion. Response curves for N and P retention and nutrient output to level of dietary DDGS were fit to linear and quadratic models.

RESULTS AND DISCUSSION

Calculated and analyzed nutrient composition of the experimental diets and diets costs for phases 1 and 2 are presented in Tables 1 and 2, respectively. Analyzed dietary CP, Ca, P, Lys, Met, and Cys were consistent across diets compared with formulated values. When DDGS was incorporated into the diet, more synthetic Lys and fat blend were added, but dicalcium phosphate decreased as DDGS increased in the diet. Feeding 25% DDGS to laying hens saved $23.07 and $10.94/1,000 kg for phase 1 and phase 2, respectively, compared with 0% DDGS. Diet prices were calculated according to

Table 3. Egg production data for phase 1 (wk 24–46) and phase 2 (wk 47–76) of experiment

Dried distillers grains with solubles, %	Feed intake, g/d		Weight gain,[1] g	Egg production, %		Egg weight, g		Haugh units		Specific gravity	
	1	2	1 and 2	1	2	1	2	1	2	1	2
0	109.16	99.58	241.87	92.11	82.40	60.63	63.09	92.42	94.68	1.086	1.080
5	110.86	102.79	261.75	89.18	83.43	60.42	62.92	92.04	93.47	1.084	1.079
10	110.26	101.69	239.79	90.68	83.56	60.76	63.32	91.00	93.76	1.085	1.080
15	108.29	99.67	260.18	89.59	81.90	60.00	61.96	92.15	93.75	1.085	1.078
20	108.74	101.77	238.83	91.21	85.24	58.96	61.97	92.89	94.25	1.086	1.080
25	109.16	99.48	189.87	91.01	81.25	59.34	61.97	92.46	95.25	1.085	1.079
SEM	1.076	1.077	21.624	1.468	1.052	0.488	0.605	0.686	0.598	0.001	0.001
P-value[2]	0.550	0.143	0.133	0.827	0.110	0.064	0.334	0.632	0.287	0.121	0.083

[1]Average hen weight gain for the entire production period. Average hen weight gain is the average of pen (6 hens).
[2]*P*-value represents the linear response for all egg production responses. No significant quadratic effect was found.

the Agricultural marketing resource center 2005 prices (Iowa State University Extension, 2005).

Feed intake and egg production results are shown in Table 3. Feed intake was not affected by dietary DDGS concentration during either phase of egg production, with an average of 109.4 and 100.8 g/hen per day for phases 1 and 2, respectively. The results showed an increase in feed intake during phase 1 in the early part of the year (January, February, and March), and feed intake decreased with age (data not shown) as the house temperatures warmed during phase 2. Feed intake results are in agreement with Lumpkins et al. (2005) and Świątkiewicz and Koreleski (2006) who also showed no difference in feed intake for hens fed up to 15 or 20% DDGS, respectively. Average hen weight gain was similar among dietary treatments for the entire production period. Lumpkins et al. (2005) and Shurson et al. (2003) also reported that feeding DDGS had no effect on hen BW when fed at 15 or 10%, respectively.

No differences in hen daily egg production were observed among dietary treatments. Average hen daily egg production was 90.63 and 82.96% during phase 1 and phase 2, respectively (Table 3). Our data were similar to Lumpkins et al. (2005) and Roberson et al. (2005). Both authors conducted experiments with laying hens incorporating up to 15% DDGS with no negative effect on egg production. Świątkiewicz and Koreleski (2006) reported a reduction in egg production for hens fed 20% DDGS in phase 2 of egg production but not in phase 1. Egg production and feed intake results indicate no negative effects of DDGS on hen performance.

Egg weight was affected ($P = 0.064$) by DDGS treatments during phase 1 of egg production (Table 3). Egg weight decreased as DDGS increased in the diets, with a trend for linear response. During phase 2, egg weight was not affected by DDGS levels. The only difference between phase 1 and phase 2 was that diets were formulated on a fixed Lys and TSAA level during phase 1, whereas during phase 2 diets were formulated for a fixed Lys and Met level, allowing TSAA level to increase because of higher predicted Cys levels in DDGS (Tables 1 and 2). The reason for changing amino acid concentration was that DDGS Cys levels were not consistent from DDGS when formulating phase 1 diets for TSAA. For instance, Met, the first-limiting amino acid in poultry, has been reported to range from 0.41 to 0.65% in DDGS samples (Spiehs et al., 2002; Martinez-Amezcua, 2005; Fastinger et al., 2006). The differences in amino acid levels and potential bioavailability as well as changing amino acid balance between phases 1 and 2 could have been the reason for egg weight reduction only during phase 1.

No differences were found in Haugh units (Table 3) among DDGS levels for the entire egg production period (phases 1 and 2). Some reports (Hughes and Hauge, 1945; Waldroup and Hazen, 1979; Lilburn and Jensen, 1984) have shown improvement in Haugh units, whereas others (Lumpkins et al., 2005; Świątkiewicz and Koreleski, 2006; Pineda et al., 2008) have shown

Table 4. Apparent retention of N and P and excretion of fecal N and P from laying hens fed diet containing graded levels of corn dried distillers grains with solubles (DDGS) for phase 2 of egg production

	Corn DDGS, %							*P*-value[2]	
Item	0	5	10	15	20	25	SEM[1]	L	Q
Apparent retention, %									
N	42.79	41.90	46.82	44.38	46.48	51.85	1.644	0.001	0.055
P	21.79	24.30	24.77	24.40	26.17	28.07	2.127	0.035	0.949
Nutrient output, g/kg of DM intake									
N	14.05	15.74	14.62	14.99	13.70	12.05	0.723	0.006	0.004
P	4.72	4.65	4.35	4.64	3.87	4.03	0.186	0.001	0.986

[1]Values are means of 8 replicate cages with 6 birds/cage.

[2]Linear (L) and quadratic (Q) contrasts among DDGS levels.

no change in interior egg quality when DDGS was fed to laying hens.

Specific gravity (an indicator of exterior egg quality) was similar among dietary treatments during both phases 1 and 2. Roberson et al. (2005) reported a linear decrease in specific gravity only at 51 wk of age with increasing dietary DDGS level, which was a limited observation.

Egg yolk color increased linearly ($P < 0.001$; Figure 1) as dietary level of DDGS increased throughout the study, with the greatest Roche color fan score of 7.2 for hens fed 25% DDGS. This indicates that xanthophylls in the DDGS were highly available. Dried distillers grains with solubles provide more xanthophylls than corn with approximately 34 mg/kg (Sauvant and Tran, 2004), which is 3 times the corn xanthophyll content (10.62 mg/kg; NRC, 1981).

Apparent N and P retention and nutrient output are presented in Table 4. A linear increase in N and P retention as DDGS levels increased was observed. The highest inclusion rate of DDGS (25%) had the greatest ($P = 0.0003$) N and P retention. Adeola and Ileleji (2009) reported a reduction in percentage N retention for broiler chicks fed up to 60% corn DDGS, but their formulation allowed CP to increase as DDGS increased. Our data conflict with the data of Adeola and Ileleji (2009), perhaps because diets in this study were kept isonitrogenous as DDGS increased.

The N and P output per kilogram of DMI is shown in Table 4. The N and P output per kilogram of DMI decreased linearly as DDGS increased ($P < 0.01$) in the diets. Our results are in disagreement with Leytem et al. (2008) and Applegate et al. (2009). Both authors reported linear increases in N excreted from broiler chicks as levels of DDGS increased in the diets as a result of higher overall CP levels in broiler compared with layer diets.

Previous research has shown that DDGS is an acceptable ingredient in laying hen diets. Roberson et al. (2005), Lumpkins et al. (2005), and Świątkiewicz and Koreleski (2006) recommend a usage rate of up of 15% DDGS in laying hen diets to maintain egg production. In the current study, results indicated that feeding corn DDGS up to 25% had no negative effect on egg production responses during both phases. However, feeding DDGS at 20 and 25% affected egg weight in phase 1 but not in phase 2. This may have been attributable to changing the amino acid balance from fixed Lys and

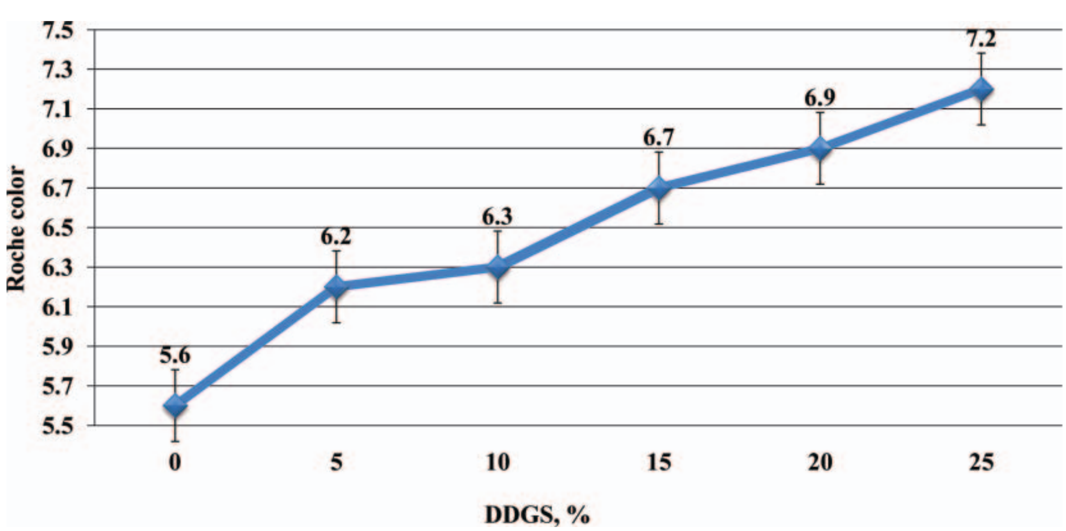

Figure 1. Average yolk color according to the Roche color fan scale for laying hens fed diet containing graded levels of corn dried distillers grains with solubles (DDGS) from 24 to 76 wk of age. A linear increase ($P < 0.0001$) in yolk color score occurred as DDGS levels increased in hens' diet. Color version available in the online PDF.

TSAA in phase 1 to fixed Lys and Met during phase 2. Feeding high inclusion rates of DDGS is possible if attention is given to amino acid balance and availability in the diets containing DDGS. In addition, DDGS can replace corn, soybean meal, dicalcium phosphate, and salt in layer diets to reduce feed costs, but Lys, fat, and limestone percentage increased as DDGS increased in the diets.

ACKNOWLEDGMENTS

The authors thank the in-kind support of Poultry Midwest Federation (Saint Paul, MN) for funding this project and the assistance provided by Alia Aljamal, Pradeep Krishnan, Trish Weber, Ruth Diedrichsen, and Lyle Robeson at University of Nebraska–Lincoln.

REFERENCES

Adeola, O., and K. E. Ileleji. 2009. 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. Poult. Sci. 88:579–585.

Iowa State University Extension. 2005. Agricultural Marketing resource center: Weekly ethanol, distillers grains and corn prices. Accessed 2010. http://www.extension.iastate.edu/agdm/energy/xls/d1-10ethanolprofitability.xls.

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.

AOAC. 1995. Official Methods of Analysis. 16th ed. 5th rev. Association of Analytical Chemists, Gaithersburg, MD.

Centurion Poultry Inc. 2009. Bovans White management guide. Accessed Aug. 10, 2010. http://centurionpoultry.com/managment-guides/1.

Dilger, R. N., and O. Adeola. 2006. Estimation of true phosphorus digestibility and endogenous phosphorus loss in growing chickens fed conventional and low-phytate soybean meals. Poult. Sci. 85:661–668.

Fastinger, N. D., J. D. Latshaw, and D. C. Mahan. 2006. Amino acid availability and true metabolizable energy content of corn distillers dried grains with solubles in adult cecectomized roosters. Poult. Sci. 85:1212–1216.

Haugh, R. R. 1937. The Haugh units for measuring egg quality. US Egg Poult. Mag. 43:552–555.

Hughes, C. W., and S. M. Hauge. 1945. Nutritive value of distillers' dried solubles as a source of protein. J. Nutr. 30:245–258.

Jensen, L. S. 1978. Distillers feeds as sources of unidentified factors for laying hens. Pages 17–22 in Proc. Distillers Research Conf., Louisville, KY. Distillers Grains Tech. Council, Louisville, KY.

Jensen, L. S. 1981. Value of distillers dried grains with solubles in poultry feeds. Pages 87–93 in Proc. Distillers Research Conf., Cincinnati, OH. Distillers Grains Tech. Council, Louisville, KY.

Leytem, A. B., P. Kwanyuen, and P. Thacker. 2008. Nutrient excretion, phosphorus characterization, and phosphorus solubility in excreta from broiler chicks fed diets containing graded levels of wheat distillers grains with solubles. Poult. Sci. 87:2505–2511.

Lilburn, M. S., and L. S. Jensen. 1984. Evaluation of corn fermentation solubles as a feed ingredient for laying hens. Poult. Sci. 63:542–547.

Lumpkins, B., A. Batal, and N. Dale. 2005. Use of distillers dried grains plus solubles in laying hen diets. J. Appl. Poult. Res. 14:25–31.

Martinez-Amezcua, C. 2005. Nutritional evaluation of corn distillers dried grains with solubles (DDGS) for poultry. PhD Diss. University of Illinois, Champaign.

National Research Council. 1981. Feeding Value of Ethanol Production By-Products. National Academy Press, Washington, DC.

National Research Council. 1994. Nutrient Requirements of Poultry. 9th ed. National Academy Press, Washington, DC.

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

Pineda, L., S. Roberts, B. Kerr, R. Kwakkel, M. Verstegen, and K. Bregendahl. 2008. Maximum dietary content of corn dried distiller's grains with solubles in diets for laying hens: Effects on nitrogen balance, manure excretion, egg production, and egg quality. Iowa State University Animal Industry Report 2008. AS leaflet R2334. Iowa State University, Ames.

Renewable Fuels Association. 2011. Industry resources: Co-products. Accessed Mar. 2011. http://www.ethanolrfa.org/pages/industry-resources-coproducts.

Roberson, K. D., J. L. Kalbfleisch, W. Pan, and R. A. Charbeneau. 2005. Effect of corn distillers dried grains with solubles at various levels on performance of laying hens and yolk color. Int. J. Poult. Sci. 4:44–51.

SAS Institute. 2008. SAS User's Guide: Statistics. Version 9.2 ed. SAS Institute Inc., Cary, NC.

Sauvant, D., and G. Tran. 2004. Corn distillers. Page 118 in Tables of Composition and Nutritional Value of Feed Materials. D. Sauvant, J.-M. Perez, and G. Tran, ed. Wageningen Academic Publishers, Wageningen, the Netherlands.

Schilling, M. W., V. Battula, R. E. Loar II, V. Jackson, S. Kin, and A. Corzo. 2010. Dietary inclusion level effects of distillers dried grains with solubles on broiler meat quality. Poult. Sci. 89:752–760.

Schneider, B. H., and W. P. Flatt. 1975. The Evaluation of Feeds Through Digestibility Experiments. University of Georgia Press, Athens.

Shurson, G.C., C. Santos, J. Aguirre, and S. Hernández. 2003. Effects of feeding Babcock B300 laying hens conventional Sanfandila layer diets compared to diets containing 10% Norgold DDGS on performance and egg quality. A commercial field trial sponsored by the Minnesota Corn Research and Promotion Council and the Minnesota Department of Agriculture, St. Paul, MN.

Spiehs, M. J., M. H. Whitney, and G. C. Shurson. 2002. Nutrient database for distillers dried grains with solubles produced from new ethanol plants in Minnesota and South Dakota. J. Anim. Sci. 80:2639–2645.

Świątkiewicz, S., and J. Koreleski. 2006. Effect of maize distillers dried grains with solubles and dietary enzyme supplementation on the performance of laying hens. J. Anim. Feed Sci. 15:253–260.

Waldroup, P. W., and K. R. Hazen. 1979. Examination of corn dried steep liquor concentrate and various feed additives as potential sources of a Haugh unit improvement factor for laying hens. Poult. Sci. 58:580–586.

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.

Williams, C. H., D. J. David, and O. Iismaa. 1962. The determination of chromic oxide in faeces samples by atomic absorption spectrometry. J. Agric. Sci. 59:381–385.