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Effect of Corn Distiller's Dried Grains with Solubles at Various Levels on Performance of Laying Hens and Egg Yolk Color

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Abstract: Distiller's dried grains with solubles produced from corn as a co-product from ethanol production was fed at 0, 5, 10, or 15% of a corn-soybean meal diet to laying hens to determine if egg production parameters or yolk color would be affected. In experiment 1, diets were fed from 48 to 56 wk of age and DDGS had a goldenrod color. Egg production, weight, mass, specific gravity and yolk color were determined biweekly. Brown colored DDGS was included in diets fed from 58 to 67 wk of age. Egg production parameters and yolk color were measured tri-weekly. Egg production parameters were not different at most ages. However, there were occasional treatment effects. As DDGS increased, there were linear decreases in egg production (52-53 wk of age), egg weight (63 wk of age), egg mass (51 and 53 wk of age), and specific gravity (51 wk of age). Yolk color was increased linearly ($p<0.01$) as DDGS was increased in the diet throughout experiment 1. In experiment 2, yolk redness (a*) was increased linearly ($p<0.001$) by increasing levels of DDGS at all ages sampled. The results show that egg yolk is visually changed within one month when 10% or higher of a lightly colored DDGS is fed and by two months with 5% DDGS. In general, corn DDGS up to 15% of the diet did not affect egg production. However, variable results of experiment 1 suggest that a lower level of DDGS should be fed when the feedstuff is introduced in the diet.

Key words: Distiller's dried grains with solubles, layer, yolk color

Introduction

Expansion of the ethanol industry is creating an ever increasing supply of DDGS. This by-product of ethanol production is considered a "co-product" by companies producing ethanol since each bushel of corn results in approximately equal portions of ethanol, DDGS and CO_2. It is estimated that by 2005, 7 million metric tons of DDGS will be available (Noll *et al*., 2001). Hence, there is an opportunity to utilize fuel derived DDGS in poultry diets in an economical manner.

Distiller's dried grains with solubles have been available as a feedstuff for poultry for many decades primarily from the beverage industry. Early use of DDGS showed growth performance benefits in various species of poultry and was often associated with "unidentified growth factors" (Noll *et al*., 2001). Early research with DDGS showed that it was a good source of riboflavin and thiamine (D'Ercole *et al*., 1939) and that most of the riboflavin is found in the solubles fraction (Sloan, 1941). Use of DDGS in poultry diets has historically been about 5% due to limitations such as supply and pricing of the product (Waldroup *et al*., 1981) and variability in nutrient content and digestibility (Noll *et al*., 2001).

Matterson *et al*. (1966) reported that DDGS could be fed in laying hen diets at 10 to 20% without affecting egg production with no supplementation of lysine. The inclusion of DDGS in the diet accounted for one-third of the protein provided to the birds. Harms *et al*. (1969) reported that 10% DDGS in a layer diet to replace a portion of the dietary protein did not affect egg production or egg weight. Jensen *et al*. (1974) observed that DDGS had a positive effect on egg interior quality (increased Haugh units), although this was not a consistent response. The authors focused on wheat-soybean meal diets in which less soybean meal was included in the diet as levels of DDGS were fed relative to a corn-soybean meal diet due to the higher protein content of wheat. When wheat was the primary energy source in the ration, supplemental lysine was needed to maintain egg production when 10% DDGS was fed compared to the control group. Alenier and Combs (1981) found that laying hens preferred diets with 10 or 15% DDGS compared to a corn-soybean meal diet without DDGS.

Lumpkins *et al*. (2003) reported on the use of DDGS in laying hens diets fed DDGS from "New Generation" plants. This new process involves a gentler drying process than DDGS produced by earlier technology. The authors fed laying hens DDGS at 0 or 15% from 21 to 43 wk of age. The researchers found no detrimental effect on egg production or quality of the egg or shell due to feeding 15% DDGS in the diet. However, no effects on egg yolk color were observed. Yolk color was measured with a Chroma Meter on intact yolks (B.Lumpkins, personal communication).

One objective of this study was to evaluate the level of corn DDGS that could be fed effectively to laying hens in post-peak production to maintain important economic egg parameters. Other objectives were to evaluate the proper ME value for DDGS to use in layer diets and the impact of various levels of DDGS on egg yolk color.

Materials and Methods

The DDGS used for this study was procured from an ethanol plant[1] and is identified commercially as Dakota Gold PLUS™[2]. The product used for experiment 1 was a goldenrod color while the DDGS used in experiment 2 was a brown color (suggestive of overheating during processing). Nutrient analyses of the two samples of DDGS are provided in Table 1. Analysis of xanthophyll content at a commercial laboratory[3] showed that there was a large measurable difference between the two samples (29.75 vs. 3.48 mg/kg) although proximate analysis of the feedstuffs showed little difference in nutrient content. Although the color of the sample does not affect measurement of xanthophyll content, changes in the processing of distiller's grains (i.e., overheating) may result in binding of xanthophyll to other compounds as oxidation products that could change the polarity of the compound being measured. This could result in partial or total passage through the column measuring xanthophyll content (T. Mawhinney, personal communication). Values for xanthophyll content of corn DDGS have been reported as 10.62 mg/kg (NRC, 1981) and 34.00 mg/kg (Sauvant and Tran, 2004). The xanthophylls value for solubles only has been reported at 2.37 mg/kg (NRC, 1981).

The birds used in the study (Hy-Line W36[4]) had previously been used for another study in which some of the birds had been fed a very low level of available phosphorus. After a four-week recovery period in which all birds were fed adequate phosphorus, the birds were allocated to levels of 0, 5, 10 or 15% DDGS (Table 2) making sure that birds were evenly distributed among treatments relative to treatments in the previous trial in case there were long-term carryover effects as well as on the basis of egg production levels the week prior to commencement of the study. The ME value used for DDGS in the study was 2750 kcal/kg which is 13.5% higher than suggested by the National Research Council (NRC, 1994). The diets were formulated similar to Hy-Line Commercial Management Guide[4] recommendations for 95 gram/day consumption in experiment 1 and 100 grams/day in experiment 2. All nutrients not specified by the management guide were fed at levels that met or exceeded NRC (1994) recommendations. The birds were 47 weeks old at the beginning of experiment 1 and had an average hen-day egg production of 85% the week before experiment 1 began. The diets were fed for approximately 5 weeks per batch mix. Sufficient corn and soybean meal were available in storage at the feed mill so that these feedstuffs would not come from different sources during the study. There were 6 rows of 40 birds each at the beginning of experiment 1. Each row contained 10 cages of 4 birds each and cage size was 41.0 cm X 51.3 cm to provide 526 cm^2 per bird. This cage density level met animal care standards at the University which require that all birds have at least 464 cm^2 of cage space (Federation of Animal Science Societies, 1999). Feed was provided by hand feeding in a trough for each row on a daily basis and birds in two adjoining cages shared a water cup. Manure was scraped from beneath the cages each day and removed from the house. Eggs were collected daily each morning. Room temperature was maintained at 19.4°C. Mortality was checked daily. Between experiments, all birds were fed the control corn-soybean meal diet for 9 days. Treatments were reallocated so that the same row of birds were not fed the same treatment in experiment 2 as in experiment 1 and egg production levels among treatments were equal. There were 38 birds per row in experiment 2 (2 of 10 cages in each row had 3 birds) and the experiment was conducted similarly to experiment 1.

Table 1: Nutrient analyses of corn distiller's dried grains with solubles (DDGS) samples used in experiments 1 and 2 (as fed basis)

	Experiment 1	Experiment 2
Crude protein[1] (%)	27.15	25.58
Ether extract[1] (%)	11.78	10.52
Crude fiber[1] (%)	6.34	6.38
Ash[1] (%)	4.36	4.36
Moisture[1] (%)	11.62	15.20
Xanthophyll[2] (mg/kg)	29.75	3.48
TMEn[3] (kcal/kg)	2,894	2,874

[1]Average analyses from University of Missouri Experiment Station Chemical Laboratory and University of Georgia Poultry Nutrition Laboratory. [2]Analyzed at University of Missouri Experiment Station Chemical Laboratory. [3]Analyzed at University of Georgia Poultry Nutrition Laboratory.

Egg production was averaged for every 2 wk in experiment 1 except for the last 3 wk which were averaged together. Egg production in experiment 2 was averaged for every 3 wk except for the last 4 wk which were averaged together. Egg production was averaged because weekly egg production numbers varied due to differences in time of egg collection by research farm employees. The egg production data are presented in a manner that matches collection of measurements of egg weight and specific gravity. Thirty eggs per row were collected the in the morning at the end of the week at 49, 51, 53 and 55 weeks of age in experiment 1 and at 61, 64 and 67 weeks of age in experiment 2 for measurement of egg weight and specific gravity. Feed intake was measured at the end of each experiment by weighing back all uneaten feed allocated to each row of birds. Feed conversion was calculated by dividing feed intake by egg mass produced per row.

Ten eggs from each row were chosen at random for yolk color measurement. In experiment 1, a Roche Yolk Colour Fan Edition 1965[5] was used to subjectively measure yolk color (Vuilleumier, 1969) on a glass plate with heavy white paper placed underneath the glass as a neutral background. The eggs were kept in the same

Table 2: Composition of the experimental diets with various levels of corn distiller's dried grains with solubles (DDGS)

	Experiment 1				Experiment 2			
	(% DDGS)				(% DDGS)			
Ingredients	0	5	10	15	0	5	10	15
Corn	64.00	61.17	58.33	55.50	67.59	64.92	62.26	59.59
Soybean meal (dehulled)	22.10	19.80	17.50	15.20	19.50	17.06	14.62	12.18
DDGS	0.00	5.00	10.00	15.00	0.00	5.00	10.00	15.00
Limestone	9.73	9.74	9.75	9.76	10.13	10.13	10.13	10.14
Monodicalcium phosphate	1.40	1.34	1.28	1.22	1.17	1.12	1.06	1.00
Salt	0.41	0.39	0.37	0.34	0.41	0.39	0.37	0.35
Vitamin premix1	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[2]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
DL-methionine	0.19	0.18	0.17	0.16	0.14	0.13	0.12	0.11
L-lysine-HCl	0.05	0.10	0.16	0.21	0.06	0.11	0.17	0.22
Calculated nutrient level								
Crude protein, %	16.00	16.00	16.00	16.00	15.00	15.00	15.00	15.00
ME, (kcal/kg)	2,850	2,850	2,850	2,850	2,816	2,816	2,816	2,816
Lysine, %	0.80	0.80	0.80	0.80	0.74	0.74	0.74	0.74
TSAA, %	0.65	0.65	0.65	0.65	0.58	0.58	0.58	0.58
Calcium, %	4.00	4.00	4.00	4.00	4.10	4.10	4.10	4.10
Phosphorus, %	0.59	0.59	0.59	0.59	0.54	0.54	0.54	0.54

[1]Vitamin premix provided per kg diet: vitamin A (all-trans-retinyl acetate), 8,000 IU; cholecalciferol, 2,500 ICU; vitamin E (all-rac-" tocopherol acetate), 8 IU; menadione (as menadione sodium bisultite), 1.0 mg; riboflavin, 5 mg; Ca pantothenate, 10 mg; nicotinic acid, 35 mg; vitamin B12, 0.01 mg; vitamin B6, 2.0 mg; thiamin (as thiamin mononitrate), 1.0 mg; folic acid, 0.5 mg; biotin, 0.05 mg; and ethoxyquin, 125 mg. [2]Mineral premix supplied per kg of diet: manganese, 65 mg; zinc, 55 mg; iron, 55 mg; copper, 8 mg; iodine, 1 mg; and selenium, 0.3 mg.

room were specific gravity and egg weight were determined. A portable fluorescent light was used to provide supplemental diffuse light in the room. In experiment 2, the eggs were moved to a larger room after egg weight measurement that had fluorescent lights overhead and additional light from a window in the room in order to use the equipment needed to make objective measurements of the egg yolks. Egg yolks were separated from albumen and placed into clear plastic 100 mm x 15 mm Petri dishes with heavy white paper placed underneath. A Minolta Chroma Meter CR-310[6] was used to measure lightness (L*), redness (a*) and yellowness (b*) every three weeks. A standard white calibration plate[7] was used to calibrate the Chroma Meter. Yolk reflective color was determined from the average of three consecutive pulses from the optical chamber of the Chroma Meter. The Roche fan was also used at 6 and 9 weeks into experiment 2 to compare with results of experiment 1. The Roche fan was used on intact yolks as in experiment 1 for visual analysis and then the yolks were scrambled to mix concentric layers of egg yolk (Mountney and Parkhurst, 1995) for objective analysis with the Chroma Meter. An extension was screwed onto the end of the Chroma Meter which kept the yolk about 7.5 cm from the optical chamber of the Chroma Meter and blocked all outside light from the measured area of the yolk.

During the first experiment, 24 extra hens (12/treatment) that were consuming the control diet were individually caged and given either the control diet or a mix of 85% control diet/15% DDGS to estimate nitrogen-corrected apparent metabolizable energy (AME_n) of DDGS. The level of 15% DDGS represented the highest treatment level in this study which followed the substitution method described by Pesti *et al*. (1986). Four birds shared the same feed trough, so there were 3 replications of 4 birds for each treatment. Water was provided for each cage with a nipple waterer. Following a one week adaptation period, excreta was collected from underneath each bird daily for 3 days. Excreta samples were pooled for birds sharing the same feed trough and freeze dried. A second evaluation was done similar to the first evaluation in which Celite™[8] (cellulose) was used as a marker at 1.5% of the diet to evaluate AME instead of using the total collection technique. Diets and excreta were analyzed for dry matter, acid insoluble ash (Vogtmann *et al*., 1975), gross energy[9], and nitrogen[10]. Calculation of AME_n for the control reference diet and substituted diet were calculated as described by Hill and Anderson (1958).

The data were analyzed by ANOVA with the general linear models procedure of SAS (SAS, 2003) using row as the experimental unit. Treatment means were separated by the Student-Newman-Kuels test. Regression analyses on levels of DDGS were performed to test for linear or quadratic effects. Statistical significance was assumed at $p<0.05$.

Results

In experiment 1, egg production was decreased linearly

Table 3: Effect of corn distiller's dried grains with solubles (DDGS) on egg production and shell quality (experiment 1)

DDGS	Egg Production (%)				Egg weight (g)				Egg mass (g/hen/d)				Specific gravity			
(%)	48-49	50-51	52-53	54-56	49	51	53	55	49	51	53	55	49	51	53	55
	(wk)															
0	86.6	84.6	86.8	82.4	63.6	64.6	64.4	63.8	55.0	54.7	55.9	52.6	1.081	1.082[a]	1.078	1.078
5	84.8	83.2	85.6	82.7	63.4	63.9	64.5	64.3	53.8	53.2	55.2	53.2	1.080	1.080[b]	1.078	1.078
10	85.2	82.9	84.4	82.5	62.6	63.6	63.8	64.0	53.4	52.8	53.9	52.8	1.080	1.080[b]	1.078	1.078
15	85.1	82.7	84.2	82.6	63.0	63.8	64.2	64.2	53.6	52.7	53.9	52.8	1.080	1.080	1.078	1.078
SEM	1.0	0.9	0.7	0.7	0.5	0.4	0.4	0.4	0.6	0.7	0.6	0.6	0.001	0.001	0.001	0.001
ANOVA																
	Probabilities															
Source df																
DDGS 3	NS	NS	0.06	NS	NS	NS	NS	NS	NS	NS	0.10	NS	NS	0.02	NS	NS
Regression analysis																
Linear 1	NS	NS	0.01	NS	NS	0.10	NS	NS	0.09	0.05	0.02	NS	NS	0.01	0.09	NS
Quadratic 1																

a-b Means with no common superscript are significantly different (p<0.05).

Table 4: Effect of corn distiller's dried grains with solubles (DDGS) on egg production and shell quality (experiment 2)

DDGS	Egg Production (%)			Egg weight (g)			Egg mass (g/hen/d)			Specific gravity		
(%)	58-60	61-63	64-67	60	63	66	60	63	66	60	63	66
	(wk)											
0	82.1	80.7	78.8	65.6	66.5	65.4	53.9	53.7	51.5	1.079	1.079	1.078
5	83.5	82.6	80.6	64.5	64.8	65.5	53.9	53.5	52.8	1.079	1.078	1.078
10	82.1	79.9	78.5	65.0	65.1	64.9	53.4	52.0	51.0	1.078	1.079	1.078
15	82.7	81.7	80.3	64.3	64.6	65.8	53.2	52.8	52.9	1.078	1.078	1.078
SEM	0.6	0.7	0.9	0.4	0.5	0.4	0.5	0.6	0.6	0.001	0.001	0.001
ANOVA												
	Probabilities											
Source df												
DDGS 3	NS	0.09	NS	NS	0.06	NS	NS	NS	NS	NS	NS	NS
Regression analysis												
Linear 1	NS	NS	NS	0.08	0.03	NS	NS	NS	NS	NS	NS	NS
Quadratic 1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 5: Effect of corn distiller's dried grains with solubles (DDGS) on yolk color

DDGS		Experiment 1				Experiment 2										
(%)		49	51	53	55	60			63				66			
								(wk)								
		(Roche[1])				L*[2]	a*	b*	L*	a*	b*	Roche	L*	a*	b*	Roche
0		7.76[b]	7.79[b]	6.81[b]	7.39[b]	77.3	1.52[c]	88.2	82.0[a]	2.84[b]	93.2[a]	8.35	77.9[a]	2.70[d]	88.1	8.63[b]
5		7.90[b]	7.81[b]	7.17[b]	7.86[a]	76.9	2.62[b]	88.3	80.6[ab]	4.36[a]	92.6[a]	8.43	75.9[b]	4.19[c]	86.7	8.98[a]
10		8.29[a]	8.00[a]	7.60[a]	7.86[a]	76.7	3.54[a]	88.3	80.3[ab]	4.39[a]	91.0[ab]	8.73	76.2[b]	4.74[b]	87.5	9.02[a]
15		8.22[a]	8.00[a]	7.89[a]	8.02[a]	76.6	4.07[a]	88.1	78.2[b]	5.27[a]	86.8[b]	8.53	75.9[b]	6.11[a]	87.7	9.22[a]
SEM		0.07	0.05	0.13	0.09	0.3	0.31	0.3	0.7	0.29	1.5	0.19	0.4	0.19	0.6	0.08
ANOVA																
		Probabilities														
Source	df															
DDGS	3	0.001	0.004	0.001	0.001	NS	0.001	NS	0.02	0.001	0.04	NS	0.004	0.001	NS	0.001
Regression analysis																
Linear	1	0.001	0.001	0.001	0.001	0.07	0.001	NS	0.002	0.001	0.007	NS	0.007	0.001	NS	0.001
Quadratic	1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

a-dMeans with no common superscript are significantly different (p<0.05). 1Roche color scores are based upon Roche Colour Fan Edition 1965.
2L*=lightness, a*=redness, b*=yellowness using a Minolta Chroma Meter.

(p<0.008) as DDGS was increased in the diet when hens were 52-53 wk of age (Table 3). However, there were no significant effects of DDGS on egg production during the other three periods of the experiment. Egg weight was not affected by diet in experiment 1. However, there were linear decreases (p<0.05) in egg mass at 51 and 53 wk of age as DDGS increased in the diet. Shell quality was adequate for all treatments throughout the experiment. However, specific gravity was higher (1.082) compared to the DDGS treatments (~1.080) at 51 wk of age. This difference is not of practical importance to the egg industry since shell quality was adequate for all the other treatments.

Egg production was not affected by treatment in experiment 2 (Table 4). Egg weight was decreased linearly (p<0.029) by DDGS levels at 64 wk of age, but was not different at 61 or 67 wk of age. However, egg mass was not affected throughout experiment 2. Specific gravity was also not affected by treatment in experiment 2.

Yolk color score was increased linearly (p<0.001) by increasing dietary DDGS at each measurement in experiment 1 as measured subjectively with a color fan (Table 5). Specifically, 10 or 15% DDGS increased (p<0.005) yolk color score throughout experiment 1 when individual treatments were compared. The inclusion of 5% DDGS began to impact yolk color during the second half of experiment 1 and resulted in significantly darker egg yolks after 8 wk of feeding. In experiment 2, redness (a*) was increased (p<0.001) by inclusion of 5% DDGS throughout the trial and was typically further increased by inclusion of 10% DDGS. However, it was difficult to detect darker yolks with the color fan from all rows in which birds were fed DDGS at 64 wk of age. At 67 wk of age, there was a clear stepwise increase in redness of the yolks as DDGS levels increased. Lightness (L*) of the yolk was decreased linearly (p<0.002) at 64 wk of age and at the end of the trial by feeding DDGS at any level (p<0.004). Differences in lightness/darkness could also be detected easily with the color fan at the end of study as yolk color score increased linearly (p<0.001) with increasing levels of dietary DDGS.

Feed intake and conversion were not affected by treatment in either experiment. Feed intake was 108.7, 109.8, 107.5, or 107.1 g/hen/d for 0, 5, 10, or 15% inclusion of DDGS in experiment 1 (SEM=1.3). Feed intake was 115.5, 115.9, 112.9, or 113.6 g/hen/d for 0, 5, 10, or 15% DDGS in experiment 2 (SEM=1.3). Feed conversion was 1.99, 2.04, 2.02, or 2.01 g feed:g egg for 0, 5, 10, or 15% DDGS, respectively, in experiment 1 (SEM=0.02). Feed conversion was 2.18, 2.17, 2.18, or 2.15 for 0, 5, 10, or 15% DDGS in experiment 2 (SEM=0.03). Hence, the ME value used for DDGS (2750 kcal/kg) did not affect feed intake or

feed conversion. Actual feed intake was about 13 g/d higher than feed formulation specifications (108 g/d or 113 g/d in experiments 1 or 2, respectively). Both AME_n collections (marker and total collection methods) indicated that the AME_n of corn DDGS was about 2770 kcal/kg for laying hens and validates the ME value used in these studies. The determined AME_n value is about 95% of the true ME value for the DDGS samples determined prior to the AME_n study by an adult cockerel assay[11].

Discussion

The results in general show that DDGS can be successfully fed at levels as high as 15% in a post-peak laying hen diet which agrees with previous research (Matterson *et al*., 1966; Lumpkins *et al*., 2003) using an ME value higher than the NRC (1994) value without having a detrimental effect on egg production or shell quality. Harms *et al*. (1969) used an ME value of 2640 kcal/kg in their studies and suggested that the actual ME value of DDGS may be higher. The lack of a feed intake effect in the feeding trials and the results of the AME study agree with the suggestion of Harms *et al*. (1969) and provide support for using 2750 kcal/kg as an ME value for DDGS which is 13.6% higher than the ME value suggested for poultry by the NRC (1994). The absence of a feed intake effect does not agree with the report of Alenier and Combs (1981) who suggested that laying hens would eat more feed when 10% DDGS is fed due to preference of the diet over a corn-soybean meal diet. The occasional linear decreases in egg production parameters in experiment 1 suggest that DDGS may need to be included in a layer diet at a lower level such as 5% to introduce the new ingredient to the birds.

The diets for this study were formulated on a total amino acid basis. Digestibility of lysine is a variable that needs to be monitored in DDGS as it can be quite variable especially when color is different. If a light ("golden") color is maintained, digestibility of lysine will likely not be a serious issue for the inclusion of DDGS at 15% or below. Recent research has shown that digestibility of lysine can be over 80% when the color of DDGS is light (Ergul *et al*., 2003). However, digestibility may be low (<60%) when the DDGS is dark (Ergul *et al*., 2003). The NRC (1994) estimate of digestibility of lysine in DDGS is 65%. Feed intake in the current study was 108 grams/day in experiment 1 and 113 grams/day in experiment 2 with no treatment effect on feed intake or conversion. According to the results, the level of digestible lysine available to the birds was generally adequate in the study. However, the linear decrease in egg weight at 64 wk of age as dietary DDGS increased may indicate that digestible methionine was limiting (Schutte and van Weerden, 1978) on a temporary basis when the DDGS was dark.

Previous research showed no effect of DDGS on shell thickness or breaking strength when added at 10% to a corn-soybean meal based diet (Jensen *et al*., 1978). Lumpkins *et al*. (2003) also reported no effect of DDGS on shell breaking strength when fed at 15% of the diet. The general lack of an effect of dietary DDGS on specific gravity in the current study agrees with Lumpkins *et al*. (2003).

The results showed that intact yolk color can be enhanced quickly with a diet containing 10% DDGS of a light color and yolk will have a darker (deep yellow or light orange) color after about two months when 5% DDGS is fed to birds previously fed a corn-soybean meal diet with no additional pigments. Egg yolk color can also be darkened visually when DDGS is a dark color, but will require more time. The results do not agree with the report of Lumpkins *et al*. (2003), but does agree with earlier studies with corn by-product feedstuff (Sullivan and Holleman, 1962). The preparation of the egg yolk by scrambling the concentric layers of the yolk together is the preferred method for measuring yolk color (Vuilleumier, 1969). The undisturbed yolk has a glossy appearance and is difficult to measure objectively (Vuilleumier, 1969). Ashton and Fletcher (1962) found that the color of broken yolk is not the same as whole yolk when evaluated chemically or visually. Redness (a*) was the most accurate measurement to distinguish changes in scrambled yolk color when varying levels of DDGS were fed. Herber-McNeill and Van Elswyk (1998) found that the a* measurement was more accurate for detecting differences in yolk color than L* or b* values. A reduction in yellowness (b*) was detected at 64 wk of age when 15% DDGS was fed. There was a noticeable decrease in b* values in two of the six replications (75.6 and 83.3) and the values were consistent within row. However, lower (<8.40) Roche color fan scores for replications within this dietary treatment were not the same as replications in which b* values were lower. The fact that egg yolk was changed even though the xanthophylls content of the dark DDGS was measured to contain only 3.5 mg/kg was surprising and results in a question of accuracy of the AOAC method used to measure free xanthophylls when DDGS goes through a deviation of normal processing. Although the method is not compromised by feedstuff color, xanthophylls may be bound at hydroxyl groups such that there is a low measurement of isolated xanthophylls content, but some carotenoid pigments from bound xanthophylls are still available to hens for deposition into yolk when dark DDGS is consumed.

The Roche scores of yolks from eggs of hens fed the control corn-soybean meal were 8.35 to 8.63 in experiment 2 compared to values of 6.81 to 7.79 in experiment 1. The difference in overhead lighting in the two rooms in which the values were determined could have influenced the scoring of the yolks between the two experiments (Vuilleumier, 1969). The egg yolks were

evaluated in a larger room that had more available light in experiment 2 to have space to use the Minolta chromameter with a row of individual Petri dishes containing egg yolks.

The economic benefit of feeding DDGS to poultry will depend on prices of other feedstuffs, especially soybean meal. Recent prices quoted for the Chicago market[12] for corn, high-protein soybean meal, distillers dried grains and choice white grease would result in a decrease in feed cost of $2.20 U.S. dollars per ton of feed for every 5% inclusion of DDGS according to the formulations used in the present study. The results show that supplementation of a layer diet with DDGS can be a cost effective means to darken yolks for the shell egg market in some countries outside the U.S. (Titus *et al*., 1938) that value a darker intact egg yolk and in the breaker market in the U.S. for production of products such as noodles and cake mixes (Titus *et al*., 1938; Sullivan and Holleman, 1962).

The results of this study provide relevant information to egg producers and nutritionists on the use of fuel derived DDGS from a source in which facilities were constructed with newer engineering technology. The nutrient profile of DDGS within and between ethanol plants can vary and a complete chemical analysis should be conducted at least annually to account for differences in nutrient composition due to the corn crop (Spiehs *et al*., 2002). The current study suggests that DDGS can be fed in layer diets at a level as high as 15% and yolk color will be darkened regardless of DDGS color.

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[1]Michigan Ethanol, Caro, MI.
[2]Dakota Gold Marketing, Scotland, SD.
[3]Experiment Station Chemical Labs, University of Missouri, Colombia, MO.
[4]Hy-Line International, West Des Moines, IA.
[5]Hoffman-La Roche, Inc., Nutley, NJ.
[6]Minolta Corporation, Ramsey, NJ.
[7]Reference number 19433053.
[8]Celite™, a diatomite product, Food Chemical Codex Grade. Celite Corp., Lompar, CA.
[9]Oxygen bomb calorimeter, Parr Instrument Company, Inc., Moline, IL.
[10]Leco Nitrogen Analyzer, Leco Corp., St. Joseph, MI.
[11]Dr. Nick Dale, Department of Poultry Science, University of Georgia, Athens, GA.
[12]Feedstuffs, August 23, 2004, Minnetonka, MN.