Effects of Corn Distiller's Dried Grains with Soluble on the Productive Performance and Egg Quality of Laying Hens

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INTRODUCTION

DDGS is considered as a "co-product" of fuel ethanol production since each bushel of corn results in approximately equal portion of ethanol and DDGS after processing. Expansion of the fuel ethanol industry is creating an ever increasing supply of DDGS in the US. There is an opportunity to economically utilize the fuel derived DDGS in poultry diets.

With about 10% fat and 27% crude protein, the caloric value of DDGS produced by these fuel ethanol plants with new technology was found to be 2820 kcal/kg for poultry in average using the TME_n assay (Dale & Batal, 2003). The amino acids of these "new generation" DDGS are highly digestible (Ergul et. al. 2003; Lumpkins et. al. 2003b). DDGS contains highly available phosphorous (Kalbfleisch and Roberson, 2005; Lumpkins, et. al., 2003a) and fermentative metabolites of yeast.

To improve the yolk color, marigold extract is regularly used in the diets of laying hens (Troche, et. al., 2003). DDGS, containing 20 to 30 mg of xanthophylls per kilogram (Lu & Chen, 2005; Roberson, et. al., 2004), can be a natural feedstuffs that provides xanthophylls and nutrients for egg-producing poultry simultaneously (Noll et al., 2001). Several new studies using new ethanol-derived DDGS for laying hen were published in the recent years. Roberson et. al., (2004) concluded that up to 15% of ethanol-derived DDGS can be used in laying hen diets without reducing egg production and the yolk color was linearly improved as the amount of DDGS increased in the diets. Commercial feeding trial in Mexico proved that adding 10% DDGS significantly improved egg production and egg yolk color (Shurson, 2003). In contrast, Lumpkins et. al., (2003c) suggested that adding 15% DDGS in laying hen diets did not significantly influence yolk color and shell breaking strength.

The objective of this study is to evaluate the effects of DDGS on the productive performance and egg quality of laying hens.

MATERIAL AND METHODS

1. Facilities and management

The trial was conducted in the experimental barn of Livestock Research Institute, Taiwan. The experimental barn was equipped with forced ventilation cooling system. At 10 weeks of age, the pullets were randomly allocated into the individual cage. The dimension of the cage was 30 × 36 × 42 cm. There were 2 rows of cages for 4 dietary treatments. Each row had 180 cages to hold the 3 replicates of the same treatment with 2 empty cages between the replicates. The automatic water nipples were used for water supply.

The DDGS was imported from the US in May, 2006 by container for this trial. Sufficient amount of DDGS from the same container was re-packed into 50kg bag and was refrigerated for this trial. The diets were mixed according to the formulation (Table 1) and were refrigerated in 25kg bags. During laying period, hens were raised in an individual cage with feed and water provided *ad libitum*.

2. Experimental animals and feeding program

Two hundred and forty Hy-Line egg-type layers were used in this study. They were randomly assigned into four treatments with three replicates in each treatment. There were 20 hens in each replicate.

Between 10-18 weeks of age, hens were on the diet with ME 2900 kcal/kg and CP 15%. Between 19-22 weeks of age, hens were on the diet with ME 2900 kcal/kg and CP17%. From 23 to 42 weeks of age, hens were randomly assigned into four treatments and were fed with the iso-caloric (ME 2900 kcal/kg) and iso-nitrogenous (CP15%) diets (NRC, 1994). The four treatments were as follows (Table 1):

(1) Control diet without DDGS added (0%DDGS).
(2) Diet with 6% DDGS added (6%DDGS).
(3) Diet with 12% DDGS added (12%DDGS).
(4) Diet with 18% DDGS added (18%DDGS).

3. Measurements and data collection

(1) Samples of DDGS and laying period diets of each treatment were collected and refrigerated for proximate composition analysis (AOAC,1994).
(2) During the laying period (23 to 42 weeks of age), egg production (laying percentage and egg mass) was recorded daily from the day of first egg. Feed intake and feed conversion efficiency were determined for five consecutive days in a four-week interval. Laying hens were weighed individually to determine the body weight change during each sampling period.

(3) Egg and eggshell quality analysis were completed within 24h of the eggs being laid. Egg quality was determined for two consecutive days in a four-week interval. Eggshell breaking strength (measured by quasistatic compression), shell weight and thickness were measured. The proportion of shell and yolk were calculated as the ratio of each component to egg weight (W), expressed as percentage. Specific gravity of eggs was measured. The interior quality of the eggs was assessed as albumen height (H) and Haugh Unit (Haugh, 1937)

$$\text{Haugh Unit} = 100 \times \log [H - 1.7(W)^{0.37} + 7.6]$$

(4) Egg yolk color was measured for two consecutive days in a four-week interval. Egg yolks were separated from albumen and placed into clear plastic 100 mm x 15 mm Petri dishes with heavy white paper placed underneath. Minolta Chroma Meter (DrLange MC reflectance colorimeter) was used to measure the lightness (L*), redness (a*), and yellowness (b*) of yolk color every four weeks. A standard white calibration plate 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.

(5) Blood samples were taken from 12 hens randomly selected from each replicate of each dietary treatment at intermediate times. Samples were taken from heparinised blood adopted kit method for analysis of total protein, uric acid , calcium, inorganic phosphate, cholesterol and triglyceride by Automatic Analyzer (HITACHI 7176A).

(6) At the age of 33 and 42 week, six eggs from each dietary treatment were randomly selected. The yolk was separated from albumen and pooled together by dietary treatment. The pooled yolk was analyzed for the cholesterol and fatty acids composition (Huang, et al., 2005). Individual fatty acid was presented as percent of their sum.

4. Statistics

Data were statistically analyzed using the general linear models procedure of SAS (SAS, 1996). Differences among groups were determined using Duncan’s multiple-range test.

Table 1. The diet composition of laying hens at 23-42 weeks of age.

Ingredients (kg/MT)	Control	6% DDGS	12% DDGS	18% DDGS
Yellow corn, ground	668	649	585	552
Soybean meal, 43.5% CP	230	192	160	130
Wheat bran	0	0	28	25
Soybean oil	0	0	5	10
Dicalcium phosphate	8.5	7.5	8	8.0
Limestone, pulverized	85	82.5	85	85
L-lysine, HCl	0	0	0	1
DL-methionine	0.5	1	1	1
Salt	3	3	3	3
Choline choride,50%	1	1	1	1
Vitamin-mineral premix [a]	3	3	3	3
Mold inhibitor [b]	1	1	1	1
DDGS	0	60	120	180
Total	1000	1000	1000	1000
Calculated value				
ME, kcal/kg	2916	2900	2902	2924
Crude protein, %	15.11	15.03	15.08	15.12
Calcium, %	3.51	3.45	3.50	3.51
Non-phytate phosphorus, %	0.27	0.26	0.26	0.26
Lysine, %	0.8	0.76	0.71	0.73
Total sulfur amino acid , %	0.65	0.68	0.70	0.70
Total Phosphorus (%)	0.79	0.8	0.8	0.81
Analyzed value, %				
Crude protein	14.94	14.91	15.12	15.16
Calcium	3.56	3.62	3.65	3.70
Total phosphorus	0.68	0.64	0.65	0.64

[a] Supplied per kilogram of diet: vitamin A, 16,000 IU ;vitamin D_3, 2,667 IU ;vitamin E , 13.3 mg ; vitamin K, 2.7 mg ;vitamin B_1, 1.87 mg ; vitamin B_2 , 6.4 mg ; vitamin B_6, 2.7 mg ;vitamin B_{12}, 16µg ; folic acid, 0.53mg；calcium pantothenate, 26.7 mg; niacin, 40 mg ; choline-Cl (50%), 400 mg; Fe ($FeSO_4$), 53.3mg ; Cu ($CuSO_4.5H_2O$), 10.7 mg ; Mn ($MnSO_4.H_2O$), 93.3 mg ; Zn (ZnO), 106.7 mg ; I (KI), 0.53 mg ; Co($CoSO_4$), 0.27 mg ; Se (Na_2SeO_3), 0.27 mg.

[b] Supplied per kilogram of diet: sodium calcium aluminosilicate 0.5% ; zeolite 0.5% ; calcium bentonite 0.5 % ; Sepiolite clay 0.5%.

RESULTS AND DISCUSSION

Egg production

The hens fed with 6% DDGS diet had significant higher (except at the 23-26 weeks of age) feed intake compared with the 18% DDGS treatment (Table 2). Adding 18% DDGS in the laying hen diet tended to decrease the feed intake (Table 2). The higher fiber and higher fat content of 18% DDGS treatment, resulted from higher DDGS including rate, can be the factors that limited the feed intake in this treatment.

For all dietary treatments, egg production rate increased with the weeks of age and reached the peak production around 31-34 weeks of age. After peak production, egg production rate slightly declined in all treatments (Table 2). After the early laying stage (23-26 weeks of age), the egg production rate (egg/d/hen) and egg mass (g/d/hen) of 18% DDGS treatment was significantly lower than the other three treatments (Table 2). Obviously, adding 18% DDGS in the laying hen diet will decrease the feed intake and productive performance. Alenier and Combs (1981) suggested that laying hens would eat less feed when more than 10% DDGS was used in the diet and resulted in lower egg production performance. Although the nutrient composition of DDGS in the Alenier and Combs (1981) study can be different with the DDGS in the current trial, the results of both trials were consistent. Roberson et. al. (2004) suggested that egg production was not decreased by DDGS level up to 15% in the diet compared to the corn-soybean meal diet in laying hens trial. Lumpkins et. al. (2003c) had similar findings with Roberson et. al. (2004) when regular commercial diets were used. When low energy density diets were used, however, diet containing 15% DDGS showed a significant depression in egg production (Lumpkins et. al., 2003c). In a commercial laying hens trial, Shurson (2003) found that average percentage of egg production was improved for the laying hens fed with the diet containing 10% DDGS.

The feed conversion efficiency of 18% DDGS treatment was significantly decreased during 31 to 38 weeks of age and tended to be worse than the other treatments during the rest of stages. The body weight change was not affected by the dietary treatment (Table 2). Overall, adding 6 to 12% of DDGS in the laying hen diet did not influence the egg production performance.

Table 2. Effects of dietary DDGS levels on the feed intake, laying performance and body weight change of laying hens from 23 to 42 weeks of age.

Item	Dietary DDGS levels,%				
	0	6	12	18	SEM
23-26 weeks of age					
Feed intake, g/d/hen	106.0	105.0	101.0	102.0	2.64
Egg production,%	84.46	85.70	83.81	82.56	2.69
Egg mass, g/d/hen	54.94	55.48	54.65	52.00	1.85
Feed conversion efficiency	1.93	1.89	1.87	1.96	0.66
Body weight change, g/ hen	35.57	30.41	28.56	29.18	5.34
27-30 weeks of age					
Feed intake, g/d/hen	115.0^{ab}	119.0^{a}	111.0^{ab}	107.0^{b}	2.44
Egg production,%	88.46^{a}	89.70^{a}	86.83^{a}	82.26^{b}	2.57
Egg mass, g/d/hen	56.94^{a}	57.58^{a}	56.65^{a}	50.00^{b}	1.18
Feed conversion efficiency	2.01	2.08	2.03	2.14	0.18
Body weight change, g/ hen	25.57	26.31	23.56	25.16	4.27
31-34 weeks of age					
Feed intake, g/d/hen	124.0^{a}	122.0^{a}	121.0^{a}	110.0^{b}	2.34
Egg production,%	90.41^{a}	89.71^{a}	88.83^{a}	82.56^{b}	2.50
Egg mass, g/d/hen	60.94^{a}	59.48^{a}	56.65^{a}	51.00^{b}	1.03
Feed conversion efficiency	2.06^{a}	2.05^{a}	2.03^{a}	2.15^{b}	0.16
Body weight change, g/ hen	26.57	24.34	23.16	17.11	5.77
35-38 weeks of age					
Feed intake, g/d/hen	114.1^{ab}	112.0^{a}	110.5^{ab}	106.0^{b}	1.54
Egg production,%	87.46^{a}	87.70^{a}	86.83^{a}	81.16^{b}	2.04
Egg mass, g/d/hen	55.94^{a}	57.48^{a}	56.65^{a}	50.00^{b}	1.03
Feed conversion efficiency	2.02^{a}	2.07^{a}	2.03^{a}	2.16^{b}	0.16
Body weight change, g/ hen	25.57	22.31	18.56	19.16	3.31
39-42 weeks of age					
Feed intake, g/d/hen	112.8^{a}	110.6^{a}	105.0^{ab}	102.1^{b}	2.42
Egg production,%	85.54^{a}	81.27^{ab}	79.83^{ab}	73.08^{b}	3.12
Egg mass, g/d/hen	53.81^{a}	51.19^{a}	50.02^{a}	47.19^{b}	1.84
Feed conversion efficiency	2.11	2.15	2.09	2.17	0.18
Body weight change, g/ hen	20.51	18.12	18.19	15.92	4.92

^{a,b} Data in the same row with different superscripts differ significantly ($P<0.05$).

Egg weight and other characteristics

The average egg weight, egg specific gravity, yolk percentage, and egg-white height were not significantly different between dietary treatments in all stages (Table 3). In the previous studies, the egg weight of laying hens was not impacted by the inclusion of DDGS in the diets (Lumpkins et. al. 2003b; Roberson, et. al. 2004; Shurson, 2003). The Haugh unit, as fresh quality of egg, of 18% DDGS treatment tended to be lower than the other treatments. Especially during the late laying stages (35-42 weeks of age), the Haugh unit of 18% DDGS treatment was significantly lower ($P < 0.05$) than the 6% and 12% DDGS dietary treatments (Table 3).

The percentage of shell and shell thickness were significantly increased ($P < 0.05$) in all the DDGS-containing treatments (except in the 23-26 weeks of age) (Table 3). Also, adding DDGS in the diets significantly enhanced the shell breaking strength in some sampling stages (Table 3). Previous research showed no effects of DDGS on the shell thickness and breaking strength when 10% of DDGS was added to a corn-soybean meal basal diet (Jensen et al., 1978). Lumpkine et. al. (2003c) did not find the influence of DDGS on the shell breaking strength of laying hens also. Shurson (2003), however, reported that broken eggs percentage was significantly higher by adding 10% of DDGS in the commercial laying hen trial. According to the results in the current trial, adding DDGS in the diets may increase the availability of calcium and phosphate to the laying hens. Therefore, the quality of eggshell was improved.

Table 3. Effects of dietary DDGS levels on the egg weight and egg characteristics of laying hens from 23 to 42 weeks of age.

Item	Dietary DDGS levels,%				
	0	6	12	18	SEM
23-26 weeks of age					
Ave. egg wt., g	50.84	50.81	50.16	50.11	0.812
Egg specific gravity	1.083	1.082	1.084	1.083	0.015
Percentage yolk, %	25.81	26.07	26.10	26.10	0.516
Egg-white height, mm	8.026	8.109	8.028	8.012	0.257
Haugh unit	221.8	224.3	218.8	214.8	3.821
Percentage shell,%	1.220	1.201	1.225	1.215	0.052
Shell thickness, mm	2.319	2.481	2.452	2.811	0.910
Shell breaking strength, kg	1.112	1.251	1.386	1.324	0.511
27-30 weeks of age					
Ave. egg wt., g	51.28	51.12	51.06	51.01	0.912

Egg specific gravity	1.084	1.081	1.084	1.081	0.016
Percentage yolk, %	25.81	26.17	25.90	26.10	0.686
Egg-white height, mm	8.024	8.089	8.058	8.050	0.252
Haugh unit	210.8	211.3	212.8	210.8	3.021
Percentage shell,%	1.120^{b}	1.311^{a}	1.305^{a}	1.315^{a}	0.041
Shell thickness, mm	2.419^{b}	3.121^{ab}	3.842^{a}	3.912^{a}	0.680
Shell breaking strength, kg	1.192^{b}	1.301^{ab}	1.456^{a}	1.351^{ab}	0.216
31-34 weeks of age					
Ave. egg wt., g	52.12	52.22	52.36	52.41	1.012
Egg specific gravity	1.083	1.082	1.084	1.085	0.018
Percentage yolk, %	25.62	26.27	26.40	26.60	0.716
Egg-white height, mm	8.116	8.169	8.121	8.102	0.261
Haugh unit	212.8	215.1	212.4	206.4	3.861
Percentage shell,%	1.121^{b}	1.351^{a}	1.365^{a}	1.385^{a}	0.043
Shell thickness, mm	2.510^{b}	3.821^{a}	4.142^{a}	4.214^{a}	0.640
Shell breaking strength, kg	1.171^{b}	1.321^{a}	1.456^{a}	1.351^{a}	0.216
35-38 weeks of age					
Ave. egg wt., g	51.88	51.82	51.96	51.91	0.922
Egg specific gravity	1.081	1.082	1.084	1.083	0.015
Percentage yolk, %	25.62	26.27	26.40	26.60	0.716
Egg-white height, mm	8.016	8.169	8.128	8.031	0.252
Haugh unit	215.8^{a}	214.3^{a}	213.8^{a}	208.1^{b}	3.081
Percentage shell,%	1.102^{b}	1.301^{a}	1.295^{a}	1.255^{a}	0.032
Shell thickness, mm	2.318^{b}	4.021^{a}	4.142^{a}	4.211^{a}	0.740
Shell breaking strength, kg	1.192^{b}	1.301^{ab}	1.456^{a}	1.251^{ab}	0.216
39-42 weeks of age					
Ave. egg wt., g	52.51	52.32	52.46	52.21	0.765
Egg specific gravity	1.081	1.080	1.081	1.080	0.042
Percentage yolk, %	26.48	26.37	25.88	25.80	0.738
Egg-white height, mm	8.081	8.109	8.108	7.860	0.283
Haugh unit	207.1^{ab}	213.8^{a}	212.9^{a}	201.2^{b}	2.165
Percentage shell,%	1.125^{b}	1.308^{a}	1.310^{a}	1.283^{a}	0.028
Shell thickness, mm	2.092^{b}	2.812^{ab}	3.512^{a}	3.811^{a}	0.910
Shell breaking strength, kg	1.092^{b}	1.154^{ab}	1.416^{a}	1.812^{a}	0.172

^{a,b} Data in the same row with different superscripts differ significantly ($P<0.05$).

The cholesterol content of yolk was increased with the increasing level of DDGS in the diets and the yolk from 18% DDGS treatment had significantly higher cholesterol content compared to the yolk from the Control treatment ($P < 0.05$) (Tbale 4). In the laying duck trial, Huang et. al. (2005) indicated that feeding 18% DDGS in the diet tended to increase the cholesterol content of yolk during the late laying stage.

Including DDGS in the diets significantly influenced the fatty acids composition of yolk (Table 4). The percentage of palmitoleic acid (16 : 1) and oleic acid (18 : 1) were decreased with the increasing levels of DDGS in the diets and the Control treatment had significantly higher percentage of these two fatty acids than 12% and 18% DDGS treatments ($P < 0.05$). In contrast, the percentage of linoleic acid (18 : 2) and erucic acid (C22:1) were significantly higher in all DDGS-containing treatments compared to the Control treatment. As the percentage of DDGS increased in the diets, the percentage of linoleic acid (18 : 2) increased linearly. The result agreed with Latour et. al. (1998) that indicated the percentage of linoleic acid (18 : 2) was significantly increased by adding corn oil in the laying hen diets. Linoleic acid is an essential fatty acid for human body. Using DDGS in the laying hen diet can increase linoleic acid content in the yolk and, therefore, improve the nutritional value of eggs. The amount of saturated fatty acids, unsaturated fatty acids and the ratio of saturated/unsaturated fatty acids were not significantly impacted by dietary treatments. DDGS, which was made from corn, contains about 11% of fat with abundant unsaturated fatty acids. Using DDGS in the laying hen diets affects the fatty acids composition of yolk is reasonable.

Table 4. Effects of dietary DDGS levels on the cholesterol, fatty acid composition and saturated/unsaturated fatty acids ratio of laying hens yolk from 23 to 42 weeks of age.

Item	Dietary DDGS levels,%				
	0	**6**	**12**	**18**	**SEM**
Cholesterol , mg/ 100g fat	282.12[b]	312.12[ab]	321.52[ab]	342.12[a]	17.23
Fatty acids composition, %					
Myristic acid (14 : 0)	0.363	0.358	0.320	0.286	0.019
Palmitic acid (16 : 0)	29.54	32.05	28.61	27.30	1.638
Palmitoleic acid (16 : 1)	3.56[a]	3.201[ab]	2.633[b]	2.093[b]	0.246
Stearic acid (18 : 0)	9.504	9.48	9.740	9.932	0.627
Oleic acid (18 : 1)	43.53[a]	41.92[ab]	39.31[b]	38.56[b]	0.593
Linoleic acid (18 : 2)	11.20[c]	14.19[b]	17.39[b]	21.54[a]	0.690
Linolenic acid (18 : 3)	0.372	0.366	0.440	0.578	0.071
Arachidic acid (C20:0)	0.301	0.303	0.253	0.261	0.019
Behenic acid (C22:0)	0.155	0.166	0.172	0.202	0.028
Erucic acid (C22:1)	1.738[b]	2.336[a]	2.151[a]	2.392[a]	0.114
Lignoceric acid (C24:0)	0.818	1.087	2.000	1.667	0.941
Saturated fatty acids	40.32	42.21	42.85	39.64	6.86
Unsaturated fatty acids	59.78	54.89	58.14	62.36	4.32
Saturated/unsaturated fatty acid ratio	1.48	1.30	1.36	1.57	0.36

[a,b] Data in the same row with different superscripts differ significantly (P<0.05).

Yolk color

The intact yolk color was measured by Minolta Chroma Meter to prevent the variation resulting from visual measuring（Figure 1）. As the dietary DDGS level was increased, the yolk color tended to be improved (Table 5). Adding more than 12% of DDGS in the diets significantly enhanced (P < 0.05) the yellowness (*b**) of yolk color (except in the 23-26 weeks of age) (Table 5). From 31 weeks of age, including more than 12% DDGS also improved the lightness (*L**) and even the redness (*a**) of yolk color (Table 5). These results indicated that the xanthophylls of DDGS was effectively absorbed and utilized by the laying hens during the laying period. Similar result was reported in the laying hen trial by Shurson (2003) and Roberson et. al. (2005). It is suggested that supplementation of a layer diet with DDGS can be a cost effective mean to improve the yolks color and to enhance the value of egg for the shell egg market in some countries.

Table 5. Effects of dietary DDGS levels on the yolk color of laying hens from 23 to 42 weeks of age.

Item[1]	Dietary DDGS levels,%				
	0	6	12	18	SEM
23-26 weeks of age					
*L** value	49.21	50.90	50.41	50.12	1.250
*a** value	2.087	2.214	2.163	2.127	1.120
*b** value	33.18	33.12	35.21	34.25	2.715
27-30 **weeks of age**					
*L** value	45.16	48.90	49.15	48.92	1.192
*a** value	1.947	2.422	2.623	2.657	1.026
*b** value	32.87^{b}	40.12^{ab}	42.69^{a}	43.34^{a}	2.264
31-34 **weeks of age**					
*L** value	50.16^{b}	52.90^{ab}	55.42^{a}	56.82^{a}	1.192
*a** value	2.867	3.012	3.653	3.147	1.526
*b** value	31.84^{b}	35.17^{ab}	42.49^{a}	43.54^{a}	2.614
35-38 **weeks of age**					
*L** value	50.16^{b}	55.90^{a}	58.15^{a}	59.34^{a}	1.362
*a** value	1.987^{b}	2.472^{ab}	3.613^{a}	3.267^{a}	1.016
*b** value	29.87^{b}	39.17^{ab}	45.49^{a}	43.14^{a}	2.564
39-42 **weeks of age**					
*L** value	51.16^{b}	56.90^{a}	59.12^{a}	59.32^{a}	1.592
*a** value	2.047^{b}	2.514^{ab}	4.013^{a}	3.547^{a}	1.166
*b** value	31.87^{b}	42.17^{a}	46.95^{a}	47.84^{a}	2.814

^{a,b} Data in the same row with different superscripts differ significantly (P<0.05).

[1]L*=lightness, a*=redness, b*=yellowness using a Minolta Chroma Meter.

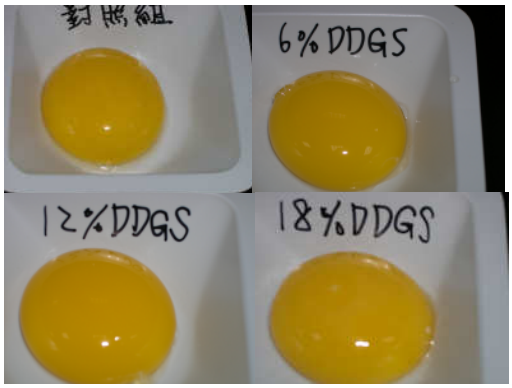

Figure 1. Effects of dietary DDGS levels on the yolk color of laying hens.

Blood characteristics

The plasma total protein, uric acid, and triglyceride were not impacted by the dietary treatments (Table 6). The hens fed with 6 or 12% DDGS diets had significantly higher ($P < 0.05$) plasma calcium content compared with the 18% DDGS treatment. The phosphate in the plasma was significantly higher than the Control treatment when 12% of DDGS was used in the diet. The 12% DDGS treatment had highest plasma calcium, phosphate (Table 6) and highest shell break strength (Table 3). Advanced study is necessary to define the relationship between plasma calcium, phosphate and the shell break strength. The plasma cholesterol content was significantly increased when 12% or 18% DDGS diets were used.

Table 6. Effects of dietary DDGS levels on the blood characteristics of laying hens from 23 to 42 weeks of age.

Item	Dietary DDGS levels,%				
	0	6	12	18	SEM
Total protein, g/L	4.512	4..822	4.489	4.540	0.629
Uric acid nitrogen, mg/L	2.215	2.172	2.292	2.438	0.522
Calcium, mg/dL	20.62^{ab}	23.24^{a}	23.53^{a}	18.71^{b}	1.732
Phosphate, mg/dL	3.146^{b}	3.621^{ab}	4.304^{a}	3.588^{ab}	0.347
Cholesterol, mg/L	99.21^{b}	101.5^{ab}	103.6^{a}	106.5^{a}	9.237
Triglyceride, mg/L	1108	1164	1174	1201	131.1

^{a,b} Data in the same row with different superscripts differ significantly ($P<0.05$).

CONCLUSION

Results from this study suggested that adding 6 to 12% of DDGS in the laying hen diets did not influence the feed intake, egg production rate, egg mass, and feed conversion efficiency. Yolk color was improved by including more than 12% of DDGS in the diets. The xanthophylls in DDGS are well utilized by the laying hens. When 12% DDGS was used in the laying diets of hens, plasma calcium and phosphate contents were increased and shell break strength was improved. In conclusion, using 12% of DDGS in the laying diet resulted in the best productive performance and egg quality among the treatments. DDGS can be efficiently used in the diets of laying hens to improve the productive performance, eggshell, and yolk characteristics.

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