Brazilian Journal of Poultry Science
Revista Brasileira de Ciência Avícola
ISSN 1516-635X Apr - Jun 2015 / v.17 / n.2 / 247-254
http://dx.doi.org/10.1590/1516-635x1702247-254

Effect of Feeding Low-Oil Ddgs to Laying Hens and Broiler Chickens on Performance and Egg Yolk and Skin Pigmentation

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■Keywords

Low-oil DDGS, egg yolk pigmentation, skin pigmentation, abdominal fat, carcass yield.

Submitted: July/2014
Approved: September/2014

SUMMARY

Two experiments were conducted to evaluate the nutritional quality of two sources of low-oil distiller's dried grains with solubles (DDGS) and their pigmenting ability for broiler chicken skin and egg yolks. In Experiment 1, 360 Bovan-White hens between 69 and 77 weeks of age were randomly assigned to five dietary treatments with 6 replicates of 12 hens each. In Experiment 2, 375 Ross 308 broiler chickens were randomly assigned to five treatments with three replicates of 25 birds each. The chickens were fed the experimental diets from one to 42 d of age. In both experiments, treatments consisted of a basal diet with no DDGS, and diets with 6% or 12% inclusion of DDGS from two sources. In Experiment 1, no significant differences in performance were detected among treatments ($p > 0.05$). Egg yolk pigmentation, according to CR-400 Minolta Colorimeter redness (a) and yellowness (b), linearly increased ($p<0.05$) with DDGS inclusions. In Experiment 2, no significant differences ($p>0.05$) were detected among treatments in growth performance, carcass yield, or abdominal fat at 42 d of age. Yellowness linearly increased ($p<0.05$) in the skin and abdominal fat of the birds that consumed diets with DDGS. The results of the current study indicate that feeding two sources of low-oil DDGS to broiler chicks or laying hens does not negatively affect egg production or growth performance while improves egg yolk and skin yellowness.

INTRODUCTION

After the fermentation process of corn to produce ethanol, the remaining fat in the by-product distiller's dried grains with solubles (DDGS) is extracted by centrifugation. The resulting by-product is known as low-fat DDGS, which has slightly higher protein content, amongst other nutrients, compared with conventional DDGS (Kshun and Kurt, 2012). The fat extraction in low-oil DDGS reduces its xanthophyll content in comparison with the conventional DDGS (Winkler and Vaughn, 2009). Lower concentrations (10-30 mg/g) of lutein and zeaxanthin have been analyzed in low-oil DDGS with respect to conventional DDGS sources (25-50 mg/kg) (Winkler and Vaughn, 2009; Moreau *et al*., 2010).

Conventional DDGS can be included up to 15% in layer diets and increase egg yolk pigmentation. When increasing the DDGS inclusion in diets for second-cycle Bovan-White birds, egg yolk pigmentation was more intense (Loar *et al* 2010). In broiler chickens fed diets with 0, 6, 12, 18, or 24% inclusion of conventional DDGS, there were no significant changes in breast skin pigmentation after cooking (Schilling *et al*., 2010). However, there are no research reports on the pigmenting ability of low-oil DDGS for egg yolk or broiler skin, which are important traits for commercialization of eggs and chicken meat in the Mexican market.

The objective of the current study was to evaluate the effect of feeding two low-oil DDGS sources on egg production, broiler growth performance, carcass yield, and egg yolk and skin pigmentation.

MATERIAL AND METHODS

Laboratory analysis

Proximate analysis of the DDGS samples was performed by wet chemistry using the AOAC methods (2006) (Table 1). Total xanthophylls, lutein, and zeaxanthin were determined through HPLC using a Hewlett-Packard 1100 chromatographer comprising a quaternary pump, a degasifier, an automatic injector, and variable-wave length detector. The UV absorbance was recorded at 450 nm. A C30 reversed phase analytical column (RP-C30; 250 X 4.6 mm, 5m) and a Bischoff pre-column (Nucleosil C18, 10 X 4.6mm, 5m) temperized at 35° C were used. The mobile phase consisted of methanol, TBME (Tert Butyl Metyl Ether), and water; solvent A: 81:15:4(vol/vol/vol); solvent B: 6:90:4(vol/vol/vol)]. The following gradient was applied: (minutes over percent of solvent A): 0/99, 39/44, 45/0, 50/99, 55/99) with a flow of 1 mL/min; injection volumen was 20L. Analytical data were collected using the HP-ChemStation Plus software. The HPLC was conducted in an LC (APcl)-MS system coupled to a Micromass VG platform II quadruple mass spectrophotometer, which was operated with an APcI interphase on a positive mode. The MS parameters were as described by Breithaunpt *et al*. (2002). Analytical results are presented in Table 1.

Table 1 – Nutrient composition of two low-oil DDGS sources.

Nutrient	1DDGS A	2DDGS B
Dry matter	95.45	95.05
Moisture	4.55	4.95
Crude protein	28.05	27.02
Ether extract	6.54	5.39
Ash	5.40	5.26
Crude fiber	8.05	8.43
Nitrogen-free extract	47.41	48.96
Total xanthophylls (mg/kg)	24.2	25.6
Lutein (mg/kg)	5.9	6.0
Zeaxanthin (mg/kg)	8.1	10.3
Lysine %	1.00	0.98
Met+Cyst %	1.03	1.06
Lysine Dig. %	0.65	0.64
Met+Cyst. Dig %	0.84	0.85

Bird husbandry

For both experiments, housing, husbandry, and euthanasia procedures were approved by the institutional committee for experimental animal care of the Faculty of Veterinary Medicine at the National Autonomous University of Mexico (UNAM). Birds were housed in an open-sided, naturally ventilated house.

Experiment 1. The objective of this experiment was to evaluate the effect of two low-oil DDGS samples included at 6% and 12% in sorghum-soybean meal diets for Bovans-White laying hens on egg production and egg yolk pigmentation. Three hundred and sixty 69-week-old Bovans White caged hens were randomly assigned to five dietary treatments with six replicates of 12 birds each (3 birds per cage). The birds received the experimental feed in the mash form, and had free access to feed and water.

Treatments consisted of: 1) basal sorghum-soybean meal diet containing 8 ppm of xanthophylls from *Tagetes erecta*; 2) As 1 + 6% DDGS source A; 3) As 1 + 12% DDGS source A; 4) As 1 + 6% DDGS source B; and 5) As 1 + 12% DDGS source B. The composition of the experimental diets is presented in Table 2. The xanthophyll content in diets of treatments 2 through 5 was higher as the inclusion of DDGS increased.

The hens received the experimental diets for 8 weeks. Egg production, egg mass, feed intake, and feed conversion ratio were recorded weekly. In weeks 4 and 8 of the experimental period, egg yolk coloration was visually evaluated using DSM's egg yolk color fan. (L*) Luminosity, redness (a*), and yellowness (b*) were also determined using a Minolta CR-400 colorimeter.

Experiment 2. The objective was to evaluate the effect of feeding two low-oil DDGS sources included at 6% and 12% in sorghum-soybean meal diets on the growth performance, carcass yield, skin pigmentation, and abdominal fat of broilers. Three hundred and seventy five 1-d-old Ross 308 male broiler chickens were randomly assigned to five dietary treatments with three replicates of 25 birds each. The birds were housed in an open-sided, naturally-ventilated house with floor pens, bell-type drinkers, feed troughs, and automatic gas brooders.

The composition of the experimental diets is presented in Tables 3, 4, and 5. Diets were designed for three growth phases: starter (0-11 d), grower (11-21 d), and finisher (22-42 d), and formulated to meet the nutrient requirements as recommended by the primary breeder (Ross 308, 2012) [9]. Treatments consisted of the following: 1) basal sorghum-soybean meal diet containing 8 ppm of xanthophylls from *Tagetes erecta*;

Table 2 – Composition of the experimental diets for Bovans-White hens from 69 to 77 weeks (Exp. 1).

Ingredient	Control	6 % DDGS A	12 % DDGS A	6% DDGS B	12% DDGS B
Sorghum	697.436	665.843	634.216	664.440	630.857
Soybean meal	178.175	150.124	120.976	149.039	119.935
Calcium carbonate	90.201	90.923	91.646	91.109	92.017
Monodicalcium phosphate	16.063	14,659	13.268	14.513	12.963
Soy oil	8.371	9.166	10.017	11.064	13.812
Salt	3.762	3.818	3.875	3.820	3.878
DL-Methionine	1.475	1.384	1.308	1.396	1.318
Vitamins*	1.000	1.000	1.000	1.000	1.000
L-Lysine HCl	0.652	0.716	1.329	1.254	--------
Yellow pigment**	0.615	0.615	0.615	0.615	0.615
Minerals*	0.500	0.500	0.500	0.500	0.500
Bacitracin 10%	0.300	0.300	0.300	0.300	0.300
Antioxidant	0.150	0.150	0.150	0.150	0.150
Choline chloride 60%	0.800	0.800	0.800	0.800	0.800
DDGS	--------	60.00	120.00	60.00	120.00
Total	1000.0	1000.0	1000.0	1000.0	1000.0
Nutrient			Calculated analysis		
Crude protein (%)	15.00	15.00	15.00	15.00	15.00
ME (Kcal/Kg)	2800	2800	2800	2800	2800
Calcium (%)	4.00	4.00	4.00	4.00	4.00
Available phosphorus (%)	0.400	0.400	0.400	0.400	0.400
Digestible lysine (%)	0.670	0.670	0.670	0.670	0.670
Dig Met-Cys (%)	0.580	0.580	0.580	0.580	0.580
Sodium (%)	0.180	0.180	0.180	0.180	0.180
Xanthophylls (mg/Kg)	8.000	8.000	8.000	8.000	8.000

*Provides per kg: Vitamin A, 3 000 000 UI; Vitamin D3, 750 000 UI; Vitamin E, 6 000 UI; Vitamin K3, 1.0 g; Riboflavin, 4 g; B12, 0.060 g; Pyridoxin, 3.0 g; Calcium pantothenate, 13.0 g; Niacin, 25 g; Biotin, 0.063 g; Choline chloride, 250 g.; selenium, 0.2 g; cobalt, 0.1 g; iodine, 0.3 g; copper, 10 g; zinc, 50 g; iron, 100 g; manganese, 100 g; carrier to 1000 g.

** 8 ppm of yellow pigment added.

2) As 1 + 6% DDGS source A; 3) As 1 + 12% DDGS source A; 4) As 1 + 6% DDGS source B; and 5) As 1 + 12% DDGS source B.

The birds received the experimental diets for 42 d, and live weight, feed intake, and feed conversion ratio were recorded weekly. At the end of the study, 12 birds per treatment (six males and six females) were euthanized by CO_2 asphyxiation. The carcasses were eviscerated, defeathered, and head, neck, and feet removed. Carcass weight was used to calculate carcass yield. Abdominal fat was collected and weighed. Yellowness (b*) was measured on the lateral apterial breast area using the CR-400 Minolta colorimeter in live birds, hot and cold carcasses, and abdominal fat.

Statistical analysis

All collected data were submitted to analysis of variance (ANOVA) using the SPSS software for Windows, version 17.0 (2012). If a significant difference was detected ($p<0.05$), treatment means were compared using Tukey's multiple comparison procedure. Skin pigmentation in live birds, hot and cold carcass, and abdominal fat weight and carcass yield were analyzed using a 3 x 2 factorial arrangement, where one factor was the inclusion of DDGS (0%, 6%, and 12%) and the other factor was the bird's sex (male or female).

RESULTS AND DISCUSSION

Coloration data for the two DDGS samples is presented in Table 2. Luminosity as measured by the Minolta CR-400 colorimeter (L*) was significantly higher in the DDGS source with the lower ether extract value ($p<0.05$). However, the redness (a*) and yellowness (b*) values were significantly greater in the DDGS source with higher ether extract ($p<0.05$).

Table 3 – Composition of the starter diets (0-10 d) for broiler chickens, Experiment 2.

Ingredient	Diet control	6% DDGS A	12% DDGS A	6% DDGS B	12% DDGS B
Sorghum	557.34	526.29	495.25	523.84	490.35
Soybean meal	365.76	336.39	307.03	336.62	307.49
DDGS	0.00	60.00	120.00	60.00	120.00
Soy oil	31.29	31.73	32.24	33.97	36.70
Monodicalcium phosphate	20.10	18.71	17.31	18.55	17.00
Calcium carbonate	13.45	14.17	14.89	14.35	15.26
Salt	3.790	3.840	3.900	3.840	3.900
L-Lysine HCl	2.090	2.700	3.320	2.690	3.290
DL-Methionine 99%	3.240	3.160	3.090	3.160	3.090
Choline chloride 60%	1.000	1.000	1.000	1.000	1.000
Vitamins*	1.000	1.000	1.000	1.000	1.000
Minerals*	0.500	0.500	0.500	0.500	0.500
Bacitracin 10%	0.300	0.300	0.300	0.300	0.300
Antioxidant	0.150	0.150	0.150	0.150	0.150
Total	1000	1000	1000	1000	1000
Nutrient	Calculated analysis				
ME (Kcal/Kg)	3025	3025	3025	3025	3025
Crude protein (%)	23.00	23.00	23.00	23.00	23.00
Dig Met+ Cyst (%)	0.94	0.94	0.94	0.94	0.94
Digestible lysine (%)	1.27	1.27	1.27	1.27	1.27
Calcium	1.05	1.05	1.05	1.05	1.05
Available phosphorus	0.50	0.50	0.50	0.50	0.50

**Provided per kg. Vitamin A, 6 000 000 UI; Vitamin D3, 1,500 000 UI; Vitamin E, 12 000 UI; Vitamin K3, 2.0 g; Riboflavin, 8 g; B12, 0.120 g; Pyridoxin, 6.0 g; Calcium pantothenate, 26.0 g; Niacin, 50 g; Biotin, 0.126 g; Choline chloride, 500 g; Selenium, 0.2 g; cobalt, 0.1 g; iodine, 0.3 g; copper, 10 g; zinc, 50 g; iron, 100 g; manganese, 100 g; carrier to 2000 g

Similar results have been reported elsewhere (Pekel *et al*., 2013), where higher fat content was associated with higher yellowness.

Experiment 1. The inclusion of DDGS at 6% and 12% did not affect egg production, egg weight, egg mass, feed intake, or feed conversion ratio of Bovans-White hens (Table 6). Research conducted elsewhere (Roberson *et al*., 2005; Cheon *et al*., 2008; Lumpkins *et al*., 2005; Wu-Haan *et al*., 2010) indicated no detrimental effects on hen performance when conventional DDGS with 10% fat were included between 5% and 20% of the diet. In the study reported herein, DDGS inclusion was within the range of inclusion reported in the published literature. Inclusion levels of DDGS as high as 32% had no detrimental effects on hen performance (Loar *et al*., 2010).

Feeding a low-oil DDGS source (5.62% fat) did not reduce hen performance when included in diets at levels as high as 20% (Noll and Purdum, 2013), which is in agreement with the results observed in the study reported herein.

Egg yolk coloration data are presented in Table 7. Luminosity was not significantly influenced by DDGS inclusion level or source ($p>0.05$). In a previous study, higher DDGS inclusion was reflected in lower egg yolk luminosity (Loar *et al*., 2010). Redness (a*) significantly increased with higher inclusion of DDGS from both sources, which is in agreement with previous research, where a positive linear relationship between egg yolk redness and DDGS inclusion was found (Robertson *et al*., 2005).

Egg yolk color score and yellowness (b*) linearly increased with increasing DDGS inclusion from both sources ($p<0.001$). This effect is attributed to the greater xanthophyll contribution (lutein and zeaxanthin) from DDGS with respect to the control diet. This effect has been documented in previous research studies (Cheon *et al*., 2008; Masa`deh *et al*., 2011; Cortés *et al*., 2012; Sun *et al*., 2013) using conventional DDGS sources. The results of the current study indicate that fat extraction in DDGS did not affect the egg yolk pigmenting capacity of this ingredient.

Table 4 – Composition of the grower diets (11-21 d) for broiler chickens, Experiment 2.

Ingredient	Control	6% DDGS A	12% DDGS A	6% DDGS B	12% DDGS B
Sorghum	597.49	566.45	535.41	593.90	530.50
Soybean meal	317.97	288.60	259.24	288.83	259.69
DDGS	0.00	60.00	120.00	60.00	120.00
Soy oil	44.74	42.23	45.70	47.44	50.13
Monodicalcium phosphate	17.69	16.30	14.91	16.15	14.59
Calcium carbonate	11.14	11.87	12.59	12.05	12.96
Salt	3.810	3.870	3.930	3.870	3.930
L-Lysine HCl	1.490	2.110	2.730	2.090	2.690
DL-Methionine 99%	2.690	2.620	2.540	2.620	2.540
Choline chloride 60%	1.000	1.000	1.000	1.000	1.000
Vitamins*	1.000	1.000	1.000	1.000	1.000
Minerals*	0.500	0.500	0.500	0.500	0.500
Bacitracin 10%	0.300	0.300	0.300	0.300	0.300
Antioxidant	0.150	0.150	0.150	0.150	0.150
Total	1000	1000	1000	1000	1000
Nutrient	Calculated analysis				
ME (Kcal/Kg)	3150	3150	3150	3150	3150
Crude protein (%)	21.00	21.00	21.00	21.00	21.00
Dig Met+ Cyst (%)	0.84	0.84	0.84	0.84	0.84
Digestible lysine (%)	1.10	1.10	1.10	1.10	1.10
Calcium	0.90	0.90	0.90	0.90	0.90
Available phosphorus	0.45	0.45	0.45	0.45	0.45

*Provided per kg. Vitamin A, 6 000 000 UI; Vitamin D3, 1,500 000 UI; Vitamin E, 12 000 UI; Vitamin K3, 2.0 g; Riboflavin, 8 g; B12, 0.120 g; Pyridoxin, 6.0 g; Calcium pantothenate, 26.0 g; Niacin, 50 g; Biotin, 0.126 g; Choline chloride, 500 g; Selenium, 0.2 g; cobalt, 0.1 g; iodine, 0.3 g; copper, 10 g; zinc, 50 g; iron, 100 g; manganese, 100 g; carrier to 2000 g.

By increasing the inclusion of DDGS in the experimental diets, it was possible to augment the total xanthophyll contribution by 1.40-1.54 ppm xanthophylls from source A, and 2.90-3.08 ppm from source B, respectively. The control diet was formulated to contain 8 ppm of total xanthophylls.

Experiment 2. Broiler growth performance data are presented in Table 8. The inclusion of low-fat DDGS at 0%, 6%, or 12% had no detrimental effect on growth performance. There was no significant difference between DDGS sources either (p>0.05). Similare results have been reported elsewhere (Guney *et al*., 2013) when broilers were fed low-oil DDGS for 18 d. Feeding levels as high as 15% of conventional DDGS (10% fat) did not significantly affect growth performance (Cortés *et al*., 2012; Lumpkins *et al*., 2004; Shim *et al*., 2011). Levels higher than 15%, however, significantly reduced growth performance rate. This reduction in growth performance was attributed to an amino acid imbalance created by reducing soybean meal inclusion, which has a better amino acid profile than DDGS.

Carcass yield results and abdominal fat weight data are presented in Table 9. No significant effect was detected for either DDGS inclusion or source. Similar results were reported by Lu and Chen (2005), who did not find any significant difference in the carcass yield of broilers fed corn-soybean meal diets with the inclusion of 10% or 20% conventional DDGS. Loar *et al*. (2012), however, reported reduced carcass yield when DDGS inclusion was higher than 14% only in the finisher phase.

The dietary inclusion of low-oil DDGS did not affect abdominal fat weight. Guney *et al*. (2013), on the other hand, reported a reduction in abdominal fat weight when low-fat DDGS was fed at 10% or 20% inclusion level.

There was no significant effect of sex on carcass yield or abdominal fat weight (p>0.05). In contrast, Shim *et al*. (2011) reported that female broilers accumulated more abdominal fat than males.

Data for skin pigmentation of live birds and pre-chill carcasses, as well as abdominal fat pigmentation, are presented in Table 10. The consumption of 272.4 and

Table 5 – Composition of the finisher diets (22-42 d) for broiler chickens.

Ingredient	Control	6% DDGS A	12% DDGS A	6% DDGS B	12% DDGS B
Sorghum	639.2	608.161	577.119	605.700	572.200
Soybean meal	270.0	240.689	211.326	240.900	211.800
DDGS	0.000	60.000	120.000	60.000	120.000
Soy oil	49.20	49.695	50.175	51.900	54.600
Monodicalcium phosphate	16.40	15.006	13.612	14.800	13.300
Calcium carbonate	10.70	11.515	12.239	11.700	12.600
Yellow pigment*	5.000	5.000	5.000	5.000	5.000
Salt	5.000	3.372	3.429	5.000	5.000
L-Lysine HCl	3.300	1.644	2.262	3.400	3.400
DL-Methionine 99%	1.000	2.432	2.336	1.600	2.200
Choline chloride 60%	2.500	1.000	1.000	2.400	2.300
Vitamins**	1.000	1.000	1.000	1.000	1.000
Minerals**	1.000	0.500	0.500	1.000	1.000
Bacitracin 10%	0.500	0.300	0.300	0.500	0.500
Antioxidant	0.300	0.150	0.150	0.300	0.300
Total	1000	1000	1000	1000	1000
Calculated analysis					
ME (Kcal/Kg)	3200	3200	3200	3200	3200
Crude protein (%)	19	19	19	19	19
Dig Met+ Cyst (%)	0.73	0.73	0.73	0.73	0.73
Digestible lysine (%)	0.94	0.94	0.94	0.94	0.94
Calcium	0.85	0.85	0.85	0.85	0.85
Available phosphorus	0.42	0.42	0.42	0.42	0.42

* 70 ppm of yellow pigment (*Tagetes erecta*).

**Provided per kg. Vitamin A, 6 000 000 UI; Vitamin D3, 1,500 000 UI; Vitamin E, 12 000 UI; Vitamin K3, 2.0 g; Riboflavin, 8 g; B12, 0.120 g; Pyridoxin, 6.0 g; Calcium pantothenate, 26.0 g; Niacin, 50 g; Biotin, 0.126 g; Choline chloride, 500 g; selenium, 0.2 g; cobalt, 0.1 g; iodine, 0.3 g; copper, 10 g; zinc, 50 g; iron, 100 g; manganese, 100 g; carrier to 2000 g.

278.7 ppm of xanthophylls from 6% or 12% DDGS from source B produced greater skin pigmentation than the consumption of DDGS from source A (260.3 and 269.8 ppm, respectively). Birds from the control group had a calculated xanthophyll consumption of 260.2 ppm. No significant difference was detected in skin pigmentation between the two levels of DDGS inclusion.

Skin pigmentation in hot carcasses was not different ($p>0.05$) between the two DDGS sources. However, the dietary inclusion of DDGS resulted in greater skin pigmentation than that observed in birds in the control group, regardless of the DDGS source. Similar results were documented by Min *et al*. (2012), where DDGS inclusion levels as high as 20% significantly increased skin pigmentation. However, those authors did not observe any effect of 6% DDGS inclusion. In contrast with these results, the inclusion of DDGS at 6, 8, 12, 18, or 24% did not have any significant effect on skin

Table 6 – Egg production (%), egg weight (g/egg), feed consumption (g/bird/d), feed conversion (kg:kg), and egg mass (g/bird) of hens fed 0%, 6%, and 12% inclusion of low-oil DDGS from 2 sources from 69 to 77 weeks of age (Experiment 1).

Treatment	Egg production (%)	Egg weight (g)	Feed intake (g)	Feed conversion ratio (kg:kg)	Egg mass (g)
0% DDGS	87 ±1.25	64.6 ±0.54	108 ±1.07	1.93 ±0.02	56 ±1.03
6% DDGS A	87 ±1.83	64.7 ±0.23	109 ±0.77	1.94 ±0.03	56 ±1.24
12% DDGS A	88 ±1.03	64.4 ±0.60	107 ±1.05	1.91 ±0.02	56 ±0.36
6% DDGS B	88 ±1.09	65.0 ±0.31	109 ±0.70	1.92 ±0.02	57 ±0.66
12% DDGS B	86 ±0.89	64.6 ±0.28	108 ±1.06	1.96 ±0.03	56 ±0.71
Probability	0.846	0.884	0.609	0.677	0.778

Table 7 – Luminosity (L*), redness (a*), yellowness (b*), and color score (DSM egg yolk color fan) in egg yolks of hens fed 0%, 6%, and 12% inclusion of low-oil DDGS from 2 sources from 69 to 77 weeks of age (Experiment 1)

Parameter	0% DDGS	6% DDGS A	12% DDGS A	6% DDGS B	12%DDGS B	Probability
L*	57.83 [a] ±5.4	65.01 [a] ±0.9	64.63 [a] ±0.9	61.21±1.9 [a]	64.66 [a] ±0.7	0.260
a*	-7.30 [b] ±0.09	-6.76 [ab] ±0.2	-6.11 [a] ±0.14	-6.69 ±0.3 [ab]	-6.17 [a] ±0.1	0.001
b*	36.47 [b] ±2.57	40.15 [ab] ±1.0	42.68±1.0 [a]	39.60 ±0.7 [ab]	42.93 [a] ±1.1	0.030
Color score	3.33 [a] ±0.21	4.08 [ab] ±0.1	4.16 [b] ±0.16	4.00 [ab] ±0.25	4.66 [b] ±0.21	0.002

Means with different superscript within columns (a-c) differ significantly (p< 0.05).

Table 8 – Growth performance of broiler chickens fed diets with 0%, 6%, and 12% inclusion of two sources of low-oil DDGS from 0 to 42 d of age (Experiment 2)

Treatment	Final weight (g)	Weight gain (g)	Feed intake (g)	Feed conversion ratio (kg:kg)
0% DDGS	2758 ±32	2717 ±32	4847 ±36	1.78 ±0.03
6% DDGS A	2692 ±32	2651 ±49	4826 ±63	1.82 ±0.04
12% DDGS A	2627 ±49	2585 ±80	4725 ±130	1.83 ±0.09
6% DDGS B	2699 ±61	2658 ±61	4861 ±154	1.83 ±0.05
12% DDGS B	2636 ±72	2595 ±72	4929 ±75	1.90 ±0.06
Probability	0.495	0.490	0.691	0.709

pigmentation, according to other research reports (Schilling *et al*., 2010; Corzo *et al*., 2009).

Table 9 – Carcass yield and abdominal fat weight of broiler chickens at 42 d of age after receiving diets with 0%, 6%, and 12% inclusion of two sources of low-oil DDGS from 0 to 42 d of age (Experiment 2).

	Male	Female	Average
Treatment		Carcass yield (%)	
0% DDGS	71.5	73.5	72.5±0.7
6% DDGS A	70.6	71.0	70.8 ±0.3
12% DDGS A	70.5	71.8	71.1 ±0.6
6% DDGS B	71.7	70.7	71.2 ±0.5
12% DDGS B	70.9	71.8	71.3 ±0.2
Average	71.1 ±0.3	71.8 ±0.3	
		Abdominal fat weight (g)	
0% DDGS	56.7	46.7	51.7 ±3.3
6% DDGS A	41.0	51.3	46.2 ±2.9
12% DDGS A	55.3	59.7	57.5 ±1.9
6% DDGS B	54.3	61.2	57.7 ±4.0
12% DDGS A	49.7	56.0	52.8 ±4.3
Average	51.4 ±2.3	55.0 ±2.0	

Means with different superscript within rows ([a-c]) or columns ([z-y]) differ significantly (p< 0.05).

Abdominal fat pigmentation was greater in the birds that consumed diets with 12% DDGS from both evaluated sources. Abdominal fat pigmentation, however, was significantly greater for source B. Increasing levels of DDGS inclusion have been reported to increase yellowness values (b*) in abdominal fat (Kimura, 2007).

Table 10 – Skin yellowness (b*) in broiler chickens at 42 d of age after receiving diets with 0%, 6%, and 12% inclusion of two sources of low-oil DDGS from 0 to 42 d of age (Experiment 2)

	Male	Female	Average
Treatment		Live bird	
0% DDGS	11.0	13.2	12.0 [c] ±0.3
6% DDGS A	12.1	13.0	12.6 [bc] ±0.5
12% DDGS A	12.5	15.1	13.9 [ab] ±0.5
6% DDGS B	13.5	14.6	14.1 [ab] ±0.4
12% DDGS B	14.3	15.1	14.7 [a] ±0.5
Average	12.5±0.3 [z]	14.2±0.3 [y]	
		Pre-chill carcass	
0% DDGS	27.8	27.5	27.7 [b] ±0.8
6% DDGS A	28.8	27.6	28.2 [ab] ±0.8
12% DDGS A	30.1	30.2	30.2 [ab] ±1.1
6% DDGS B	31.2	30.0	30.6 [ab] ±0.7
12% DDGS B	32.1	30.9	32.0 [a] ±1.2
Average	30.2 ±0.8	29.2 ±0.6	
		Chilled carcass	
0% DDGS	36.4	35.5	35.9 [a] ±0.7
6% DDGS A	35.7	37.5	36.6 [a] ±1.2
12% DDGS A	40.0	38.5	39.3 [a] ±1.0
6% DDGS B	40.9	37.5	39.2 [a] ±1.4
12% DDGS B	39.3	39.9	39.6 [a] ±0.8
Average	38.5 ±0.6	37.8 ±0.8	
		Abdominal fat	
0% DDGS	20.2	21.6	20.9 [c] ±0.6
6% DDGS A	21.3	21.6	21.5 [bc] ±0.8
12% DDGS A	24.5	24.4	24.5 [ab] ±0.7
6% DDGS B	22.6	25.0	23.8 [abc] ±0.9
12% DDGS A	27.4	23.9	25.7 [a] ±1.0
Average	23.2±0.7	23.3±0.5	

Means with different superscript within rows ([a-c]) or columns ([z-y]) differ significantly (p< 0.05).

Skin pigmentation in live birds was significantly higher in females ($p<0.05$), which may be explained by their higher subcutaneous fat deposition. Nevertheless, there was no effect of sex on pre-chill carcass or abdominal fat pigmentation ($p<0.05$).

The results of the study reported herein indicated that production performance in Bovans White laying hens and Ross 308 broilers was not affected when fed 6% or 12% inclusion of two sources of low-oil DDGS in sorghum-soybean meal-based diets. Egg yolk yellowness linearly increased with two sources. Carcass yield and abdominal fat content were not significantly affected in broilers. Moreover, feeding 6% or 12% inclusion of low-oil DDGS from two sources linearly increased skin yellowness in live birds, pre-chill and chilled carcass, and abdominal fat. The findings regarding the improvement on egg yolk and broiler skin pigmentation should be an aid for poultry nutritionists to consider the xanthophyll content of low-oil DDGS, when formulating diets for these poultry species.

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