Original Research

Effect of Feeding Corn Distiller's Dried Grains with Solubles (cDDGS) on Egg Quality Traits in Commercial Layers

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Abstract

The present experiment was conducted involving 180 layer chickens (BV- 300) for period of 10 weeks. The birds were randomly distributed into 5 treatment groups T1 (Control), T2, T3, T4 and T5 having 4 replicates of 9 layer birds each. The birds in treatment group T1 fed basal ration as per the recommendation of BV-300 layer strain and treatment groups T2, T3, T4 and T5 were offered diets containing 5, 10, 15 and 20% corn DDGS replacing soybean meal. Egg weight in control group T1 was significantly (P<0.01) higher compared to all other groups. The shape index of eggs from treatment group T5 was significantly (P<0.05) higher as compared to control group. The control group T1 was recorded significantly (P<0.01) higher egg surface area as compared to all other DDGS supplemented groups. The albumin index from control group T1 was recorded significantly (P<0.05) highest as compared to treatment group T2 receiving diet at 5% corn DDGS. There was non-significant difference in all treatment groups for the yolk index, haugh unit and percent egg shell weight. The treatment groups from T2, T3, T4 and T5 recorded significantly (P<0.01) increased yolk colour score as compared to control group. The egg shell thickness from treatment group T5 was significantly (P<0.01) increased as compared to control group. It may be concluded that the inclusion of corn DDGS at 20 % in layer diets found to improve egg quality parameters such as shape index, yolk colour score and egg shell thickness which is beneficial for egg processing industry.

Key words: Corn DDGS, Layers, External Egg Quality, Internal Egg Quality

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Introduction

Use of unconventional feed ingredients is one of the alternatives to reduce the cost of production by replacing the conventional feed ingredients. But the choice of these alternative ingredients depends on many factors and the important ones are availability, absence of toxic principle, nutrient availability, quality composition, cost of product and economical feasibility. Different types of cereals are used for the production of biofuel. Distiller's dried grains with solubles (DDGS) is a by-product of the distilling industry, which is recovered after the condensing and drying of stillage from dry mill ethanol production. It is source of energy, protein, water soluble vitamins and minerals (Jensen, 1978; Waldroup *et al*., 1981; Parsons *et al*., 2006). It is also a good source of xanthophylls (Runnels, 1957) and linoleic acid (Scott, 1965) and as well as riboflavin and thiamine (D'Ercole *et al*., 1939). The total metabolizable energy content of corn distiller's dried grains with solubles (cDDGS) is 2827 kcal/kg (Lumpkins *et al*., 2005) and 2906 kcal/kg (Batal and Dale, 2006). DDGS contains CP in the ranged 23 % and 32 % (Batal and Dale, 2006). The phosphorus in DDGS ranges from 0.59 to 0.95 % (Spiehs *et al*., 2002). The studies showed that DDGS can be fed to laying hens up to 20% inclusion rates without negatively affecting egg production or other production parameters (Robertson *et al*., 2005, reviewed by Batal and Bregendahl, 2012). Distiller's dried grains with solubles is a valuable source of protein and sulphur amino acids and was used at 50–200 g/kg inclusion concentrations in layer diets without affecting performance (Swiątkiewicz *et al*., 2013; Abd El-Hack *et al*., 2015 a, b; Sun *et al*., 2015). A favorable effect on some egg quality parameters had been seen by distiller's dried grains with solubles (Jensen *et al*., 1978). Many of the research finding observed that use of 10% DDGS in laying hens had not produced any adverse effect on egg production, egg quality parameter, Haugh unit, as well as egg composition and specific gravity (Roberts *et al*., 2007). While some of the studies recorded lower egg weight when diet containing more than 20% DDGS was fed in layer diets. Moreover, the addition of 15 to 20% DDGS in the diet has improved yolk colour, yolk colour index and shell thickness (Shalash *et al*., 2009; Roberson *et al*., 2005; Roberts *et al*., 2007; Pineda *et al*., 2008). With the increase in DDGS production and based on its nutritional value, DDGS could be an attractive low cost ingredient to replace soybean meal and corn in poultry rations (Masa'deh *et al*., 2012; Swiatkiewicz *et al*., 2014).Therefore, the present experiment was carried out to evaluate the effect of feeding corn DDGS on egg quality traits in commercial layers.

Materials and Methods

Experimental Design and Management

The experiment was conducted on 180 layer birds (BV 300 strain) for period of 10 weeks from 22nd to 31st weeks of age of the layer birds at Poultry Research Centre, Post Graduate Institute of Veterinary and Animal

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Sciences, Akola, Maharashtra, India. The experimental layer birds were randomly distributed into 5 equal treatments T1 (control), T2, T3, T4 and T5 with 36 layer birds in each group having 4 replicates of 9 layer birds each. The diets were formulated as per strain recommendation. The dietary treatment groups were the control diet control – basal diet (T1), basal diet with 5% level of cDDGS replacing soyabean meal (T2), basal diet with 10% level of cDDGS replacing soyabean meal (T3), basal diet with 15% level of cDDGS replacing soyabean meal (T4), basal diet with 20% level of cDDGS replacing soyabean meal (T5). The birds were reared on three tier California cage housing system with three birds per compartment. All the groups were provided with similar environmental and management conditions. The total 16 hours of light and eight hours of darkness was provided to the birds throughout the experimental period of 10 weeks. The replicates were distributed in such a manner so as to nullify the row and tier effect. The birds were having free access to ample fresh, clean and wholesome water throughout experimental period.

Procurement of Ingredients and Feed Formulation

The good quality feed ingredients were procured from local market for preparation of experimental diets. The corn DDGS was procured from M/s. Grainotch Industries Ltd., Aurangabad, Maharashtra, India. The chemical analysis of corn DDGS was carried out as per A.O.A.C. (1995) and presented in Table 1. Lumpkins *et al.* (2005) reported metabolizable energy in corn DDGS was 2827 kcal/kg and same was considered for the feed formulation.

Table 1: Chemical composition of corn DDGS (%DM)

Nutrient	Corn DDGS
Moisture (%)	11.34
Crude protein (%)	38.59
Crude fat (%)	8.65
Total ash (%)	4.41
Acid insoluble ash (%)	0.63
Salt (NaCl) (%)	0.16
Total phosphorus (%)	0.78
Calcium (%)	0.23
Crude fiber (%)	4.47

The experimental diets were prepared as per the recommendation of BV-300 layer strain. All the layer diets were balanced isocaloriec and iso-nitrogenous. The ingredients and nutrient composition of layer mashes for different treatment groups is shown in Table 2.

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Table 2: Ingredients (%) and nutrient composition of layer mashes

Ingredients (%)	Treatment Groups				
	T1 (Control)	T2 (5% cDDGS)	T3 (10% cDDGS)	T4 (15% cDDGS)	T5 (20% cDDGS)
Maize	57.95	56.5	54.485	52.905	51.24
De-oiled rice bran	10	10.77	12.51	13.41	14.5
Soyabean meal	19	14.7	10	5.5	1
Corn DDGS	-	5	10	15	20
Marble grit	8.3	8.3	8.3	8.5	8.6
Limestone powder	2.5	2.5	2.5	2.5	2.5
Dicalcium phosphate	1.05	0.95	0.85	0.75	0.65
L-Lysine	-	0.1	0.2	0.3	0.4
DL-Methionine	0.16	0.14	0.12	0.095	0.07
Trace mineral mixture*	0.1	0.1	0.1	0.1	0.1
Vitamin premix**	0.05	0.05	0.05	0.05	0.05
Salt Pure	0.28	0.25	0.22	0.19	0.17
Sodium bicarbonate	0.1	0.11	0.125	0.14	0.13
Choline chloride 60%	0.1	0.12	0.13	0.15	0.18
Phytase 5000	0.01	0.01	0.01	0.01	0.01
Livertonic	0.05	0.05	0.05	0.05	0.05
Electrolytes	0.1	0.1	0.1	0.1	0.1
Toxin binder	0.1	0.1	0.1	0.1	0.1
Probiotics	0.05	0.05	0.05	0.05	0.05
Acidifier	0.1	0.1	0.1	0.1	0.1
Total	**100**	**100**	**100**	**100**	**100**
Nutrient Composition (%DM)					
Metabolizable energy (kcal/kg)	2570	2576	2571	2570	2570
Crude protein (%)	15.3	15.36	15.35	15.34	15.34
Ether extract (%)	2.62	2.97	3.3	3.65	3.99
Crude fiber (%)	4.24	4.27	4.38	4.41	4.46
Calcium (%)	4.07	4.05	4.03	4.07	4.07
Available phosphorus (%)	0.42	0.42	0.42	0.42	0.42
Dig. Lysine (%)	0.659	0.662	0.66	0.659	0.659
Dig. Methionine (%)	0.37	0.36	0.36	0.35	0.34
Dig. Cystine (%)	0.21	0.22	0.23	0.24	0.24
Dig. Methionine + Cystine (%)	0.580	0.584	0.587	0.585	0.583
Calcium**:** avail. Phosphorus ratio	9.76	9.68	9.61	9.7	9.71

**Trace Mineral Mineral mixture: each 1kg contains Cu-10g, Fe-80g, Mn-12g, Zn-92g, Se-1g, I-1g.*

*** Vitamin premix: each 1kg contains Vitamin A-12.5 MIU, Vitamin B3-3.3 MIU, Vitamin E-40 g, Vitamin K- 2 g, Vitamin B_1-4g, Vitamin B2-10g, Vitamin B_6- 5g, Vitamin B_{12}- 0.016 g, Niacin- 33g, Folic acid-1 g, Biotin- 0.1 g.*

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Data Collection

For studying external and internal quality of egg, two eggs were randomly collected from each replicate i.e. total eight eggs from each treatment were collected at 2nd, 4th, 6th, 8th and 10th weeks. The egg quality parameters were calculated as follows-

Egg Weight (g)

Egg weight was measured by using a 0.0g sensitive digital scale during every interval of egg quality parameters.

Shape Index

Length and width of the egg were measured with electronic digital vernier caliper. The shape index was calculated using the following formula as Shape index = width of egg/ Length of egg x 100 (Anderson *et al*., 2004).

Egg Surface Area (cm^2)

Egg surface area was calculated by using following formula-

Egg surface area (S) = $4\pi r^2$. Radius (r) was calculated as ¼ (length + breath) of egg, π=3.14159.

Albumin Index

Height of albumen (mm) was measured by spherometer and length of albumen (mm) was measured by vernier caliper. Albumen index was calculated with the following formula (Doyon *et al*., 1986).

$$AI = AH/ (AL+AW) \times 100$$

(Where, AI = albumen index, ah = albumen height, al = albumen length, aw = albumen width, mm= millimeter)

Yolk Index

Height of yolk (mm) was measured by spherometer and diameter of yolk (mm) was measured by vernier caliper. Yolk index calculated using the following formula as described by Doyon *et al*., 1986.

$$\text{Yolk Index} = \text{Yolk Height} / \text{Yolk Width} \times 100$$

Haugh Unit

$$\text{Haugh Unit} = 100 \times \log (h - 1.7w^{0.37} + 7.6)$$

(Whereas, h = Average height of albumen in mm, w = Weight of egg in grams)

Yolk Color Score

Colour of yolk was directly assessed by comparing with Roche Yolk Colour Fan (RYCF) standard (Vulleumier, 1969).

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Percent Egg Shell Weight

Egg shell weight calculated after breaking of an egg and the weight of egg shell with shell membrane was expressed as a percentage of the whole egg.

Egg Shell Thickness (mm)

Egg shell thickness was measured with shell membrane by the micro screw gauge.

Statistical Analysis

The differences among treatments, within treatment groups were determined by analyzing the data generated by using the factorial Randomized Block Design for egg quality parameters as per described by Snedecor and Cochran (1994).

Results and Discussion

The results pertaining to egg weight, shape index and egg surface area are presented in Table 3. The results related to albumin index, yolk index and haugh unit are presented in Table 4 and the data on yolk colour score, percent egg shell weight and egg shell thickness have been presented in Table 5.

Egg Weight

The treatment means for egg weight obtained from the birds from control group T1 recorded significantly ($P<0.01$) higher egg weights as compared to other treatments groups (Table 3). However, the differences in egg weights obtained from groups T3, T4 and T5 were statistically non-significant with each other. Egg weight decreased as DDGS increased in the diets, with a trend for linear response. The present investigation was in agreement of Shalash *et al.* (2010) who reported that increasing DDGS up to 15 to 20 in laying hen diets significantly decreased egg weight as compared with other levels at 0, 5 and 10%. Roberson *et al.* (2005) also reported that the linear decreased in egg weight as DDGS level increased in layer diet. Abousekken (2014) observed that the average egg weight of laying *Japanese quails* was significantly decreased as dietary inclusion of corn DDGS was increased. The reason for decreased egg weight was due to the potential bioavailability of amino acid.

Shape Index

The shape index of eggs from treatment group T5 was significantly ($P<0.05$) higher as compared to control group T1 (Table 3). However, the differences in shape index of eggs from groups T1, T2, T3 and T4 were statistically non-significant with each other. The findings of the present study are in accordance with the work of Zile and Sajjan (2014) who reported that inclusion of DDGS with or without multienzyme supplementation in layer diet recorded significant ($P<0.05$) difference in shape index of egg.

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Egg Surface Area (cm^2)

The control group T1 was recorded significantly (P<0.01) higher egg surface area as compared to all other DDGS supplemented groups i.e. T2, T3, T4 and T5 (Table 3).

Table 3: Effect of different cDDGS levels on egg weight, shape index and egg surface area

Weeks	Treatment Groups				
	T1 (Control)	**T2 (5% cDDGS)**	**T3 (10% cDDGS)**	**T4 (15% cDDGS)**	**T5 (20% cDDGS)**
Egg weight (g/egg)					
2nd	55.44±0.72	53.40±1.64	53.20±1.08	50.47±1.09	52.37±1.35
4th	56.83±0.97	55.63±0.77	55.48±1.53	55.57±0.86	53.72±0.77
6th	59.20±0.85	58.18±0.59	57.45±0.72	55.11±0.47	58.67±1.04
8th	58.35±0.99	57.25±0.49	58.28±0.42	56.07±0.61	56.11±0.63
10th	58.32±0.67	55.66±0.91	55.08±0.93	54.79±0.96	54.42±0.70
Mean	**$57.63±0.42^c$**	**$56.02±0.49^b$**	**$55.90±0.51^{ab}$**	**$54.40±0.48^a$**	**$55.06±0.53^{ab}$**
CD	**1.502****				
Shape Index					
2nd	75.71±0.72	76.89±1.59	75.22±0.74	75.68±0.63	75.31±0.65
4th	74.89±0.50	75.09±0.48	75.55±0.61	75.52±0.70	76.44±1.02
6th	74.74±0.85	74.85±0.47	75.84±0.90	75.52±0.54	76.01±1.02
8th	75.34±0.83	75.40±0.48	75.95±0.39	76.24±0.62	75.99±0.45
10th	75.92±0.67	76.58±0.68	77.56±0.66	76.96±0.73	77.69±0.47
Mean	**$75.32±0.32^a$**	**$75.77±0.39^{ab}$**	**$76.02±0.32^{ab}$**	**$75.98±0.29^{ab}$**	**$76.29±0.35^b$**
CD	**0.923***				
Egg Surface Area (cm^2)					
2nd	74.80±0.74	71.84±1.61	73.59±1.25	70.70±1.10	72.70±1.34
4th	77.16±0.91	76.38±0.71	75.84±1.53	76.05±0.72	73.49±0.70
6th	79.74±0.84	78.08±0.74	77.14±0.99	75.11±0.65	79.24±1.20
8th	78.56±1.20	77.36±0.63	77.99±0.39	76.26±0.48	75.35±0.71
10th	77.92±0.60	75.37±0.92	74.20±0.62	73.88±0.81	73.59±0.68
Mean	**$77.64±0.46^b$**	**$75.80±0.55^a$**	**$75.75±0.52^a$**	**$74.40±0.46^a$**	**$74.87±0.56^a$**
CD	**1.532****				

*The means bearing different superscripts within a row differ significantly. *P<0.05, **P<0.01.*

Albumin Index

The albumin index from control group T1 was recorded significantly (P<0.05) highest as compared to treatment group T2. Whereas, there was a numerical increase in the values for albumen index of eggs in groups T3, T4 and T5 as compared to treatment group T2 but the statistical difference was non-significant with each other (Table 4). Similarly, Zile and Sajjan (2014) reported that inclusion of DDGS with or without multi-enzyme supplementation in layer diet recorded similar albumin index in all treatment groups.

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Yolk Index

The differences in the yolk index of eggs between the groups were statistically non-significant. However, there was a numerical increase in the values for yolk index of eggs in treatment group T5 as compared to control group, which is beneficial for the value addition in the egg quality (Table 4). The findings of the present study are in accordance with the work of Zile and Sajjan (2014) who reported that the inclusion DDGS at 0, 2, 4, 6 and 8% in the basal diet by replacing 0, 10, 20, 30 and 40% soyabean meal and supplemented with multi-enzyme recorded similar yolk index in all treatment groups.

Haugh Unit

It was revealed that the mean haugh units of eggs obtained from the birds from different groups were statistically non-significant. The haugh unit of eggs obtained from the birds from T5 group was recorded numerically higher haugh unit as compared to control group. Whereas, the treatment groups T2, T3, T4 and T5 recorded numerically lower haugh unit as compared with control group T1, but the differences was found to be non-significant (Table 4).

Table 4: Effect of different cDDGS levels on albumin index, yolk index and haugh unit

Weeks	Treatment Groups				
	T1 (Control)	**T2 (5% cDDGS)**	**T3 (10% cDDGS)**	**T4 (15% cDDGS)**	**T5 (20% cDDGS)**
Albumin index					
2nd	12.81±0.61	11.11±0.34	12.19±0.70	12.24±0.62	11.54±0.39
4th	15.01±0.59	11.44±0.49	12.31±0.78	11.71±0.74	12.54±0.82
6th	15.06±0.85	15.42±0.58	15.81±0.95	15.87±0.83	16.62±0.24
8th	10.52±0.62	10.44±0.68	10.34±0.71	10.75±0.68	11.67±0.64
10th	12.21±0.65	12.64±0.25	12.01±0.47	12.16±0.59	12.35±0.60
Mean	**13.12±0.40^{b}**	**12.21±0.35^{a}**	**12.53±0.42^{ab}**	**12.55±0.41^{ab}**	**12.95±0.39^{ab}**
CD	**0.801***				
Yolk Index					
2nd	47.76±0.60	45.95±1.11	48.12±0.65	47.15±2.13	47.90±1.07
4th	47.86±0.74	46.46±0.48	46.69±1.09	49.38±0.97	47.42±0.63
6th	51.25±0.43	49.79±0.46	48.21±0.59	50.04±0.87	50.10±0.89
8th	45.91±1.66	46.55±1.17	47.44±1.11	46.61±0.96	47.57±0.53
10th	47.26±0.58	47.47±0.96	48.30±0.61	46.11±0.96	47.81±0.92
Mean	**48.01±0.48**	**47.24±0.44**	**47.75±0.37**	**47.86±0.59**	**48.16±0.39**
Haugh unit					
2nd	96.81±1.78	93.59±0.64	95.71±1.94	95.87±1.16	93.74±0.50
4th	100.82±1.85	93.99±1.45	94.85±1.81	93.63±2.04	96.07±2.09
6th	102.39±1.91	104.11±1.09	103.42±2.08	103.25±1.96	106.26±0.68
8th	90.38±2.27	91.11±2.23	89.36±2.35	92.35±2.94	94.80±1.76
10th	95.71±1.65	97.22±0.77	94.88±1.14	95.18±1.53	95.27±1.70
Mean	**97.22±1.05**	**96.00±0.92**	**95.64±1.08**	**96.06±0.99**	**97.23±0.97**

The means bearing different superscripts within a row differ significantly. P<0.05

The findings of the present study are in accordance with the work of Cheon *et al.* (2008) who reported that the haugh unit was not affected by the addition of corn DDGS up to 20% in the layer diets. Similarly, Rew *et al.* (2009) also reported that haugh unit was not influenced by the supplementation of corn DDGS at 0, 10 and 20% inclusion levels in the layer diets.

Yolk Colour Score

It was revealed that the treatment groups T2, T3, T4 and T5 recorded significantly (P<0.01) increased yolk colour score as compared to control group. However, the treatment groups T4 and T5 was recorded significantly (P<0.01) increased yolk colour score as compared to treatment groups T1 and T2 (Table 5). The similar findings are in accordance with Cheon *et al.* (2008) who reported that the yolk colour was significantly (P<0.05) increased by corn DDGS supplementation in laying hens. Krawczyk *et al.* (2012) also reported that dietary inclusion of corn DDGS increased yolk colour intensity. 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). This further improves the yolk colour which is beneficial for the value addition in the eggs and poultry product processing industry.

Percent Egg Shell Weight

The percent egg shell weight from all the groups was statistically non-significant. It is revealed that the percent egg shell weight from treatment group T4 was numerically increased as compared to all other groups (Table 5). Similarly, Rew *et al.* (2009) who reported that egg shell weight was not affected by the supplementation of corn DDGS in laying diets. Swiatkiewicz and Korelski (2006) revealed that feeding of 0, 10, 15 or 20% corn DDGS of rye DDGS had no effect on egg shell percent. Khose *et al.* (2017) reported that inclusion of corn DDGS up to 15% with or without enzyme did not affect the nutrient utilization in broilers.

Egg Shell Thickness (mm)

The egg shell thickness from treatment group T5 was recorded significantly (P<0.01) increased as compared to control group (Table 5). However, the egg shell thickness from treatment groups T1, T2, T3 and T4 was statistically non-significant with each other. The finding are in accordance with Shalash *et al*. (2009) and Pineda *et al*. (2008) reported that the addition of 15 to 20% DDGS in the diet has improved yolk colour, yolk colour index and shell thickness. However, Swiatkiewicz and Koreleski (2006) reported that the level of DDGS in the diet had no negative effect on eggshell thickness. Similarly, Rew *et al.* (2009) reported that egg shell thickness was not affected by DDGS feeding in laying hens.

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Table 5: Effect of dietary cDDGS levels on yolk colour score, percent egg shell weight and egg shell thickness (mm)

Weeks	Treatment Groups				
	T1 (Control)	**T2 (5% cDDGS)**	**T3 (10% cDDGS)**	**T4 (15% cDDGS)**	**T5 (20% cDDGS)**
Yolk Color Score					
2nd	6.00±0.33	6.13±0.30	6.75±0.25	6.88±0.23	7.00±0.00
4th	5.63±0.18	6.25±0.16	6.63±0.26	7.13±0.13	7.75±0.16
6th	5.88±0.13	6.75±0.25	7.00±0.27	7.38±0.26	7.50±0.27
8th	4.88±0.30	6.13±0.23	6.88±0.13	7.13±0.23	7.38±0.18
10th	5.88±0.23	6.50±0.33	6.88±0.23	7.13±0.23	7.25±0.25
Mean	**5.65±0.12[a]**	**6.35±0.12[b]**	**6.83±0.10[c]**	**7.13±0.10[dc]**	**7.38±0.09[d]**
CD	**0.376****				
Percent Egg Shell Weight					
2nd	10.81±0.22	10.49±0.33	11.09±0.28	10.94±0.20	10.62±0.27
4th	10.58±0.12	10.37±0.14	10.28±0.13	10.54±0.26	10.86±0.27
6th	10.42±0.21	11.24±0.20	10.99±0.12	10.72±0.23	10.79±0.22
8th	10.75±0.21	10.69±0.20	10.51±0.24	10.81±0.18	10.48±0.31
10th	11.26±0.25	10.68±0.27	10.77±0.30	11.13±0.13	10.54±0.17
Mean	**10.76±0.10**	**10.70±0.10**	**10.73±0.11**	**10.83±0.09**	**10.66±0.11**
Egg Shell Thickness (mm)					
2nd	0.41±0.01	0.39±0.01	0.41±0.01	0.39±0.01	0.41±0.01
4th	0.37±0.01	0.38±0.01	0.39±0.01	0.40±0.01	0.41±0.01
6th	0.35±0.01	0.40±0.02	0.39±0.01	0.39±0.01	0.40±0.01
8th	0.38±0.01	0.37±0.01	0.36±0.01	0.38±0.01	0.39±0.01
10th	0.40±0.01	0.40±0.01	0.40±0.01	0.40±0.01	0.38±0.01
Mean	**0.38±0.0[a]**	**0.39±0.0[ab]**	**0.39±0.00[ab]**	**0.39±0.00[ab]**	**0.40±0.00[b]**
CD	**0.017****				

*The means bearing different superscripts within a row differ significantly. *P<0.05, **P<0.01.*

Conclusion

It may be concluded that the inclusion of corn DDGS at 20 % in layer diets found to improve egg quality parameters such as shape index, yolk colour score and egg shell thickness which is beneficial for egg processing industry.

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