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Effect of Rice Distiller Dried Grain Solubles (RDDGS) With or Without Enzyme Supplementation on Performance and Biochemical Parameters on Commercial Layer Chicken

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ABSTRACT

The objective of this study was to evaluate the effect of rice distiller dried grain solubles (RDDGS) with or without enzyme supplementation on performance of commercial layer chicken. Two hundred forty commercial layer chickens at 26 weeks age were randomly allocated to 10 treatments, each treatment containing 6 replicates and 4 layers in each replicate. A standard layer ration (crude protein 18%, metabolizable energy 2600 kcal/kg diet) was offered to all birds. Cocktail enzyme was supplemented at 250 g/ton of feed. The feed and water were provided *ad lib* during the entire experimental period. The birds were raised in cages under uniform management and fed the respective diets from 27th to 42nd weeks of age. The study revealed that 15%RDDGS with enzyme supplementation was more effective among all the dietary treatments in terms of performance and serum biochemical variables in White Leghorn (WL) layer during the entire experimental period. It was concluded that with enzyme supplementation RDDGS can be included up to 15% in layer diets without affecting the performance and serum biochemical parameters

Key words: Body weight, Feed intake, Feed conversion ratio, White Leghorn layer

INTRODUCTION

Rice distiller dried grain with solubles (RDDGS) is the byproduct of the processing of rice alcohol industry which is produced from the distillation of fermented rice. During processing, rice is cooked at 131°C and 2.6 kg/m^2 pressure and yeast is added to the cooked rice for fermentation (Huang *et al.,* 1999). Then the alcohol is distilled from fermentation liquor, the leftover is known as rice distillers dried grains with solubles (RDDGS). Corn, wheat, barley and sorghum are the commonly used cereals used for bioethanol production. In the present context, rice as substrate for bioethanol production is increasing due to its relative lower price, higher production and easy availability, there by leading to increased availability of RDDGS. It comprises of 65% of distiller's grain and 35% of solublse (Babcock *et al.,* 2008). Most of the research work on distillers grain (DDGS) with soluble are on corn, wheat, barley and sorghum DDGS. Very scanty information is available in literature regarding the feeding value of RDDGS in poultry. So, there is need to explore its nutritive value, RDDGS contains 47% CP and 3500 kcal/ kg of ME (National Research Council, 1989; Chiou *et al.,* 1996). It is also more nutritious than the cereal grains from which it is made up of, as it contains other nutrients recovered from the fermented grains. It is also high in protein compared to rice, and more in energy and less in fiber than its other byproduct like rice bran or rice polishing. The final product also contains yeast residue. It does not contain any antinutritional factor, as might be the case with trypsin inhibitors in soybean, commonly used protein source in poultry ration. The cost of RDDGS is always less than that of the soy bean meal. Further, supplementation of exogenous enzymes may improve nutrient utilization (Deniz *et al.,* 2013). Considering these points, this experiment was designed to evaluate the effect of RDDGS with or without cocktail enzymes on performance of layers.

MATERIALS AND METHODS

Two hundred forty commercial layer chickens at 26 weeks age were randomly allocated to 10 treatments, each treatment having 6 replicates and 4 layers in each

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replicate. A standard layer ration (CP 18%, ME 2600 kcal/kg diet) was offered to birds in T_1 (without enzyme) and T_2 (with enzyme). Experimental diets from T_3 to T_6 were formulated with four levels of RDDGS without enzyme (5%, 10%, 15% and 20%). Experimental diets from T_7 to T_{10} were formulated with four levels of RDDGS with enzyme (5%, 10%, 15% and 20%). Cocktail enzyme was supplemented at 250 g/ton of feed. The feed and water were provided *ad lib* during the entire experimental period (27 to 42 weeks). Parameters such as daily hen day egg production, egg weight, weekly feed intake and feed conversion ratio were measured.

Eggs were collected two times a day. The sum of the two collections along with the number of birds alive on each day was recorded and summarized at the end of the each period. Eggs were collected at the end of each period for three consecutive days and the average egg weights were recorded. Hen day egg production in per cent was calculated by dividing the total number of eggs laid every day by number of hens survived during each day. Feed intake/ period (g) were calculated by subtracting the residual feed/ period (g) from the total feed (g) offered during the period. Feed intake /hen/day (g) was calculated accordingly. On cumulative basis of feed intake, feed intake/hen/d was arrived at the end (feed intake/hen days) by considering the mortality in that period. The feed conversion ratio (FCR) was calculated (feed intake /egg mass). The egg weight (g) was recorded to the nearest 0.1 g accuracy in each of the replicate. The weight of all the eggs produced during last three consecutive days of each laying period was recorded to calculate the mean egg weight of each treatment group. Six eggs were collected from each treatment to determine the average egg weight. The egg mass (g) per day was calculated by multiplying the average egg weight by the total no of eggs produced in each replicate and was expressed as g/hen.

Blood samples were collected at the end of the experiment from the wing vein, serum was collected, and stored frozen till analysis. Cholesterol in serum was measured using a commercial kit following manufacturer's instruction. The data were analysed using General Linear Model procedure of Statistical Package for Social Sciences (SPSS) 15th version and comparison of means was done using Duncan's multiple range test (Duncan, 1955) and significance was considered at $P<0.05$.

RESULTS AND DISCUSSION

The per cent hen day egg production (Table 1) in White Leghorn layers was higher ($P<0.05$) in the birds fed diets containing 15% RDDGS with enzyme as compared to the RDDGS without enzyme (5, 10 and 15%) and control group during first and second periods. During the periods P3 (35-38 weeks) and P4 (39-42 weeks) egg production was higher ($P<0.05$) in 15% RDDGS with enzyme group as compared to groups fed 5 and 10% RDDGS with or without enzyme. Lower egg production was noticed in the control and 20% RDDGS fed group irrespective of enzyme supplementation during all periods. During the overall period (27-42 wks), egg production was significantly higher ($P<0.05$) in groups fed 15% RDDGS supplemented with enzyme as compared to control group, and lower egg production was observed in groups fed 20% RDDGS irrespective of enzymes supplementation. Data indicate that RDDGS can not be included in layer ration at more than 15% level of inclusion. These findings are similar to many previous studies (Roberson *et al.,* 2005; Lumpkins *et al.,* 2005; Pineda *et al.,*2008; Swiatkiwicz and Koreleski, 2006; Deniz *et al.,* 2013; Jiang *et al.,* 2013; Abd El-Hack *et al.,* 2015) which recommended a usage rate of 15% DDGS in laying hen diets to maintain egg production. The differences in daily egg production were observed among the dietary treatments even at greater inclusion levels of RDDGS. The findings were similar to Lumpkins *et al.* (2005) and Roberson *et al.* (2005). Swiatkiewicz and Koreleski (2006) reported a reduction in egg production in hens fed 20% DDGS in phase II of egg production, but not during phase I. Egg production results indicate no negative effects of DDGS on hen performance at 15% level of inclusion.

Significant (P<0.05) difference was observed in feed intake (Table 2) during first (27-30wks), second (31-34wks), third (35-38wks), fourth (39-42wks) and over all period (27-42weeks). Feed intake was significantly (P<0.05) significantly lower in control as compared to other groups indicating no adverse impact of RDDGS on feed intake. Similarly, other research workers (Roberson *et al.,* 2005; Roberts *et al.,* 2007a,

Table 1. Ingredient and nutrient (%) composition of commercial layer diets (27-42 weeks)

	Control	Control +E	5% RDDGS +NE	10% RDDGS +NE	15% RDDGS +NE	20% RDDGS +NE	5% RDDGS +E	10% RDDGS +E	15% RDDGS +E	20% RDDGS +E
Maize	57.7	57.7	54.8	51	47.7	44.35	54.8	51	47.7	44.35
SBM	27	27	21.9	17	11.6	6.6	21.9	17	11.6	6.6
RDDGS	0	0	5	10	15	20	5	10	15	20
DORB	0.5	0.5	3.5	7	10.9	14.1	3.5	7	10.9	14.1
Enzyme (E)	0	0.025	0	0	0	0	0.025	0.025	0.025	0.025
Stone grit	12.03	12.03	12.06	12.1	12.15	12.16	12.06	12.1	12.15	12.16
DCP	2.01	2.01	2.01	2	2.01	2.01	2.01	2	2.01	2.01
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Soda.bicarb	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
DL-Methionine	0.13	0.13	0.1	0.06	0.02	0.01	0.1	0.06	0.02	0.01
Lysine HCL	0.01	0.01	0.1	0.19	0.29	0.38	0.1	0.19	0.29	0.38
TMM	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
AB2D3K	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
B Complex	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Coccistat	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Antibiotic	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Choline chloride	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Toxin Binder	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Tylosine	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
TOTAL	100.3	100.3	100.4	100.3	100.6	100.6	100.4	100.3	100.6	100.6
Estimated nutrient content on dry matter basis										
ME (kcal/ kg)	2601	2601	2608	2599	2602	2601	2608	2599	2602	2601
CP (%)	18.06	18.06	18.03	18.09	18.00	18.00	18.03	18.09	18.00	18.00
Ca (%)	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80
Av.P. (%)	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Lysine(%)	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
Methionine(%)	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
NaCl (%)	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36

E, enzyme; NE no enzyme; SBM, soybean meal; RDDGS, rice distillers dried grains with soluble; soda bicarb, sodium bicarbonate, TMM, trace mineral mixture; ME, metabolizable energy; CP, crude protein; av P, available phosphorus; Vitamin premix provided per kg diet: vitamin A, 200000 IU; vitamin D_3 3000 IU; vitamin E, 10 mg; vitamin K, 2 mg; riboflavin, 25 mg, vitamin B_1 1 mg, vitamin B_6, 2 mg, vitamin B_{12}, 40 mg, and niacin 15 mg; [*]TMM provided per kg diet: manganese, 120 mg, zinc 80 mg, iron 25 mg, copper 10 mg, iodine 1mg and selenium 0.1mg.

Table 2. Effect of dietary inclusion of rice distiller dried grain with solubles (RDDGS) with enzyme on percent hen day egg production (%) in White Leghorn layers

Treatment	RDDGS% in diet	Enzyme at 250 g/ton of feed	Age in weeks				Mean
			P1 (27-30)	P2 (31-34)	P3 (35-38)	P4 (39-42)	27-42 wks
T_1	0	-E	90.03	85.42	89.73^{a}	91.97^{ab}	89.29^{ab}
T_2	0	+E	91.22	89.58	90.77^{a}	92.86^{a}	91.11^{a}
T_3	5	-E	91.82	93.60	89.44^{a}	90.92^{ab}	91.44^{a}
T_4	10	-E	93.90	90.92	88.69^{a}	90.03^{ab}	90.89^{a}
T_5	15	-E	91.22	87.50	91.37^{a}	91.67^{ab}	90.44^{a}
T_6	20	-E	88.10	88.69	81.25^{b}	82.00^{c}	85.01^{b}
T_7	5	+E	94.20	88.39	91.52^{a}	92.56^{ab}	91.67^{a}
T_8	10	+E	93.15	92.86	90.77^{a}	90.18^{ab}	91.74^{a}
T_9	15	+E	96.28	96.28	92.02^{a}	92.02^{ab}	94.15^{a}
T_{10}	20	+E	91.81	90.77	87.50^{a}	87.65^{b}	89.44^{ab}
N			6	6	6	6	6
P Value			0.265	0.302	0.001	0.001	0.017
SEM			0.658	0.930	0.609	0.597	0.520

$^{a-c}$Mean bearing at least one common superscript in a column differ significantly (P<0.05); $^{P1-P4}$ P1, period 1; P2, period 2; P3, period 3 and P4, period 4; RDDGS, rice distillers dried grain with solubles +E: with enzyme, - E: without enzyme

b; Masa'deh 2011; Deniz *et al.,* 2013) had reported that inclusion of corn distilleries dried grain soluble up to 15% of the diet did not affect feed intake. Abd El-Hack *et al.* (2015), observed that increasing DDGS level up to 16.5% was associated with an increase in feed intake.

The results revealed that, there was no significant (P>0.05) difference in feed conversion ratio (feed intake/egg mass) (Table 3) during period-P2

Table 3. Effect of dietary inclusion of rice distiller dried grain with solubles (RDDGS) with enzyme on feed intake in White Leghorn layers

Treatment	RDDGS% in diet	Enzyme @ 250 g/ton of feed	Age in weeks				Mean
			P1 (27-30)	P2 (31-34)	P3 (35-38)	P4 (39-42)	27-42 wks
T_1	0	-E	97.65^{b}	98.15^{c}	101.1^{c}	100.3^{d}	99.3^{d}
T_2	0	+E	97.97^{b}	99.73^{bc}	103.1^{bc}	103.9^{bcd}	101.2^{cd}
T_3	5	-E	103.9^{ab}	107.4^{a}	110.1^{a}	111.0^{a}	108.1^{a}
T_4	10	-E	106.3^{a}	107.0^{a}	107.0^{ab}	108.0^{ab}	107.1^{ab}
T_5	15	-E	103.5^{ab}	106.5^{a}	106.5^{ab}	106.3^{bc}	105.7^{abc}
T_6	20	-E	107.2^{a}	108.8^{a}	98.50^{c}	95.98^{d}	102.6^{bcd}
T_7	5	+E	104.1^{ab}	105.0^{ab}	109.9^{a}	107.5^{ab}	106.6^{ab}
T_8	10	+E	105.6^{a}	107.4^{a}	107.9^{ab}	106.5^{abc}	106.8^{ab}
T_9	15	+E	106.6^{a}	109.1^{a}	100.7^{c}	102.1^{cd}	104.6^{abc}
T_{10}	20	+E	104.7^{a}	105.7^{ab}	107.5^{ab}	107.2^{ab}	106.3^{ab}
N			6	6	6	6	6
P Value			0.014	0.003	0.001	0.001	0.001
SEM			0.731	0.743	0.709	0.686	0.559

$^{-c}$ Mean bearing at least one common superscript in a column differ significantly (P<0.05); P1, period 1; P2, period 2; P3, period 3 and P4, period 4; RDDGS, rice distillers dried grain with solubles +E: with enzyme, - E: without enzyme

(31-34 weeks), whereas, significant (P<0.05) difference was observed in period-P1 (27-30 weeks), period-P3 (35-38 weeks), period-P4 (38-42 weeks) and over all period (27-42 weeks) of age. The overall feed conversion ratio (feed intake/ egg mass) was significantly (P<0.05) improved in group fed 15% RDDGS without enzyme. The results are in agreement with the findings of earlier research workers (Roberson *et al.,* 2005; Ghazalah *et al.,* 2011; Romero *et al.,* 2012; Swiatkiewicz *et al.,* 2013) which indicated that inclusion of DDGS at the level of 200 g/kg with enzyme (xylanase and phytase) in the diet had no effect on feed intake and feed conversion ratio, and DDGS may be incorporated in the diet of laying hens without any negative effects. Gupta *et al.* (2020) observed significant (P<0.01) improvement in FCR with enzyme supplementation. It was reported that RDDGS can be used up to 100 g/kg diet of laying hens along with enzyme supplementation for better productivity of layer hens. Higher methionine content in DDGS diet may be associated with higher egg mass and better FCR per kilogram egg production. DDGS is also rich source of water-soluble vitamins, microelements, and other biologically active substances like nucleotides, mannanoligosacharids, β-1, 3/1,6-glucan, inositol, glutamine, and nucleic acids, which may be associated with higher egg production performance due to beneficial effect on the health of animals (Gupta *et al.* 2020).

In periods 1 and 2, there was no significant difference in the egg weight in different dietary treatments. However, during period 3, 4 and overall periods the egg weight was significantly (P<0.05) higher in groups fed diets containing 15% RDDGS supplemented with enzyme. The results are similar to that of other reports (Masa'deh, 2011; Romero *et al.,* 2012; Gupta *et al.,* 2020). There was a significant (P<0.05) decrease in cholesterol (Table 4) levels among different dietary treatments. A lower serum cholesterol level was noticed in the group fed 15% RDDGS

Table 4. Effect of dietary inclusion of rice distiller dried grain with solubles (RDDGS) with enzyme on feed conversion ratio in White Leghorn layers

Treatment	RDDGS% in diet	Enzyme @ 250 g/ton of feed	Age in weeks				Mean
			P1 (27-30)	P2 (31-34)	P3 (35-38)	P4 (39-42)	27-42 wks
T_1	0	-E	1.980^{b}	1.896	2.029^{bc}	1.959^{d}	1.966^{cd}
T_2	0	+E	1.956^{b}	1.801	2.044^{bc}	2.014^{cd}	1.954^{d}
T_3	5	-E	2.018^{b}	1.939	2.131^{ab}	2.061^{bcd}	2.037^{bcd}
T_4	10	-E	2.063^{b}	1.893	2.181^{a}	2.145^{ab}	2.070^{abc}
T_5	15	-E	2.009^{b}	1.836	1.946^{c}	1.979^{d}	1.942^{d}
T_6	20	-E	2.096^{b}	1.894	2.182^{a}	2.154^{ab}	2.082^{ab}
T_7	5	+E	2.069^{b}	1.866	2.205^{a}	2.186^{ab}	2.081^{ab}
T_8	10	+E	2.030^{b}	1.902	2.242^{a}	2.219^{a}	2.098^{ab}
T_9	15	+E	2.079^{b}	1.991	2.111^{ab}	2.104^{abc}	2.071^{abc}
T_{10}	20	+E	2.267^{a}	2.084	2.215^{a}	2.124^{abc}	2.172^{a}
N			6	6	6	6	6
P Value			0.014	0.236	0.001	0.001	0.001
SEM			0.018	0.022	0.016	0.016	0.013

[a-c] Mean bearing at least one common superscript in a column differ significantly (P<0.05); P1, period 1; P2, period 2; P3, period 3 and P4, period 4; RDDGS, rice distillers dried grain with solubles +E: with enzyme, - E: without enzyme

Table 5. Effect of dietary inclusion of rice distiller dried grain with solubles (RDDGS) with enzyme on serum cholesterol level in White Leghorn layers

Treatment	RDDGS% in diet	Enzyme @ 250 g/ton of feed	Cholesterol (mg/dl) 42 weekAge
T_1	0	-E	179.00[ab]
T_2	0	+E	185.53[a]
T_3	5	-E	174.47[abc]
T_4	10	-E	178.10[ab]
T_5	15	-E	144.62[de]
T_6	20	-E	153.37[cde]
T_7	5	+E	173.80[abc]
T_8	10	+E	174.38[abc]
T_9	15	+E	140.53[e]
T_{10}	20	+E	143.40[de]
N			6
P Value			0.001
SEM			2.777

[a-c] Mean bearing at least one common superscript in a column differ significantly (P<0.05); P1, period 1; P2, period 2; P3, period 3 and P4, period 4; RDDGS, rice distillers dried grain with solubles +E: with enzyme, - E: without enzyme

supplemented with enzyme, whereas higher (P<0.05) cholesterol level was observed in control. The results are in agreement with the findings of Gupta *et al.* (2017) which reported that feeding of DDGS manifested lowering effect on serum lipid profile.

CONCLUSIONS

Feeding of RDDGS at 15% level of incorporation along with enzyme supplementation was more effective among all the dietary treatments in terms of improved hen day production and feed conversion ratio with cholesterol lowering effect. It was concluded that incorporation of RDDGS at 15% in the layer ration with enzyme supplementation improved performance.

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REFERENCES

Babcock, B.A., Hays, D.J. and Lawrence, J.D. 2008. *Using Distillers Grains in the U.S. and International Livestock and Poultry Industry*. Midwest Agribusiness Trade Research and Information Center, 1st ed. Ames, Iowa, USA.

Cheon, Y.J., Lee, H.L., Shin, M.H., Jang, A., Lee, S.K., Lee, J.H., Lee, B.D. and Son, C.K. 2008. Effect of corn distiller's dried grains with solubles on production and egg quality in laying hens. *Asian Australas. J. Anim. Sci.* 21: 1318-1323.

Chiou, P.W.S., Chen, K.J., Kuo, K.S., Hsu, J.C. and Yu, B. 1996. Studies on the protein degradabilities of feedstuffs in Taiwan. *Anim. Feed. Sci. Technol.* 55 : 215-226.

Duncan, D.B. 1955. Multiple range and multiple F-test. *Biometric.* 11: 01-42.

Deniz, G.H., Gencoglu, S.S., Gezen, I.I., Turkmen, A., Orman and Kara, C. 2013. Effects of feeding corn distiller's dried grains with solubles with and without enzyme cocktail supplementation to laying hens on performance, egg quality, selected manure parameters, and feed cost. *Livest. Sci*. 152: 174-181.

Ghazalah, A.A., Abd-Elsamee, M.O. and Al-Arami, A.A. 2011. Use of distillers dried grains with solubles (DDGS) as replacement for yellow corn in laying hen diets. *Egyptian Poult. Sci.* 31: 191-202.

Gupta, S.L., Tyagi, P.K. and Mir, N.A. 2020. Feeding value of rice distiller's dried grains with solubles as protein supplement in diet of laying hens. *Trop. Anim. Health Prod.* 52: 1229-1237.

Gupta, S.L., Tyagi, P.K., Tyagi, P.K., Mandal, A.B., Dinani, O.P. and Rokade, J.J. 2017. Feeding effect of rice based dry distillers grains with soluble on hemato-biochemical and egg sensory attributes during 45th to 54th week of laying, *Int. J. Pure Appl. Biosci.* 5: 1521-1527.

Hack, M.A., El-Hindawy, M.M., Attia, A.I. and Khalid, M. 2015. Effects of feeding dried distillers grains with solubles with or without enzyme or vitamin E supplementation on productive performance of hisex brown laying hens. Zagazig. *J. Agric. Res.* 42: 71-79.

Huang, H.J., Chiou, P.W., Chen, C., Chiang, J. and Yu, B. 1999. Effects of rice distillers' and grain supplementation on performance of lactacting cows. *Anim. Feed Sci. Technol.*77: 303-315.

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

Masa'deh,Purdum,M.K., S.E. and Hanford, K.J. 2011. Dried distillers grains with solubles in laying hen diets. *Poult. Sci.* 90: 1960-1966.

Pineda, L., Roberts, S., Kerr, B., Kwakkel, R., Verstegen, M. and Bregendahl, K. 2008. Maximum dietary content of corn dried distiller's grains with solubles in diets for laying hens: effects on nitrogen balance, manure excretion, egg production, and egg quality. A.S. Leaflet R2334.

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

Roberts, S.A., Xin, H., Kerr, B.J., Russell, J.R. and Bregendahl, K. 2007a. Effects of dietary fiber and reduced crude protein on ammonia emission from laying-hen manure. *Poult. Sci.* 86: 1625-1632.

Roberts, S.A., Xin, H., Kerr, B.J., Russell, J.R. and Bregendahl, K. 2007b. Effects of dietary fiber and reduced crude protein on nitrogen balance and egg production in laying hens. *Poult. Sci.* 86: 1716-1725.

Romero, C., Abdallh, M.E., Powers, W., Angel, R. and Applegate, T.J. 2012. Effect of dietary adipic acid and corn dried distillers grains with solubles on laying hen performance and nitrogen loss from stored excreta with or without sodium bisulfate. *Poult. Sci*. 91: 1149-1157.

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

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