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EFFECTS OF CORN DISTILLERS DRIED GRAINS WITH SOLUBLES ON REPRODUCTIVE PERFORMANCE OF ARBOR ACRES BROILER BREEDER HENS

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Abstract

The objective of this study was to examine the productive performance, egg quality and reproductive parameters of commercial Arbor Acres (AA) broiler breeder hens fed different levels of corn distillers dried grains with solubles (DDGS). A total of 2340 AA broiler breeder hens, 26 weeks of age, were allocated for a 14-week experimental period in a feeding trial consisting of 3 dietary treatments (0, 10, and 15% DDGS), and 4 replicates per treatment. Each replicate consisted of a group of 195 hens (male to female ratio 1: 10). All experimental diets were prepared as iso-protein (16%) and isocaloric (ME 11.7 MJ/kg) and with similar content of total sulfur amino acids, Ca and available P. The use of DDGS up to 15% in AA broiler breeder hens diet did not have adverse effects on egg production, feed intake, feed conversion ratio and egg mass (P>0.05). DDGS, also led to a significantly increased yolk color intensity (P<0.001), while having no effect on egg interior and exterior quality, especially on eggshell quality, such as egg specific gravity. Fertility and hatchability of fertile eggs were not affected by the dietary DDGS levels. Based on the results, DDGS could be included up to a level of 15% in AA broiler breeder hens' diet without any significant detrimental effects on the egg production, egg quality and reproductive performance.

Key words: *Arbor Acres broiler breeder hen, distillers dried grains with solubles, egg quality, hatchability.*

INTRODUCTION

Broiler breeder diets influence subsequent egg production performance and also embryogenesis and hatchability of broiler eggs (Adeyemo et al., 2007; Bozkurt et al., 2008; Javanka et al., 2010; Krawczyk et al., 2012). Efficient management practices must be maintained for the female broiler breeder to lay eggs and therefore pass on her genetic potential for rapid growth to her progeny (Richards et al., 2010). Therefore, one of the challenges of a nutritionist should be to include in broiler breeder diets of any *alternative* product as an ingredient to minimize the cost of feed. Distillers dried grains with solubles (DDGS) production has increased greatly over the past several years, mostly because of the increase in beverage and as well as ethanol production. DDGS as a by-product has traditionally been fed primarily to ruminants due to its high fiber content and variability of nutrients (Singh et al., 2005). Poultry diets must be formulated precisely, and previous research has shown that DDGS is a valuable source of energy, protein, and amino acids (Parsons and Baker, 1983; Robertson et al., 2005; Wang et al., 2007). Likewise, DDGS are a good source of phosphorus (P), containing 0.72% total P (NRC, 1994), and the bioavailability of P is higher than the 25 to 35% that is typical of most plant ingredients.

In the literature, there is an abundance of information about the composition and use of DDGS presented in various forms. In many earlier studies, it was concluded that DDGS was a useful feed ingredient for laying hens, broiler chickens and turkeys (Roberson, 2003; Noll et al., 2004; Roberson et al., 2005; Lumpkins et al., 2004; 2005; Noll and Brannon, 2006; Świątkiewicz and Koreleski, 2006; 2008; Loar et al., 2010; Masa'deh et al., 2011; Shim et al., 2011; Niemiec et al., 2012; 2013). There is sparse research regarding the use of DDGS in broiler breeder hen diets (Krawczyk et al., 2012; Mejia et al., 2012).

Feeding higher levels of this by-product could have a significant effect on feed costs for poultry producers as a result of the higher availability of this by-product for livestock usage and the current price fluctuations of feed ingredients.

The current study was designed to assess the effect of the inclusion of DDGS in the maternal diet on embryo viability, hatchability, and initial growth of the progeny. An important aspect of the study was to evaluate how this ingredient affects the egg quality and, in particular, egg interior and exterior quality. Therefore, we assessed the egg production, quality of eggs and reproductive parameters during peak production on Arbor Acres broiler breeder hens that were fed diets with graded levels of DDGS, providing the opportunity to replace corn and soybean meal.

MATERIALS AND METHODS

The study protocol was approved by the Animal Ethics Committee of the National Research and Development Institute for Animal Biology and Nutrition Baloteşti, Romania, and was in accordance with the principles of the EU Directive 2010/63/EU and Romanian Law on Animal Protection.

Birds, management and diets

A total of 2340 broiler breeder hens Arbor Acres, 26-wk-old, were weighed individually (BW = 2.90 ± 4.7 kg) and reared in 12-floor pens with wood-shaving litter (6.2 birds/m^2). All birds were housed under controlled climate conditions (temperature 18 ± 2^{0}C, relative humidity 70%, light schedule 16L: 8D). Feed and water were provided *ad libitum* throughout the experimental period. Vaccination and medical care were done according to common veterinary care under veterinarian's supervision.

Birds were randomly allocated to 3 dietary treatments of 780 hens per treatment (male to female ratio 1: 10). Each dietary treatment had 4 replications. Experimental diets were fed from 26 to 39 wk of age. Males were fed together with hens in the same feeders; separate-sex feeding was not applied. So, the amount of daily feed allowance for males was assumed to be similar to females. Corn-DDGS was included in the breeder's diet at 0, 10, and 15%, respectively (DDGS-0, DDGS-10 and DDGS-15) at the expense of corn and soybean meal. Diets were in mash form and were manufactured to be isonitrogenous, isocaloric, and with similar content of total sulfur amino acids (TSAA), calcium and available P compared to breeders' recommendation (Arbor Acres, 2013).

Sampling and analysis

To ensure the accurate formulation of the experimental diets (Table 1), samples of ingredients were analyzed using standard procedures according to the methods of the Commission Regulation (EC) no. 152 (OJEU, 2009). The metabolizable energy content of the diets was calculated on the basis of the energy content of individual feed ingredients using regression equations from the NRC (1994). Amino acids (AA), excluding tryptophan, which was not determined, were analysed using a high performance liquid chromatography (HPLC system; Thermo Fisher Scientific Inc., San Jose, CA USA), fitted with a quaternary system for solvent pumping, and with photodiode array detectors (Surveyor PDA Plus Detector), according to the conditions described by Ciurescu et al. (2018). We used a highly pure Hypersil GOLD silica chromatographic column, designs to optimize separations and maximize productivity. AA standards certified and purchased from Sigma-Aldrich were injected for the qualitative and quantitative determinations. All reagents were certified and had HPLC purity.

Egg production and performance

Daily hen egg production and mortality were recorded daily throughout the 14-week experimental period. Egg characteristics were measured daily for all eggs laid during week 39 and included egg and egg components weight (albumen [AW], yolk [YW] and eggshell [ESW]), eggshell specific gravity (ESG), albumen height (AH) and yolk color. ESG was assessed by the flotation method (Bennett, 1992). Eggs were then weighed and cracked carefully separating contents from eggshell, using a micrometer with ultrasonic wave system (SANOVO Technology A/S, Odense NV, Denmark). The same equipment also detected the AH and the yolk color with an RGB sensor.

Table 1. Composition of experimental diets (g/kg^{-1})

Ingredients	DDGS-0	DDGS-10	DDGS-15
Corn	433.2	353.6	319.3
Wheat	270.0	302.4	313.7
Soybean meal	195.0	143.0	117.3
Corn-DDGS	-	100.0	150.0
Vegetable oil	4.0	5.7	6.0
Monocalcium phosphate	11.0	8.0	6.0
Calcium carbonate	73.5	74.2	74.7
Sodium chloride	2.0	2.0	2.0
Vitamin-mineral premix[1]	10.0	10.0	10.0
DL-methionine (99%)	1.3	1.1	1.0
Calculated nutrient composition (g/kg)			
Crude protein	160.0	160.3	160.4
ME (MJ/kg)	11.7	11.7	11.7
Lysine, total	7.7	7.1	6.8
Lysine, digestible	6.7	6.0	5.7
Methionine, total	3.8	3.8	3.8
Methionine, digestible	3.6	3.5	3.5
TSAA, total	6.7	6.7	6.7
TSAA, digestible	6.0	5.8	5.7
Calcium	30.0	30.0	30.0
Phosphorus, available	3.4	3.4	3.4
Crude fat	30.0	37.4	40.6
Crude fibre	24.0	29.0	31.5
Analysed (g/kg)			
Dry matter	898.9	902.5	899.3
Crude protein	159.6	161.2	159.8
Crude fibre	28.5	27.6	29.9
Crude fat	29.2	38.5	45.7

[1]Supplied per kg diet: vitamin A from retinyl acetate, 12,000 IU; vitamin D_3, 3,500 IU; vitamin E from dl-α-tocopheryl acetate, 100 mg; menadione sodium bisulphite, 5 mg; thiamine mononitrate, 3 mg; riboflavin, 12 mg; vitamin B_6 from pyridoxine mononitrate, 5 mg; cyanocobalamin, 0.030 mg; Ca-panthotenate, 13 mg; niacin, 50 mg; folic acid, 2 mg; d-biotin, 0.3; choline (choline chloride), 1200 mg; Mn, 120 mg; Zn, 110 mg; Fe, 50 mg; Cu, 10 mg; I, 2.0 mg; Se, 0.30 mg; Co, 0.25 mg.

Eggshell weight (ESW) was expressed as a percentage of the egg weight. Albumen weight (AW) was calculated by subtracting the weights of yolk (WY) and eggshell from the weight of the egg. Egg mass was calculated by multiplying egg weight by egg production.

At 39 week the residual feeds and birds were weighed and the final BW, feed intake, and feed conversion ratio (FCR) were determinate. FCR was expressed as kg of feed consumed per kg of egg produced. The magnitude of production variables such as feed intake and egg production was adjusted for hen mortalities. Deaths were recorded daily as they occurred. Replicate pen means for each parameter were used for analyses.

Hatchability

Hatching eggs were collected daily at 39 weeks of age (n = 1,300), identified by date of collection and pen, and were stored at 18^{0}C and 70% relative humidity until incubation. Any cracked eggs or eggs weighing less than 52 g were not used in this experiment. The remaining eggs were incubated in a Petersime Incubator (Petersime Incubator Co., Ohio, USA). Incubator was set at 37.6^{0}C dry bulb and 28.6^{0}C wet bulb temperatures. Eggs were candled on day 10 of incubation for determination of infertile eggs. All infertile eggs were opened and examined macroscopically for evidence of embryonic mortality. Fertility was expressed as a rate of fertile eggs to total eggs set. On day 19, eggs were transferred to the hatching cabinet of the same incubator for hatching. Hatching incubator was set at 37.5^{0}C dry bulb and 29.2^{0}C wet bulb temperatures. The number of eggs that hatched was recorded at 21.5 days of incubation. Hatchability of fertile eggs was expressed as the rate of hatching chicks to fertile eggs. After hatching, the initial chick body weight was determined.

Statistical analysis

The collected data were analyzed by the General Linear Models (GLM) procedure using the SPSS software version 20.0 (SPSS, 2011). *Post hoc* Tukey's multiple comparison test was used to evaluate the statistical significance of differences among the treatment means. Differences were considered significant at $P < 0.05$.

RESULTS AND DISCUSSIONS

Nutrient composition of corn-DDGS

Table 2 shows the chemical composition of corn DDGS (n = 28 samples). When converted to a dry matter basis, the contents of crude protein ranged from 24.8 to 36.2%, ether extract from 10.8 to 12.5%, crude fiber from 9.1 to 10.5%, ash from 5.0 to 5.7%, and starch from 4.1 to 13.3%. The coefficient of variation (CV) for these nutrients ranged from 4.3 to 45.7%. The average values for crude protein, ether extract, fiber, ash, and starch were 25.1, 11.8, 9.4, 5.2, and 8.3%, respectively. The average dry matter content was 93.6% with a CV of 11.9%.

In an early study, Cromwell et al. (1993) evaluated the physical, chemical, and nutritional properties of DDGS from nine different sources (two from beverage and seven from fuel-alcohol production systems), and found that considerable variability in nutrient contents existed among DDGS samples. A decade later, Spiehs et al. (2002) evaluated the nutrient content and variability of DDGS in a total of 118 samples from 10 fuel-ethanol plants during 1997, 1998, and 1999. They noted that the values are not substantially different from those of Cromwell et al. (1993), and both showed higher variation in ash content and lower variation in dry matter content. Belyea et al. (2004) analyzed 235 DDGS samples from a fuel-ethanol plant in Minnesota and found that the average values (% dry matter) for protein, oil, ash, crude fiber, and ADF were 31.4, 12.0, 4.6, 10.2, and 16.8, respectively. They also reported the average content of residual starch as 5.3%. Thus, Belyea et al. (2004) gave higher average values of protein, oil, and crude fiber and a lower value of ash compared to Spiehs et al. (2002). Liu (2008) showed average values of six DDGS samples for protein, oil, ash, and starch as 27.4, 11.7, 4.4, and 4.9%, respectively, dry matter basis. The lower estimate of the protein value as compared with the previous three studies might be due to the use of 5.75 as conversion factor from nitrogen instead of 6.25. We also assessed amino acids (AA) content on 12 corn-DDGS samples, and the average content of lysine varied from 6.67 to 8.05 g/kg (converted to dry matter basis), methionine from 5.66 to 7.10 g/kg, threonine from 8.55 to 9.82 g/kg and arginine from 8.10 to 11.36 g/kg (Table 2).

Table 2. Chemical composition of the DDGS[1] (g/kg DM)

Nutrients	Mean	Limits	CV[2]
n	*28*	*28*	
Dry matter	936	925-945	11.9
Crude protein	251	248-362	4.3
Ether extractives	118	108-125	5.8
Crude fibre	94	91-105	10.1
Ash	52	50-57	7.2
Starch	83	41-133	45.7
ME[3] (kcal/kg)	2.464	2.350-2.562	136.5
n	*12*	*12*	
Amino acids (g/kg DM)			
Lysine	7.37	6.67-8.05	12.8
Methionine	6.20	5.66-7.10	5.7
Cysteine	4.59	4.23-5.44	11.4
Threonine	9.08	8.55-9.82	7.3
Tryptophan	-	-	-
Leucine	21.69	19.86-24.77	16.5
Arginine	9.75	8.10-11.36	28.7
Histidine	6.52	6.33-8.94	11.8
Isoleucine	9.94	8.85-12.10	8.9
Valine	13.59	12.76-17.55	12.6
Phenylalanine	12.97	12.54-13.33	4.1
Tyrosine	7.71	5.37-9.21	38.7
Aspartic acid	20.85	20.66-21.33	6.9
Serine	16.22	16.11-16.53	4.2
Glutamic acid	41.63	41.61-41.74	5.7
Proline	25.77	25.70-25.81	6.6
Glycine	11.14	11.11-11.22	3.3

[1]Analysed data in INCDBNA chemistry laboratory; [2]Coefficient of variation, (%); [3]Metabolizable Energy value was calculated based on regression equations from the NRC (1994).

Lysine was the most variable among the 18 both essential and nonessential measured, with a CV = 12.8%, followed by leucine with a CV=16.5%, arginine with a CV = 28.7%, and tyrosine with a CV =3 8.7%. Nevertheless, lysine, one of the essential amino acids, was contained 2.9 times higher in DDGS than that of corn. In the Spiehs et al. (2002) study, 118 DDGS samples were analyzed for 10 essential amino acids; lysine was found to be the most variable among the 10 amino acids measured, with an average CV = 17.3%. Cromwell et al. (1993) and Spiehs et al. (2002) only analysed essential AA, but others (Batal and Dale, 2006; Han and Liu, 2010) looked at content of both essential and nonessential Salim et al. (2010) noted that although the nutrient content of DDGS is relatively consistent within the same processing source the main problem in the use of DDGS as a feed component is the high variability of nutrient concentration and quality among different DDGS sources.

Productive performance and egg quality

Mortality was low (< 2.5%) and unrelated to treatment. Egg production, egg weight, egg mass, feed intake, FCR and BW at the end of the trial are shown in Table 3. Hens fed the DDGS-10 and DDGS-15 diets yielded similar (P > 0.05) laying percentage, egg mass, as well as feed intake, FCR and final BW, compared with hens fed 0% DDGS.

Table 3. Egg production parameters and final BW of Arbor Acres broiler breeder hens fed diets with various DDGS levels from 26 to 39 weeks of age

Treatment[1]	Laying percentage, %	Egg weight, g	Egg mass, g/d	Feed intake, g/d	FCR, g/g egg	Final BW, g
DDGS-0	71.23	56.73	40.41	169.57	4.20	3362
DDGS-10	70.80	57.10	40.43	171.34	4.24	3378
DDGS-15	71.96	56.49	40.65	172.08	4.23	3366
SEM[2]	2.18	0.29	0.45	0.96	0.03	16.89
P-value	0.225	0.343	0.177	0.454	0.672	0.534

[1]DDGS-0 = control treatment (corn-wheat-soybean meal basal diet); DDGS-10 and DDGS-15 represents the basal diet (DDGS-0) containing DDGS at 10% (DDGS-10), or 15% (DDGS-15); [2]SEM - standard error of means.

In previous study, Mejia et al. (2012) did not observe differences in hen daily egg production and feed intake of broiler breeder hens (Cobb 500) fed diets with 25% DDGS and 3 different levels of digestible lysine intake: 1000, 800 or 600 mg/hen per day. In our current study all the diets were calculated to be isonitrogenous, isocaloric, and with similar content of TSAA, lysine and tryptophan, calcium and available phosphorus. Krawczyk et al. (2012), also, demonstrated that DDGS (up to 10%) can serve as a useful source of protein in the nutrition of hens included in the genetic resources conservation program because it improves laying performance. On the other hand, Lumpkins et al. (2005) and Roberson et al. (2005), when conducted experiments on laying hens incorporating up to 15% DDGS, reported no negative effect on egg production and feed intake. Results reported by Loar et al. (2010) noted that DDGS does not negatively affect production results of laying hens even at a level of DDGS as high as 32%.

Additionally, Masa'deh et al. (2011) showed that feeding DDGS up to 25%, had no effect on hen egg production and feed intake. On the contrary, Świątkiewicz and Koreleski (2006) reported a reduction in egg production for hens fed 20% DDGS in phase 2 (44-68 weeks of age) of egg production, but not in phase 1 (26-43 weeks of age).

In the present study, corn DDGS-10 or DDGS-15 diets fed to Arbor Acres broiler breeder hens did not adversely affect egg quality characteristics (P > 0.05), except for yolk color (P < 0.001; Table 4), which significantly increase as the dietary level of DDGS increased. According to our results, Masa'deh et al. (2011) also reported that corn DDGS at up to 25% dietary levels, during egg production cycles (Bovan Single Comb White Leghorn-type), had no negative effects on Haugh units, or specific gravity, and improved yolk color at the highest levels. In our experiment, the inclusion of DDGS (up to 15%) in broiler breeder hens' diets increase linearly yolk color. This indicates that dietary DDGS can make the yolk color more intense. Also, ESG (an indicator of eggshell quality) was similar among dietary treatments.

This finding is consistent with the report of Cheon et al. (2008) who found no differences in eggshell weight between layer hens (Hy-line Brown) fed a diet with 0, 10, 15 and 20% of DDGS. Krawczyk et al. (2012) noted that a diet containing 10% DDGS increased yolk color intensity and Haugh units while having no effect on eggshell quality in hens from two different local breeds. This indicates that xanthophylls in the DDGS were highly available. The carotenoid pigments especially xanthophylls contents of corn and DDGS are 17 mg/kg (NRC, 1994) and 30 mg/kg (Roberson et al., 2005), respectively, alleviating the need to use extra pigments in layer diets. The increase in yolk color intensity also, found in the earlier studies by Roberson et al. (2005), Świątkiewicz and Koreleski (2006), Loar et al. (2010), and Masa'deh et al. (2011) who indicates a high availability of carotenoids found in DDGS. Additionally, in an own previous study (Ciurescu et al., 2002) with laying hens (ROSO-SL; peak egg production) fed 30% corn DDGS resulted similar egg production and egg quality, compared with hens fed soybean meal diet. Furthermore, DDGS can contribute as much as half of the protein needed in the laying hen. Our results are partially in agreement with the observations of Lumpkins et al. (2005) who found no significant differences in yolk color, and interior egg quality, as measured by Haugh units, and the eggshell quality, as indicated by the shell breaking strength or specific gravity of the eggs between hens (Hy-line White Leghorn-type) fed diet with 0 or 15% of DDGS.

Reproductive Performance

Reproductive performance was estimated by determining fertility, hatchability of fertile eggs, embryonic mortality and initial growth of the progeny (Table 5).

Fertility and hatchability are the major parameters of reproductive performance which are most sensitive to genetic influences (Liptoi and Hidas, 2006). Fertility refers to the percentage of incubated eggs that are fertile while hatchability is the percentage of fertile eggs that hatch.

The statistical analysis of data of incubated eggs (n = 1,300) showed no significant differences among dietary treatments for hatchability (P > 0.05) but tended to improved fertility percentages (P = 0.085). Fertility numerically improved about 2.40% and 0.87% for the hens fed diet contained 15 and 10% DDGS, respectively than those no fed DDGS. Hatchability of fertile eggs was similar between treatments, possibly because in germ or in shell dead yielded similar results among all treatments (Table 5).

Table 4. Egg quality characteristics of Arbor Acres broiler breeder hens fed diets with various DDGS levels from 26 to 39 weeks of age

Treatment[1]	AH, mm	YW, g	Yolk colour,	AW, %	ESW, %	ESG, unit
DDGS-0	5.83	16.11	7.43 [c]	61.48	10.38	1.088
DDGS-10	5.90	16.07	7.96 [b]	61.46	10.31	1.086
DDGS-15	6.01	16.13	8.28 [a]	61.47	10.16	1.089
SEM[2]	0.66	0.05	0.83	1.07	0.07	0.08
P-value	0.341	0.372	<0.001	0.478	0.265	0.197

Abbreviations: AH, albumen height, YW, yolk weight, AW, albumen weight, ESW, eggshell weight, ESG, egg specific gravity. [1]DDGS-0 = control treatment (corn-wheat-soybean meal basal diet); DDGS-10 and DDGS-15 represents the basal diet (DDGS-0) containing DDGS at 10% (DDGS-10), or 15% (DDGS-15). [2]SEM - standard error of means. [a, b, c] Means within columns with different superscript letters are different ($P < 0.05$).

Table 5. Reproductive performance of Arbor Acres broiler breeder hens fed diets with various DDGS levels from 26 to 39 wk. of age

Treatment[1]	Fertility, %	Hatchability of fertile eggs, %	Dead in germ, %	Dead in shell, %	Chick initial BW, g/chick
DDGS-0	91.7	87.6	3.89	1.91	38.9
DDGS-10	92.5	88.1	3.76	1.89	39.2
DDGS-15	93.9	88.7	3.78	1.87	38.8
SEM[2]	3.22	0.93	0.85	0.42	0.67
P-value	0.085[T]	0.177	0.535	0.282	0.383

[1]DDGS-0 = control treatment (corn-wheat-soybean meal basal diet); DDGS-10 and DDGS-15 represents the basal diet (DDGS-0) containing DDGS at 10% (DDGS-10), or 15% (DDGS-15); [2]SEM - standard error of means.

Our results, also, showed that no significant differences were found among dietary treatments in chicks' post-hatch weight as percent of egg weight (P>0.05).
It is well known that egg weight is positively correlated with chick weight (Wilson, 1991; McNaughton et al., 1978; Tufft and Jensen, 1991).

CONCLUSIONS

On the basis of the results from our current study, inclusion levels of 15% of DDGS in Arbor Acres broiler breeder diets had no adverse effect on egg production and quality characteristics of the egg. Moreover, the use of DDGS improved significantly yolk color intensity and had a positive effect on reproductive parameters results, such as fertility percentage. Therefore, the research demonstrates that corn-DDGS may be an acceptable feed ingredient to be used in broiler breeder diets, replacing a part of imported soybean meal and corn or other cereals. In addition, DDGS might be advantageous to nutritionists in formulating a breeding hen diet at a lower cost.

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