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Nutritive and Economic Values of Corn Distiller's Dried Grains with Solubles in Broiler Diets

H. S. Choi, H. L. Lee, M. H. Shin, Cheorun Jo, S. K. Lee and B. D. Lee*
Department of Animal Science and Biotechnology, Chungnam National University, Daejeon 305-764, Korea

ABSTRACT : A feeding trial was conducted to investigate the effects of the addition of corn distiller's dried grains with solubles (DDGS) to broiler diets on growth performance and meat characteristics. A total of 3,200 d-old, unsexed Cobb-500 broiler chicks were randomly allotted to 16 pens (replicates), with 200 chicks per pen. There were four diet treatments (0, 5, 10, and 15% DDGS), and four replicates per treatment. From 8 to 21 d of age, the birds were fed broiler starter diets containing similar energy (TMEn 3,100 kcal/kg) and protein (21.6%) contents. From 22 to 35 d of age, they were fed grower diets containing similar nutrients (3,150 kcal/kg, 19.5% crude protein). No significant difference was found in growth performances among the four treatments. As the DDGS level increased, the concentration of unsaturated fatty acids in meat increased ($p<0.05$). The color scores of breast and thigh muscles were not significantly influenced by DDGS, however, the yellowness of shank increased significantly by the addition of DDGS. The hardness of breast and thigh meats was not affected by the addition of DDGS. It was shown that the use of DDGS in broiler diets up to 15% could decrease the feed cost by replacing part of corn and soybean meal, without any negative effect on growth performance and meat qualities. (**Key Words :** Corn Distiller's Dried Grains with Solubles, Broilers, Fatty Acids, Color Score, Meat Hardness)

INTRODUCTION

Due to the escalated production of ethanol from corn as a biofuel in the U.S., the demand for corn in the global grain market is ever increasing, causing a sharp increase in the corn price. When corn price rises, the prices of other grains, such as wheat, barley, and soybean, rise too. This will make the situation of the feed industry even worse in Far Eastern countries, such as Japan, Taiwan, and South Korea, where most of the feed grains are imported. On the other hand, the production of corn distiller's dried grains with solubles (DDGS) in the U.S. is expected to double within the next few years, providing the opportunity to utilize it as an alternative grain source to the feed industry (Noll et al., 2001; Shurson, 2003).

During the past two decades, active research was conducted with DDGS to replace corn, soybean meal, and calcium phosphate in poultry feeds. Waldroup et al. (1981) reported that up to 25% DDGS could be used in broiler diets if dietary energy was held constant. Parsons et al. (1983) reported that the protein quality of DDGS was comparable to that of dehulled soybean meal when supplemented with lysine. The physical, chemical and nutritional characteristics of DDGS for chicks and pigs were evaluated (Cromwell et al., 1993), and a great amount of variability was found in these properties among the sources of DDGS available to the feed industry. Lumpkins et al. (2004) concluded that DDGS from modern ethanol plants was an acceptable feed ingredient for broiler diets and could be safely used at 6% in the starter period and 12 to 15% in the grower and finisher periods.

Owing to the high cost of transportation and handling, only minimal amounts of DDGS were imported and used in poultry feeds in South Korea so far. However, the importance of DDGS as a poultry feed ingredient will increase markedly as described above. Thus, a feeding trial was conducted to evaluate the nutritive and economic values of high quality DDGS in commercial broiler diets.

MATERIALS AND METHODS

Experimental protocol

In this experiment, high quality DDGS imported from the U.S. was used, and its composition is shown in Table 1. One-day old, unsexed Cobb-500 broiler chicks (3,200) were

* Corresponding Author: B. D. Lee. Tel: +82-42-821-5778, Fax: +82-42-825-9754, E-mail: leebd@cnu.ac.kr
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Table 1. Analyzed chemical composition of corn distillers dried grains with solubles[1]

Items	%
Dry matter	87.52
Crude protein	26.53
Crude fat[2]	12.50
Crude fiber	5.79
Crude ash	4.48
Calcium	0.06
Phosphorus	0.77
Lysine	0.76
Methionine	0.50
Threonine	0.99
Palmitic acid	1.71
Stearic acid	0.28
Oleic acid	3.26
Linoleic acid	6.88
TMEn (kcal/kg)[3]	3,278.00

[1] A private logistics company collected 5 metric tons of light color DDGS from several ethanol plants in the mid-western area of the U.S. and shipped in container boxes.
[2] Extracted 3 h with petroleum ether (AOAC, 1995).
[3] Calculated values.

randomly allotted to 16 pens (replicates) according to body weight, with 200 chicks per pen (4.5 m×4.75 m). There were four diet treatments (0, 5, 10, and 15% DDGS), and four replicates per treatment. A commercial prestarter diet (CP 23%, TMEn 3,050 kcal/kg) was offered to all birds until 7 d of age. From 8 to 21 d of age, the birds were fed experimental starter diets containing similar energy (TMEn 3,100 kcal/kg) and protein (21.6%) contents (Table 2). From 22 to 29 d of age, they were fed experimental grower diets containing similar nutrients (3,150 kcal/kg, 19.5% crude protein, Table 3). All diets were crumbled, and rice hull was used as litter. Feed, water, and light were provided without cessation. A commercial feed program (Bestmix 5.04, Adifo b.v., Maldegem, Belgium) was used to formulate the experimental diets for economic analysis.

Measurements and analyses

Birds were weighed by pen at 8, 21, and 29 d of age. Feed conversion ratios (feed/gain) were obtained from dividing total feed intake by body weight gain. After measuring the final body weight, one bird from each pen was selected and sacrificed by exsanguinating the jugular vein.

Table 2. Formula, chemical composition and ingredient price of experimental diets for broiler starters (8-21 d of age)

Items	DDGS				Ingredient price (won/kg)[1]
	0%	5%	10%	15%	
Ingredients (%)					
Yellow corn	34.68	33.04	31.17	29.18	151.8
Wheat	25.00	25.00	25.00	25.00	157.2
Soybean meal	17.18	14.35	11.66	8.94	241.6
Dehulled soybean meal	10.00	10.00	10.00	10.00	270.5
Rapeseed meal	2.00	2.00	2.00	2.00	156.4
Corn gluten meal	3.00	3.00	3.00	3.00	380.0
Animal fat	4.25	3.61	3.05	2.54	520.0
Lysine-HCl (30%)	0.86	1.04	1.22	1.39	425.0
DL-Methionine (99%)	0.33	0.32	0.30	0.30	2,250.0
L-threonine (98%)	0.07	0.07	0.08	0.09	3,670.0
Salt	0.15	0.15	0.15	0.15	104.0
Limestone	0.83	0.97	1.11	1.25	30.0
Dicalcium phosphate	0.82	0.62	0.43	0.33	328.0
Sodium bicarbonate	0.20	0.20	0.20	0.20	190.0
Choline-Cl (50%)	0.12	0.12	0.12	0.12	970.0
Mineral premix[2]	0.20	0.20	0.20	0.20	760.0
Vitamin premix[3]	0.06	0.06	0.06	0.06	5,040.0
Other additives[4]	0.25	0.25	0.25	0.25	
DDGS[5]	0	5.00	10.00	15.00	219.40
	100.00	100.00	100.00	100.00	
Analyzed composition					
TMEn, (kcal/kg)[6]	3,104	3,105	3,106	3,107	
Crude protein (%)	21.59	21.60	21.61	21.63	
Crude fat (%)	6.78	6.90	7.09	7.32	
Calcium (%)	0.87	0.87	0.87	0.89	
Phosphorus (%)	0.60	0.58	0.56	0.56	
Lysine (%)	1.28	1.28	1.28	1.28	
Methionine (%)	0.64	0.64	0.63	0.63	
Threonine (%)	0.83	0.84	0.84	0.85	
Feed cost (won/kg)	228.75	227.21	226.16	225.38	

[1] Ingredient prices of June 2006 were used (945 won/dollar US).
[2] Provided following per kg of diet: Cu, 66 mg; Fe, 80 mg; Mn, 60 mg; Zn, 40 mg; I, 0.9 mg; Se, 0.2 mg; Co, 0.3 mg.
[3] Provided following per kg of diet: vit. A, 12,000 IU; vit. D_3, 3,000 IU; tocopherol, 15 mg; vit. K_3, 2 mg; thiamin, 2 mg; riboflabin, 6 mg; pyridoxin, 2 mg; vit. B_{12}, 0.03 mg; folic acid, 1 mg; biotin, 0.15 mg; niacin, 45 mg; D-Ca pantothenic acid, 15 mg; antioxidant, 0.5 mg.
[4] Other additives: carbohydrases, 0.05%; phytase, 0.05%; coccidiostats, 0.15%. [5] Refer to Table 1. [6] Calculated values.

Table 3. Formula, chemical composition and ingredient price of experimental diets for broiler growers (22-29 d of age)

Items	DDGS			
	0%	5%	10%	15%
Ingredients (%)				
Yellow corn	42.66	40.98	37.56	34.11
Wheat	25.00	25.00	25.00	25.00
Soybean meal	11.19	8.49	7.75	7.09
Dehulled soybean meal	10.00	10.00	10.000	10.00
Corn gluten meal	4.00	3.86	2.79	1.63
Animal fat	3.24	2.64	2.55	2.51
Lysine-HCl (30%%	1.07	1.25	1.35	1.45
DL-methionine (99%)	0.32	0.31	0.30	0.29
L-threonine (98%)	0.11	0.11	0.12	0.12
Salt	0.15	0.15	0.15	0.15
Limestone	0.89	1.04	1.25	1.42
Dicalcium phosphate	0.51	0.31	0.32	0.37
Sodium bicarbonate	0.20	0.20	0.20	0.20
Choline-Cl (50%)	0.10	0.10	0.10	0.10
Mineral premix[1]	0.20	0.20	0.20	0.20
Vitamin premix[2]	0.06	0.06	0.06	0.06
Other additives[3]	0.30	0.30	0.30	0.30
DDGS[4]	0	5.00	10.00	15.00
	100.00	100.00	100.00	100.00
Analyzed composition				
TMEn (kcal/kg)[5]	3,150	3,150	3,150	3,150
Crude protein (%)	19.45	19.46	19.47	19.50
Crude fat (%)	6.01	6.16	6.71	7.28
Calcium (%)	0.85	0.85	0.85	0.85
Phosphorus (%)	0.54	0.52	0.50	0.50
Lysine (%)	1.17	1.17	1.17	1.17
Methionine (%)	0.61	0.60	0.60	0.59
Threonine (%)	0.78	0.78	0.79	0.79
Feed cost (won/kg)	221.76	220.40	219.96	219.66

[1] Ingredient prices of June 2006 were used (945 won/dollar US).
[2] Provided following per kg of diet: Cu, 66 mg; Fe, 80 mg; Mn, 60 mg; Zn, 40 mg; I, 0.9 mg; Se, 0.2 mg; Co, 0.3 mg.
[3] Provided following per kg of diet: vit. A, 12,000 IU; vit. D_3, 3,000 IU; tocopherol, 15 mg; vit. K_3, 2 mg; thiamin, 2 mg; riboflabin, 6 mg; pyridoxin, 2 mg; vit. B_{12}, 0.03 mg; folic acid, 1 mg; biotin, 0.15 mg; niacin, 45 mg; D-Ca pantothenic acid, 15 mg; antioxidant, 0.5 mg.
[4] Other additives: carbohydrases, 0.05%; phytase, 0.05%; coccidiostats, 0.15%. [5] Refer to Table 1.

Table 4. Effects of corn distillers dried grains with solubles in broiler diets on the performance of broilers

Items	DDGS			
	0%	5%	10%	15%
8-21 d				
Feed intake (g/bird)	1,140±44.5[1]	1,126±20.0	1,105±27.3	1,141±33.7
BW gain (g/bird)	828±21.9	819±19.8	805±23.2	832±4.6
Feed/gain	1.38±0.02	1.38±0.01	1.37±0.01	1.37±0.03
Survivability (%)	98.8±0.50	97.6±1.60	98.5±0.82	96.8±1.32
22-29 d				
Feed intake (g/bird)	1,039±30.0	1,065±24.9	1,040±29.3	1,057±22.6
BW gain (g/bird)	597±42.5	627±22.9	603±16.1	614±24.7
Feed/gain	1.74±0.08	1.70±0.03	1.72±0.01	1.72±0.04
Survivability (%)	99.0±0.58	98.7±0.50	98.9±0.76	99.1±0.26
8-29 d				
Feed intake (g/bird)	2,179±46.4	2,191±28.4	2,145±52.9	2,198±56.2
BW gain (g/bird)	1,425±40.6	1,446±26.8	1,408±35.8	1,446±28.5
Feed/gain	1.53±0.03	1.52±0.01	1.52±0.00	1.52±0.02
Survivability (%)	97.8±0.50	96.4±1.38	97.4±1.11	95.9±1.31

[1] Mean±SD.

Muscles from breast and thigh, and shanks from both sides, were sampled and kept on ice for texture (Texture Analyzer, TA-XTⅡ, Stable Micro system Ltd., UK) and color (JX-777, Color Techno System Co. Ltd., Japan) analyses. Thigh meat samples were homogenized to analyze the fatty acid composition (Korea Food Code, 2005).

Data were subjected to one-way ANOVA using the GLM procedure at a probability level of $p<0.05$ to determine the statistical significance, and polynomial contrast (linear, quadratic, cubic) was done when significant

Table 5. Effects of corn distillers dried grains with solubles on the fatty acid composition of broiler thigh meats

Items	DDGS				Polynomial contrasts		
	0%	5%	10%	15%	Linear	Quadratic	Cubic
Total fat (%)	9.28±0.66[1]	9.75±0.94	9.25±0.83	8.81±0.50	NS[2]	NS	NS
Fatty acid composition (% of total fat)							
Palmitic acid	25.24[a]±0.38	25.00[a]±0.33	23.77[b]±0.41	23.77[b]±0.39	p<0.05	NS	NS
Stearic acid	6.73[a]±0.16	6.28[ab]±0.17	6.38[ab]±0.10	5.93[b]±0.23	p<0.05	NS	NS
Oleic acid	43.24[a]±0.63	42.25[ab]±0.41	41.26[ab]±1.01	40.38[b]±0.82	p<0.05	NS	NS
Linoleic acid	14.45[c]±0.39	16.02[b]±0.51	18.62[a]±0.85	19.88[a]±0.40	p<0.05	NS	NS
Saturated fatty acid	33.37[a]±0.46	32.62[ab]±0.40	31.55[bc]±0.49	30.88[c]±0.42	p<0.05	NS	NS
Unsaturated fatty acid	66.63[c]±0.46	67.38[bc]±0.40	68.45[ab]±0.49	69.12[a]±0.42	p<0.05	NS	NS

[1] Mean±SD. [2] Not significant.

[a-c] Means with different superscripts in the same row significantly differ (p<0.05).

Table 6. Effects of corn distillers dried grains with solubles on the color and hardness of broiler meats and shanks

Items	DDGS			
	0%	5%	10%	15%
Color scores				
Breast				
ΔE[1]	48.49±3.13[6]	50.31±3.26	50.67±5.73	49.18±11.87
L*[2]	46.45±3.30	47.59±3.42	47.13±6.35	48.09±6.20
a*[3]	10.28±2.14	13.01±2.18	13.21±2.22	13.52±4.63
b*[4]	8.68±2.53	9.36±2.08	11.17±3.25	9.74±2.71
Thigh				
ΔE	46.21±2.88	45.73±4.03	46.38±4.66	45.46±7.18
L*	44.02±2.50	41.68±5.71	43.10±4.70	42.96±6.05
a*	11.28±2.48	13.62±1.65	13.15±2.34	13.04±3.35
b*	7.76±2.60	10.01±2.80	10.72±2.63	9.01±1.62
Shank				
ΔE	45.34±5.72	51.32±8.93	50.77±4.98	52.53±6.27
L*	18.01±4.54	20.45±6.42	14.60±3.46	15.03±5.33
a*	11.25±3.41	14.49±5.36	10.45±3.94	11.75±3.14
b*[5]	39.47[b]±7.05	44.27[ab]±7.55	47.16[ab]±5.58	48.54[a]±6.50
Hardness				
Breast (kg/cm^2)	18.18±3.45	18.07±3.67	17.59±2.36	15.49±1.97
Thigh (kg/cm^2)	20.04±3.30	21.57±4.70	17.07±2.20	18.92±3.98

[1] Difference of color, $\Delta E = \sqrt{L^2 + a^2 + b^2}$.

[2] Lightness of sample, where 0 = black to 100 = white. [3] Redness of sample, where -80 = green to 100 = red.

[4] Yellowness of sample, where -80 = blue to 70 = yellow.

[5] Yellowness of shank was linearly increased as DDGS level gradually increased. [6] Mean±SD.

[a-b] Means with different superscripts in the same row significantly differ (p<0.05).

(SAS, 2000).

RESULTS AND DISCUSSION

Growth performance

The DDGS supplementation did not exert any significant influence (p<0.05) on the growth performance during the starter and grower periods (Table 4). This appears due to the similar plane of nutrition of experimental diets as shown in Table 2 and 3. Lumpkin et al. (2004) reported that 15% of DDGS improved the growth performance of broiler chicks during 0 to 18 d of age when they were fed iso-caloric diets, and no difference in growth performance during 0 to 42 d of age when they were fed iso-caloric and iso-protein diets containing 12% DDGS. On the other hand, Shurson (2003) observed improved growth rate and survivability in broiler chicks when fed diets containing 10% DDGS during 14 to 38 d of age.

Different laboratories have reported different energy values for DDGS: TMEn 3,097 kcal/kg by NRC (1994), TMEn 2,894 kcal/kg by Roberson et al. (2005) and TMEn 2,820 kcal/kg by Batal et al. (2006). In this experiment, we used the value of TMEn 3,278 kcal/kg DDGS (Table 1), which is somewhat higher than normal values. Since no significant difference was found in the growth performance among the four treatments (Table 4), it could be inferred that the TMEn value used in this experiment was fairly reasonable. More research is required to obtain proper energy values for DDGS having different qualities or nutrient contents.

It appears that corn and soybean meal in broiler diets could be replaced by high quality DDGS up to the level of 15%. Parsons (1983) and Noll (2003) recommended supplementation with synthesized amino acids, such as

Table 7. Economic analysis of corn distillers dried grains with solubles for broilers diets

Items	DDGS			
	0%	5%	10%	15%
8-21 d				
Feed cost (won/kg)	228.75	227.21	226.16	225.38
Feed/gain	1.38	1.38	1.37	1.37
Feed cost/kg gain[1] (won/kg)	315.68	313.55	309.84	308.77
	(100.00)	(99.33)	(98.15)	(97.81)
22-29 d				
Feed cost (won/kg)	221.76	220.40	219.96	219.66
Feed/gain	1.74	1.70	1.72	1.72
Feed cost/kg gain (won/kg)	385.86	374.68	378.33	377.82
	(100.00)	(97.10)	(98.05)	(97.92)

[1] Feed cost/kg gain = feed cost×feed/gain.

lysine, methionine, and threonine, when using DDGS in broiler diets.

Fatty acid composition of thigh meat

Although the dietary fat contents were gradually increased as the levels of DDGS increased (Tables 2 and 3), no difference was detected in the fat content of broiler thigh meats among the four treatments (Table 5).

The concentration of saturated fatty acids decreased and that of unsaturated fatty acids increased (linear, $p<0.05$) as the levels of DDGS increased (Table 5). It seemed that the high linoleic acid content in DDGS (Table 1, 6.88%) caused the difference in the concentration of unsaturated fatty acids in the thigh meats. NRC (1994) also reported high linoleic acid content in DDGS (4.55%), supporting the result of this experiment. It is inexplicable why the concentration of oleic acid in thigh meats decreased (linear, $p<0.05$) as the DDGS level increased.

Color and hardness of meats

DDGS did not exert any influence on the color of breast and thigh meats, however, the yellowness of shank increased significantly (linear, $p<0.05$) as the DDGS level increased (Table 6). Roberson et al. (2005) reported that the xanthophyll content of DDGS was 29.75 mg/kg, compared to 17 mg/kg in corn (NRC, 1994). It appears that the xanthophyll is not well deposited in the muscle compared to the shank.

The hardness of breast and thigh meats was not affected by the different supplementation levels of DDGS. There is a dearth of information on the relationship between muscle hardness and dietary DDGS in chicks.

Economics of DDGS

As shown in Table 1, the value of TMEn of 3,278 kcal/kg was used for DDGS in this experiment, which was much higher than those values reported by Roberson et al. (2005) of 2,894 kcal/kg and by Batal et al. (2006) of 2,820 kcal/kg). All experimental diets were formulated to be iso-caloric and iso-protein by using a commercial feed mix program as shown in Table 2 and 3. The costs of feed decreased in starter and grower periods as the level of DDGS increased (Tables 2 and 3). The results of the feeding trial showed no difference in growth performance (Table 4), and meat quality (Tables 5 and 6) among the dietary treatments containing graded levels of DDGS up to 15%. This indicates that high quality DDGS could effectively be used up to 15%, replacing corn and soybean meal in broiler diets.

Another approach is to compare the feed cost needed to produce unit weight of broilers as shown in Table 7. During the starter period, the feed cost per kg gain decreased as the DDGS level increased. The effect of DDGS was very similar during the grower period by reducing the feed costs in DDGS-containing diets compared to the control. The 5% DDGS group showed the lowest feed cost per kg gain. The study showed that DDGS is a viable means to replace corn and soybean meal in broiler diets.

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