



Effects of Dietary Replacement of Soybean Meal with Corn Distillers Dried Grain with Solubles on Growth Performance and Carcass Characteristics of Broilers

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ABSTRACT

The purpose of the present study was to investigate the effects of dietary replacement of soybean meal (SBM) with corn distillers dried grain with solubles (cDDGS) on growth performance and carcass characteristics of broilers. A total of six hundred and forty-eight 21-day-old Sanhuang Broiler with similar weight (443.89 ± 13.2 g) were divided into 6 treatments: (1) Control group (T0), (2) 20% replacement group (T1), (3) 40% replacement group (T2), (4) 60% replacement group (T3), (5) 80% replacement group (T4), and (6) 100% replacement group (T5). Each treatment had 6 replicates, and each replicate had 18 broilers. The experiment lasted for 21 days. The results showed that: (1) Dietary replacement of SBM with cDDGS had significant ($P < 0.05$) effects on the final body weight, ADG, ADFI and F/G of broilers. (2) Dietary replacement of SBM with cDDGS had significant ($P < 0.05$) effects on the slaughter rate, semi-eviscerated rate of broilers, and there was a tendency of decrease in eviscerated rate when dietary replacement of 40% SBM with cDDGS ($P = 0.053$). There were no effects of dietary replacement of SBM with cDDGS on breast muscle rate and abdominal fat rate ($P > 0.5$). In conclusion, under the conditions of the present study, dietary replacement of SBM with cDDGS had significant effects on the growth performance and carcass characteristics of broilers. Based on the results from this experiment, it could conclude that dietary replacement of no more than 40% SBM with cDDGS (cDDGS amount less than 13.55%) may be used safely in commercial broilers diets.

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Authors' Contribution

XT and PP conducted the experiment, analyzed the data. XT wrote this article. KX helped in experimental design and provided financial support for this study. DD revised the paper.

Key words

Chemical composition, Broilers, Carcass characteristics, Corn distillers dried grain with solubles, Growth performance

INTRODUCTION

Animal husbandry is one of the most important parts of a modern agricultural industrial system. Traditionally, soybean meal (SBM) is used as the main protein source in animal feed, due to its high crude protein and energy concentration, and good digestibility than other protein sources (NRC, 2012). However, the shortage of soybean and the continuation of increased prices of SBM seriously restrict the development of animal husbandry in China. Unconventional protein resources, such as corn distillers dried grains with solubles (cDDGS), development and utilization have been considered as one of the effective methods to solve this problem. cDDGS is a by-product produced by dry-grind ethanol production from corn, which has commonly been used as a replacement for SBM in

animal feed due to its high protein and energy content, reasonable price and availability (Villela *et al.*, 2017; Oczkiewicz *et al.*, 2018). cDDGS is not a new feed material and has been used in broilers diets for many decades (Parsons *et al.*, 1983; Lumpkins *et al.*, 2004; Li *et al.*, 2013; Kim *et al.*, 2018), but the maximum inclusion level of cDDGS in broiler diet remains to be defined. Lumpkins *et al.* (2004) reported that cDDGS can be safely used in broiler diet at 6% in the starter period and 12 to 15% in the grower and finisher periods. Wang *et al.* (2007) demonstrated that 15 to 20% good-quality cDDGS could be used in broiler diets with little adverse effect on growth performance. Shim *et al.* (2011) even showed that diets containing up to 24% cDDGS had no adverse effect on performance of broiler in finisher period. But high levels of DDGS would compromise the physical form of the pellet (Shim *et al.*, 2011, 2018) and affect the meat quality of broiler (Schilling *et al.*, 2010). Therefore, the appropriate cDDGS addition ratio should be determined before it is widely used in broiler diets, so as to balance production performance and economic benefits. The nutrient composition of DDGS varies greatly due to the

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type, variety, and quality of the grains used and efficiency of the starch conversion process. So, the analysis of DDGS before the feed formulation is necessary.

Therefore, the objective of this study was to investigate the effects of dietary replacement of soybean meal with cDDGS on growth performance and carcass characteristics of broilers, as well as to provide reference for the application of cDDGS in the diets of broilers.

MATERIALS AND METHODS

The experimental procedures involving animals were reviewed and approved by the Institutional Animal Care and Use Committee at the Guizhou Normal University (Guiyang, Guizhou Province, China). cDDGS used in this study was imported from USA. Sanhuang broilers, a kind of high quality Chinese cross breeds that are distribution throughout the country were provided by Tangrenshen Group (Zhuzhou, China).

Chemical analysis of cDDGS

Dry matter (DM), crude protein (CP), crude fat (EE), crude fiber (CF), Ash, nitrogen free extract (NFE), Calcium (Ca) and Phosphorus (Pi) content of cDDGS were determined according to the [AOCS \(2009\)](#) method. Amino acids (AA) profile of cDDGS was analyzed using an automatic AA analyzer (L-8800; Hitachi, Tokyo, Japan).

DM digestibility and metabolic energy determination

DM digestibility and metabolic energy were measured by emptying-force-feeding method ([Sibbald, 1976](#)). A total of 16 Sanhuang broilers (male) with similar weight (2.20 ± 0.15 kg) were divided into 2 treatments: (1) The starvation group and (2) cDDGS group. Each treatment had 8 replicates. The starvation group was used to estimate metabolic and endogenous excretion ([da Silva *et al.*, 2012](#)). The experiment procedure performed as previously described ([Tang *et al.*, 2018](#)). DM was determined according to the [AOCS \(2009\)](#) method. Energy was measured by oxygen bomb calorimeter Parr 1281 (Parr Instrument Company, IL, USA) according to [ISO 9831 \(1998\)](#). Apparent DM digestibility (ADMD), true DM digestibility (TDMD), apparent metabolizable energy (AME), true metabolizable energy (TME) values were calculated according to the following formulae:

$$\text{ADMD (\%)} = (\text{DM input} - \text{DM output}) / (\text{DM input}) \times 100$$

$$\text{TDMD (\%)} = [\text{DM input} - (\text{DM output} - \text{endogenous DM loss})] / (\text{DM input}) \times 100$$

$$\text{AME} = (\text{ingested energy} - \text{fecal energy}) / (\text{ingested energy})$$

$$\text{TME} = (\text{ingested energy} - (\text{fecal energy} - \text{endogenous energy loss})) / (\text{ingested energy})$$

Growth performance

A total of six hundred and forty-eight 21-day-old Sanhuang broilers were divided into 6 treatments, (1) Control group (T0, cDDGS replacement of 0% SBM, 0% cDDGS), (2) 20% replacement group (T1, cDDGS replacement of 20% SBM, 6.83% cDDGS), (3) 40% replacement group (T2, cDDGS replacement of 40% SBM, 13.55% cDDGS), (4) 60% replacement group (T3, cDDGS replacement of 60% SBM, 20.20% cDDGS), (5) 80% replacement group (T4, cDDGS replacement of 80% SBM, 27.00% cDDGS), and (6) 100% replacement group (T5, cDDGS replacement of 100% SBM, 33.60% cDDGS). Each treatment had 6 replicates, and each replicate had 18 broilers (half male and half female). The composition and nutrition level of the diets is shown in [Table I](#). All diets were formulated to meet nutrient requirements suggested by [NRC \(1994\)](#). The broilers were housed in an environmentally controlled room with a 24-h constant light schedule and *ad libitum* access to water and feed. The experiment lasted for 21 days (from d 21 to d 42).

Broilers were weighted by pen and feed consumption was recorded weekly. Average daily gain (ADG), average daily feed intake (ADFI) and feed to meat ratio (F/G, where $F/G = \text{ADFI} / \text{ADG}$) was calculated.

Carcass characteristics

On day 21, six broilers from each treatment fasted for 12 h, weighed the body weight. All broilers bled to death after intravenous injection of pentobarbital. Then the carcasses were cut according to a standardized procedure (NY/T 823-2004) to determine the slaughter rate (carcass weight/body weight, %), semi-eviscerated rate (semi-eviscerated weight/body weight, %), eviscerated rate (eviscerated weight/body weight, %), breast muscle rate (expressed as a percentage of eviscerated weight), and abdominal fat rate (expressed as a percentage of eviscerated weight plus abdominal fat weight).

Statistical analysis

Results of chemical composition, apparent DM digestibility, true DM digestibility, AME, TME of cDDGS were expressed as mean. Results of growth performance and carcass characteristics were expressed as mean \pm SD and analyzed by One-way ANOVA using the SPSS 21.0 programs (SPSS, Inc., Chicago, IL, USA). Differences among treatment mean were determined using Duncan's multiple comparison test. $P < 0.05$ was considered significant, $P < 0.10$ was considered as significant tendency.

Table I. Diets composition and nutrient levels (as feed basis).

Ingredients (%)	T0*	T1	T2	T3	T4	T5
Corn	61.90	59.00	56.22	53.50	50.60	47.95
Wheat flour	4.00	4.00	4.00	4.00	4.00	4.00
Soybean meal	18.00	14.40	10.80	7.20	3.60	0.00
Corn DDGS	0.00	6.83	13.55	20.20	27.00	33.60
Cottonseed meal	1.00	1.00	1.00	1.00	1.00	1.00
Corn protein	6.50	6.50	6.50	6.50	6.50	6.50
Meat-bone meal	1.20	1.20	1.20	1.20	1.20	1.20
CaHPO ₄	1.20	1.10	1.00	0.90	0.80	0.70
Limestone	0.90	1.00	1.10	1.18	1.28	1.36
Methionin	0.10	0.09	0.08	0.08	0.07	0.06
Lysine	0.58	0.66	0.73	0.81	0.89	0.97
Threonine	0.02	0.02	0.02	0.03	0.03	0.04
Choline chloride	0.10	0.10	0.10	0.10	0.10	0.10
NaCl	0.30	0.30	0.30	0.30	0.30	0.30
Oil	1.80	1.80	1.80	1.80	1.83	1.82
Zeolite powder	2.00	1.60	1.20	0.80	0.40	0.00
Vitamin premix [#]	0.20	0.20	0.20	0.20	0.20	0.20
Mineral premix [†]	0.20	0.20	0.20	0.20	0.20	0.20
Total	100.00	100.00	100.00	100.00	100.00	100.00
Nutrient levels (%) [‡]						
ME (Mcal/Kg)	2.97	2.97	2.97	2.97	2.97	2.97
CP	18.78	18.79	18.78	18.78	18.79	18.77
EE	4.72	5.25	5.77	6.29	6.84	7.35
Lys	1.00	1.00	1.00	1.00	1.00	1.00
Met	0.42	0.42	0.42	0.42	0.42	0.42
Met+Cys	0.71	0.72	0.74	0.74	0.74	0.75
Ca	0.79	0.79	0.80	0.79	0.80	0.80
Available Pi	0.37	0.37	0.37	0.37	0.37	0.37

*T0, cDDGS replacement of 0% SBM; T1, cDDGS replacement of 20% SBM; T2, cDDGS replacement of 40% SBM; T3, cDDGS replacement of 60% SBM; T4, cDDGS replacement of 80% SBM; T5, cDDGS replacement of 100% SBM.

[#]provided per kg of diets: vitamin A, 3000 IU; vitamin D₃, 500 IU; vitamin E, 10 mg; vitamin K, 0.5 mg; vitamin B₁, 2 mg; vitamin B₂, 5.0 mg; vitamin B₆, 4.0 mg; vitamin B₁₂, 12 µg; folic acid, 0.55 mg; nicotinic acid, 20 mg; D-pantothenic acid, 15 mg.

[†]provided per kg of diets: Fe, 90 mg; Cu, 20 mg; Mn, 70 mg; Zn, 60 mg; I, 0.38 mg; Se, 0.20 mg.

[‡] All nutrient levels were calculated values.

RESULTS

Chemical composition of cDDGS

The chemical composition of cDDGS is shown in Table II. According to this table, the DM, CP, EE, CF,

Ash, NFE, Ca and Pi content of cDDGS was 89.90%, 25.67%, 10.15%, 8.29%, 4.06%, 41.73%, 0.02% and 0.78%, respectively. The composition of AA in cDDGS is presented in Table III. There are 16 kinds of amino acids in cDDGS in the present study. The content of glutamic acid (Glu, 4.11%) was the highest AA in cDDGS, followed by proline (Pro, 2.98%), and the methionine (Met, 0.53%) is the lowest AA in the present study.

Table II. The chemical composition of cDDGS (dry matter basis, %).

Items	Content
Dry matter	89.90
Crude protein	25.67
Crude fiber	8.29
Ether extract	10.15
Ash	4.06
Nitrogen free extract	41.73
Calcium	0.02
Phosphorus	0.78

Table III. The amino acids content of cDDGS (%).

Amino acids	Content	Amino acids	Content
Arginine	1.28	Histidine	0.69
Lysine	0.83	Alanine	2.01
Methionine	0.53	Proline	2.98
Threonine	1.01	Tyrosine	1.37
Aasparaginic acid	1.71	Valine	1.23
Serine	1.34	Isoleucine	0.94
Glutamic acid	4.11	Leucine	2.86
Glycine	1.04	Phenylalanine	1.05
Total	24.98		

DM digestibility and metabolic energy of cDDGS

DM digestibility and metabolic energy of cDDGS are shown in Table IV. In this study, the ADMD and TDMD of cDDGS was 44.31% and 51.31%, respectively. The AME, TME of cDDGS was 2.52 Mcal/Kg and 2.81 Mcal/Kg, respectively.

Effects of cDDGS on growth performance of broilers

As shown in Table V, dietary replacement of SBM with cDDGS has significant ($P < 0.05$) effects on the final body weight, ADG, ADFI, and F/G of broilers. Compared to control group, dietary replacement of 80% SBM with cDDGS would not affect the final body weight, ADG, ADFI and F/G of broilers, while dietary replacement of

100% SBM with cDDGS significantly ($P < 0.05$) decreased the final body weight and ADG of broilers. Compared with control group and other replacement groups, dietary replacement of 20% SBM with cDDGS can significantly ($P < 0.05$) improve the ADFI of broilers. Dietary replacement of 60%, 80%, 100% SBM with cDDGS would decrease ADG of broilers significantly ($P < 0.05$).

Table IV. DM digestibility and metabolic energy of cDDGS.

Items	Content
Apparent DM digestibility (%)	44.31 ± 2.10
True DM digestibility (%)	51.31 ± 1.50
Apparent metabolizable energy (Mcal/Kg)	2.52 ± 0.06
True metabolizable energy (Mcal/Kg)	2.81 ± 0.05

Effects of cDDGS on carcass characteristics of broilers

The carcass characteristics of broilers were presented in Table VI. Dietary replacement of SBM with cDDGS have significant ($P < 0.05$) effects on the slaughter rate, semi-eviscerated rate of broilers, and there was a tendency ($P = 0.053$) of decrease in eviscerated rate when dietary replacement of 40% SBM with cDDGS. There was no effect of dietary replacement of SBM with cDDGS

on breast muscle rate and abdominal fat rate ($P > 0.5$). Compared to control group, dietary replacement of 20%, 40%, 60%, 80% and 100% SBM with cDDGS did not affect the slaughter rate. However, compared to 20% replacement group, dietary replacement of 80% and 100% SBM with cDDGS significantly ($P < 0.05$) decreased the slaughter rate of broilers. Compared to 40% replacement group, dietary replacement of 100% SBM with cDDGS significantly ($P < 0.05$) decreased the slaughter rate of broilers. Compare to control group, dietary replacement of 40%, 60%, 80% and 100% SBM with cDDGS did not affect the semi-eviscerated rate of broilers, while dietary replacement of 20% SBM with cDDGS significantly ($P < 0.05$) increased the semi-eviscerated rate of broilers. Compared to 20% replacement group, dietary replacement of 60%, 80% and 100% SBM with cDDGS significantly ($P < 0.05$) decreased the semi-eviscerated rate of broilers.

DISCUSSION

Chemical composition of cDDGS

According to the results, attention should be paid to the high CF and low Ca content in cDDGS in feed formulation. The nutritional profiles of cDDGS vary widely according to different studies. For example, the CP content of cDDGS in present study is lower than the values

Table V. Effects of cDDGS on the growth performance of broilers.

Items	T0*	T1	T2	T3	T4	T5	P-value
IBW, g [‡]	411.11±3.52	411.11±3.52	412.04±4.18	411.11±3.93	411.11±2.49	410.65±3.25	0.991
FBW, g	1396.86±48.13 ^{bcd}	1441.67±20.69 ^d	1414.19±41.78 ^{cd}	1369.91±32.22 ^{abc}	1365.22±31.88 ^{ab}	1338.62±29.97 ^a	0.001
ADFI, g/d	111.29±3.75 ^a	116.56±3.13 ^b	111.70±1.06 ^a	112.34±2.39 ^a	109.22±1.35 ^a	109.10±4.66 ^a	0.004
ADG, g/d	46.91±2.14 ^{bc}	49.05±0.92 ^{cd}	47.83±1.95 ^d	45.66±1.55 ^{ab}	45.43±1.48 ^{ab}	44.19±1.35 ^a	<0.001
F/G	2.39±0.08 ^{abc}	2.38±0.07 ^{ab}	2.34±0.03 ^a	2.46±0.03 ^{bc}	2.40±0.05 ^{abc}	2.47±0.08 ^c	0.019

*T0, cDDGS replacement of 0% SBM; T1, cDDGS replacement of 20% SBM; T2, cDDGS replacement of 40% SBM; T3, cDDGS replacement of 60% SBM; T4, cDDGS replacement of 80% SBM; T5, cDDGS replacement of 100% SBM.

[‡]IBW, initial body weight; FBW, final body weight; ADFI, average daily feed intake; ADG, average daily gain; F/G, feed to meat ratio.

^{a-d} Values within a row lacking a common superscript letter are different ($P < 0.05$).

Table VI. Effects of cDDGS on the carcass characteristics of broilers (%).

Items	T0*	T1	T2	T3	T4	T5	P-value
Slaughter rate	91.22±1.22 ^{abc}	92.84±1.32 ^c	91.91±1.41 ^{bc}	90.98±1.09 ^{abc}	90.59±1.74 ^{ab}	89.66±2.30 ^a	0.030
Semi-eviscerated rate	81.11±1.02 ^a	83.64±1.34 ^b	82.82±1.80 ^{ab}	81.55±0.83 ^a	81.04±2.19 ^a	81.04±1.44 ^a	0.019
Eviscerated rate	70.03±0.47	72.41±1.18	71.60±1.75	70.80±0.87	70.16±2.40	70.22±1.37	0.053
Breast muscle rate	24.71±2.19	25.35±1.23	24.76±1.96	23.91±1.15	23.94±2.14	23.53±0.86	0.438
Abdominal fat rate	3.64±0.89	2.91±1.14	3.55±0.83	3.54±1.25	3.31±0.90	4.03±0.58	0.491

*T0, cDDGS replacement of 0% SBM; T1, cDDGS replacement of 20% SBM; T2, cDDGS replacement of 40% SBM; T3, cDDGS replacement of 60% SBM; T4, cDDGS replacement of 80% SBM; T5, cDDGS replacement of 100% SBM.

^{a,b,c} Values within a row lacking a common superscript letter are different ($P < 0.05$).

of Kerr *et al.* (2013), Batal and Dale (2006), Pedersen *et al.* (2007), Stein *et al.* (2009), Anderson *et al.* (2011) which the CP content range from 27.33% to 31.6%. The EE content of cDDGS in present study is lower than the values in NRC (2012), Stein *et al.* (2009), Anderson *et al.* (2011), in which the CP content range from 10.43% to 13.2%. It is important to analyze the proximate composition of cDDGS before it is used in animal feed.

According to the present study, the content of essential amino acid (EAA) in cDDGS was lower than that in SBM but was about 3 times than that in corn (NRC, 2012). However, the level of Met in cDDGS was similar to that in SBM, which could reduce the addition of Met in feed. It seems that the Lys in cDDGS can satisfy the requirement of poultry, but, in fact, due to the maillard reaction during cDDGS processing, the utilization rate of Lys in cDDGS by poultry was quite low. In addition to high CF, low Ca content and low Lys utilization rate, CP and other AA can meet the nutritional needs of broiler. Thus, the disadvantages of cDDGS can be compensated by reasonable feed proportion to make it meet the nutritional needs of poultry.

DM digestibility and metabolic energy of cDDGS

The metabolic energy values of cDDGS were different in varieties and processing techniques, which was the main reason that cDDGS could not be widely applied in livestock and poultry feed. Lumpkins *et al.* (2004) reported that the TME value of cDDGS for chicken was 11.72 MJ/kg (2.80 Mcal/Kg). Jie *et al.* (2013) reported that the AME of adult roosters to cDDGS was 5.93 to 12.19 MJ/kg (1.41 to 2.91 Mcal/Kg), TME was 7.28 to 13.54 MJ/kg (1.74 to 3.23 Mcal/Kg). The ME value of this study was in the range of the above study. So, it is necessary to analyze the metabolic energy values of cDDGS before it is used in animal feed, which plays an important role in the accuracy of the feed formulation. There is an easy way to estimate the TME content of cDDGS by measuring the DM digestibility of cDDGS, because the DM apparent digestibility of cDDGS was positively correlated with TME (Jie *et al.*, 2013).

Effects of cDDGS on growth performance of broilers

Corn DDGS is a high-quality protein feedstuff for poultry. cDDGS has been used in broilers diets for many decades, which reported that a certain level of cDDGS would not affect the growth performance of broilers chickens (Parsons *et al.*, 1983; Lumpkins *et al.*, 2004; Li *et al.*, 2013; Kim *et al.*, 2018), but the appropriate inclusion level of cDDGS in broiler diet remains controversial. Lumpkins *et al.* (2004) demonstrated that cDDGS can be safely used in broiler diet at 12 to 15% in the grower

and finisher periods which consistent with the results of the present study. Wang *et al.* (2007) demonstrated that 15 to 20% cDDGS could be used in broiler diets with little adverse effect on growth performance, and Shim *et al.* (2011) even showed that finisher diets containing up to 30% cDDGS had no adverse effect on performance of Chinese Yellow broiler, which is inconsistent with the results of the present study. High levels of cDDGS can have a negative impact on broiler production. Wang *et al.* (2007) showed that the feed conversion efficiency of broiler chickens would significantly reduce when the cDDGS addition amount exceeded 25%. High levels of DDGS would compromise the physical form of the pellet (Shim *et al.*, 2011, 2018) and affect the meat quality of broiler (Schilling *et al.*, 2010). Based on the ADG, ADFI and F/G from this experiment, it can be concluded that dietary replacement of no more than 40% SBM with cDDGS (cDDGS amount less than 13.55%) may be used safely in commercial broiler diets.

Effects of cDDGS on carcass characteristics of broilers

Carcass characteristics can directly reflect the animal body composition and the proportion of edible parts, which is an important indicator of animal production performance (Li *et al.*, 2019). According to the present study, an appropriate level of cDDGS did not affect the carcass performance of broilers, while high levels of cDDGS may affect the carcass performance of broilers. Previous studied have also confirmed this conclusion. Dozier *et al.* (2016) indicated that added 14% DDGS in finisher period did not affect carcass characteristics of broilers. Wang *et al.* (2007) showed that the cDDGS addition amount exceeded 25% in the diet significantly reduced the slaughter performance and breast muscle rate of broilers. Therefore, in broiler diets, cDDGS should not add too high levels, in terms of slaughter performance, the dietary replacement of SBM with cDDGS should not exceed 40% (cDDGS amount less than 13.55%) under the conditions of the present study.

There is no doubt that cDDGS can be used as a replacement for soybean meal safely in commercial broilers diets, due to its high concentration of energy, protein, amino acids, available phosphorus, and its relatively low market price (Fastinger *et al.*, 2006; Kowalczyk *et al.*, 2012; Villela *et al.*, 2017). It could be speculated that broilers diet supplemented with cDDGS had a higher economic benefit than SBM. Since a certain level of cDDGS in broiler diet did not influence the growth performance and carcass characteristics of broilers, however cDDGS is much cheaper than corn and SBM, from an economic point of view, that an increase in DDGS inclusion reduces the costs of feed. For poultry production, any measures

leading to lowered feeding costs are welcomed by poultry producers. So, on the premise of reasonable utilization, cDDGS has a broad market prospects.

CONCLUSIONS

In conclusion, under the conditions of the present study, dietary replacement of SBM with cDDGS have significant effects on the growth performance (the final body weight, ADG, ADFI and F/G of broilers) and carcass characteristics (slaughter rate, semi-eviscerated rate) of broilers. Based on the ADG, ADFI, F/G, slaughter rate and semi-eviscerated rate from this experiment, it could conclude that dietary replacement of no more than 40% SBM with cDDGS (cDDGS amount less than 13.55%) may be used safely in commercial broilers diets.

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Statement of conflict of interest

The authors have declared no conflict of interest.

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