

« Research Note »

Nutritive Value of Sorghum Dried Distillers Grains with Solubles and its Effect on Performance in Geese

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The study was conducted to determine the chemical composition and nutritive value of sorghum dried distillers grains with solubles (sDDGS) and its effect as a feed supplement on the performance of geese. Experiment 1 showed that the gross energy, crude protein, ether extract, crude fiber, calcium, phosphorus, and amino acid content values of sDDGS were 17.87 MJ/kg and 15.48, 4.26, 31.46, 0.17, 0.25, and 0.06–3.18% [dry matter basis (DM)], respectively. Experiment 2 used fasting–force feeding to measure the true metabolizable energy of sDDGS (11.38 MJ/kg DM) and true total tract digestibility of amino acids (43.16–80.92% DM) in geese. Experiment 3 examined the effectiveness of sDDGS as a feed supplement for geese. Three hundred and fifteen 35-day-old male Sichuan white geese with an initial average body weight of 1,732 g were randomly allocated to five treatments. Geese in each treatment group were fed one of five experimental diets (control diet alone, or supplemented with 4, 8, 12, or 16% sDDGS) until 70 days of age. Inclusion of sDDGS in the diet did not affect daily average weight gain ($P > 0.05$). Birds fed diets containing up to 8% sDDGS had higher average feed intake ($P < 0.05$) than geese fed the control diet, and the feed/gain ratio in geese fed diets containing 16% sDDGS was higher ($P < 0.05$) than in the control and the 4% sDDGS group. The yields of breast meat, leg meat, subcutaneous fat and skin, and abdominal fat were not affected ($P > 0.05$) by dietary sDDGS levels. Generally, sDDGS is a potentially valuable feedstuff for geese, but it should be supplemented with a high-energy or protein-rich ingredient. To improve growth performance and carcass yield, up to 12% sDDGS can be included in diets from 35 to 70 days of age.

Key words: carcass yields, chemical composition, digestibility, geese, growth performance, sorghum dried distillers grains with solubles

J. Poult. Sci., 55: 54–59, 2018

Introduction

Sorghum is a premier upland crop cultivated in Africa, Asia, Oceania, and America. Besides its use as a feedstuff, sorghum is used to produce distilled spirits and biofuel. In China, about 2.5–2.8 million tons of sorghum is used per year in distilled spirits production, and this produces about 1.5–1.7 million tons of sorghum dried distillers grains with solubles (sDDGS) as a by-product (Lu *et al.*, 2009). sDDGS is rich in crude fat (8.8–13%), crude protein (32.9–35.9%), and amino acids (0.38–6.92%) (Al-Suwaiegh *et al.*, 2002; Urriola *et al.*, 2009). Recently, sDDGS has been successfully used as an energy and protein source to feed beef and lactating dairy cattle (Al-Suwaiegh *et al.*, 2002; Gill *et al.*,

2008; Van Overbeke *et al.*, 2008; May *et al.*, 2010), pigs (Stein and Shurson, 2009; Urriola *et al.*, 2009), and broilers (Barekatin *et al.*, 2013a, b).

Goose meat is a source of high-quality protein for human consumption, and it is rich in both unsaturated and essential fatty acids, and low in cholesterol (Schmid, 2010). As a result, there is growing interest in increasing goose production throughout the world. In 2013, more than 6.48 billion geese were used for meat production in China (Gong, 2015). Furthermore, because of their ability to digest fiber-rich feed, geese can be supplied with food supplemented with roughage, thus allowing some cost savings over the use of conventional feed grains such as corn and soymeal. Given the nutritive value of sDDGS, it may be useful as a common feed for geese, although there is little information regarding the potential value of sDDGS in goose production. This study was conducted to determine the chemical composition of sDDGS, its digestibility by geese, and its effect on goose growth performance and carcass characteristics.

Received: November 15, 2016, Accepted: May 26, 2017

Released Online Advance Publication: July 25, 2017

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Materials and Methods

Animal Ethics

The present research was approved by the Animal Care and Welfare Committee of the Chongqing Academy of Animal Science (CAAS), China. The sDDGS used in the present study was a by-product of a mixture of 5% rice hull and 95% red sorghum used for distilled spirit production, and it was obtained from Zhisheng Distilled Spirit Company Limited, Chongqing, China. All geese used in this experiment were obtained from the goose-breeding center of CAAS.

Chemical Composition of sDDGS

The samples were analyzed for dry matter (AOAC 4.1.06), gross energy (PARR 6400 calorimeter, Moline, IL, USA), crude protein (AOAC 990.03), ether extract (AOAC 920.39), crude fiber (AOAC 978.10), calcium (AOAC 4.8.03), and total phosphorus (AOAC 3.4.11) (AOAC International, 2000). Methionine and cystine content was analyzed according to the method recommended by Xie *et al.* (2004). Tryptophan and other amino acids were determined according to the method supported by the State Bureau of Quality Technical Supervision of China (2000). Briefly, the methionine and cystine in sDDGS was oxidized in a mixture of 88% formic acid and 30% hydrogen peroxide (9:1) and then hydrolyzed at 110°C in 6 M HCl for 24 h. The pH of the hydrolysate was adjusted to 2.2 and it was then analyzed for methionine and

cystine using an amino acid analyzer (L-8900, Hitachi, Tokyo, Japan). Tryptophan content was determined using alkali hydrolysis. The sample was hydrolyzed in 4 M LiOH at 110°C for 20 h, and then sodium citrate (pH 2.2) and 6 M HCl were added. After centrifugation at 1,520 g for 8 min at 4°C and filtration through a 0.22- μ m filter membrane, the filtrate was analyzed by high-performance liquid chromatography (Agilent 1260, Santa Clara, CA, USA). The content levels of other amino acids were determined by ion-exchange chromatography with an amino acid analyzer (L-8900, Hitachi, Tokyo, Japan) after hydrolysis in 6 M HCl at 110°C for 24 h.

sDDGS TTTD Determination in Geese

Amino acid digestibility of sDDGS was determined using the Sibbald method with minor modifications (Sibbald, 1976). Briefly, 24 male Sichuan white geese (194 days old) with an average body weight of 3.5 kg were assigned to sDDGS treatment groups and a non-nitrogen treatment group according to their initial weight, with 12 replicates per treatment. Feathers within a 5-cm zone adjacent to the vent of the birds were removed to expose the skin and a special plastic retainer was sutured to the exposed skin. Birds were kept individually in metal cages (56×36×60 cm) and fed with a standard feed for 48 h. Birds subsequently assigned to the sDDGS and non-nitrogen treatment groups were fed sDDGS and corn starch diets (Table 2), respectively, *ad libitum* for 24 h. Following 24 h of fasting, individuals in the sDDGS-treatment groups were tube-fed 65 g of sDDGS diet (Table 2), and birds in the non-nitrogen treatment group were tube-fed 65 g of corn starch diet (Table 2). All geese had unrestricted access to drinking water, and light was provided during tube-feeding, water was added to the dietary pellets to produce a paste. At the time of tube-feeding, a bottle cut to a length of 3 cm with a collection bag was screwed to the sutured plastic lids for excreta collection, which lasted for 24 h. The metabolism cages with the experimental birds were

Table 1. Chemical composition of sDDGS (as % DM)

Item	Content ¹
Gross energy (MJ/kg)	17.87
Crude protein	15.48
Ether extract	4.26
Crude fiber	31.46
Calcium	0.17
Phosphorous	0.25
Amino acids	
Methionine	0.12
Lysine	0.41
Valine	0.70
Leucine	1.38
Isoleucine	0.54
Threonine	0.45
Phenylalanine	0.65
Arginine	0.42
Histidine	0.25
Glycine	0.53
Proline	1.22
Serine	0.58
Cystine	0.12
Alanine	1.03
Glutamate	3.18
Tyrosine	0.32
Aspartate	0.89
Tryptophan	0.06

¹ Values are the means of three samples.

Table 2. Diet ingredients in Experiment 1 (% as fed)

Item	Diet	
	sDDGS	Corn starch
sDDGS ¹	94.5	—
Corn starch	—	94.5
Mineral and vitamin premix ²	0.25	0.25
Salt	0.30	0.30
Total	100.00	100.00

¹ sDDGS, sorghum dried distillers grains with solubles. The same as below.

² Mineral and vitamin premix contained the following minerals in milligrams per kilogram of diet: Cu, 8; Fe, 85; Zn, 80; Mn, 85; Se, 0.3; and I, 0.4; and the following vitamins per kilogram of diet: vitamin A, 2500 IU; vitamin D₃, 2000 IU; vitamin E, 10 IU; vitamin K₃, 2 mg; thiamine, 1.5 mg; riboflavin, 10 mg; pyridoxine hydrochloride, 3 mg; cobalamin, 0.02 mg; pantothenic acid, 10 mg; nicotinic acid, 50 mg; folic acid, 1 mg; biotin, 0.15 mg; and choline chloride, 1000 mg.

put in artificial climate chambers with the temperature set at 24°C and the relative humidity at 60%. The light:dark (L:D) cycle was 16L:8D during the experimental period. Excreta samples were dried at 65°C for determination of energy and amino acids. The duration of the fasting period and the excreta collection period (24 h each) was chosen based on the study results of Sheng (2005). The methods used to determine energy and amino acids were identical to those used in Experiment 1.

The true total tract digestibility (TTTD) of amino acids contained in sDDGS was calculated as:

$$\text{TTTD}(\%) = \frac{\text{AI}_{\text{sDDGS}} - \text{AO}_{\text{sDDGS-excreta}} + \text{AO}_{\text{corn starch-excreta}}}{\text{AI}_{\text{sDDGS}}} \times 100$$

where AI_{sDDGS} is the total amino acid intake from the tube-fed sDDGS (g), $\text{AO}_{\text{sDDGS-excreta}}$ is the total amino acid output in the excreta when tube-feeding sDDGS (g), and $\text{AO}_{\text{corn starch-excreta}}$ is the total amino acid output in the excreta when tube-feeding corn starch (g).

sDDGS TME Determination in Geese

Twenty-four male Sichuan white geese were allotted to an sDDGS treatment group or a fasting treatment group for sDDGS true metabolizable energy (TME) determination. Following 24 h of fasting, the birds in the sDDGS treatment group were tube-fed 65 g of sDDGS diet (Table 2), while the birds in the fasting treatment group were fasted sequentially.

The experimental methods were identical to those used in amino acid digestibility estimation. The TME was calculated according to:

$$\text{TME}(\text{MJ}/\text{kg}) = \frac{\text{GE}_{\text{diet}} - \text{GE}_{\text{excreta}} + \text{GE}_{\text{fasting-excreta}}}{\text{GE}_{\text{diet}}} \times \text{GE}_{\text{sDDGS}}$$

where GE_{sDDGS} is the gross energy of sDDGS (MJ/kg), GE_{diet} is the total energy intake from tube-fed sDDGS (MJ), $\text{GE}_{\text{excreta}}$ is the total energy output in the excreta when tube-feeding sDDGS (MJ), and $\text{GE}_{\text{fasting-excreta}}$ is total energy output in the excreta when fasting.

Experiment 3 examined the effect of sDDGS on the growth performance of geese. Three hundred and fifteen 35-day-old male Sichuan white geese with an initial average body weight of 1,732 g were randomly allocated to five treatments with seven replicate pens, each containing nine birds. Geese in each treatment group were fed one of five experimental diets: 0% sDDGS, 4% sDDGS, 8% sDDGS, 12% sDDGS, or 16% sDDGS. All diets were isoenergetic and isonitrogenous. The compositions and chemical analyses of the diets are shown in Table 3. Birds were kept in plastic-wire-floored pens with dimensions of 150 × 200 × 60 cm in an environmentally controlled duck house; the ambient conditions were room temperature and approximately 60% relative humidity. A stainless-steel feeder was used in the current experiment; the feeder's length, bottom width, upper width, inner height, and external height were 140, 12, 20, 12, and 18 cm, respectively. All birds had free access to pelleted

feed and water, and the light program was 16 h of light per day. At 70 days of age, live weight gain for all geese was measured and recorded following 12 h of fasting; feed intake and feed/gain values were calculated throughout the experimental period. Feed intake and feed/gain were all corrected for mortality. Two geese were selected from each pen according to average body weight and killed by cervical dislocation. Breast meat (including pectoralis major and pectoralis minor), leg meat (including thigh and drumstick), subcutaneous fat and skin, and abdominal fat were removed from the two carcasses, weighed, and expressed as relative weight to live body weight at processing.

Statistical Analysis

The goose performance data and carcass data were subjected to one-way analysis of variance (ANOVA) using the GLM procedure in SAS (SAS software 9.1.3). Differences were considered significant at $P < 0.05$ and means were compared using Tukey's test. The experimental unit was the individual goose for energy and amino acid digestibility, and the replicate pen for the growth and carcass traits. The optimal dietary supplemental level of sDDGS was estimated using a broken-line regression model (Robbins *et al.*, 2006) by the NLIN procedure in SAS (Version 9.0): $y = l + u(r - x)$; where y is the average daily feed intake, x is the dietary sDDGS level, u is the slope of the curve, r is the optimal dietary supplemental level of sDDGS, and l equals y when x is equal to r .

Results and Discussion

Chemical Composition of sDDGS

The chemical composition [as % dry matter (DM)] of sDDGS is shown in Table 1. The sDDGS composition was: crude protein, 15.48% DM; ether extract, 4.26% DM; and crude fiber, 31.46% DM. These results are generally lower than those in previous studies (Al-Suwaiegh *et al.*, 2002; Urriola *et al.*, 2009), which reported 32.9–35.9% for crude protein and 8.8–13% for ether extract. These discrepancies reflect the differences between the sDDGS materials used in the different studies. In the experiment of Al-Suwaiegh *et al.* (2002) and Urriola *et al.* (2009), sDDGS was produced from the fermentation of 100% sorghum, while the sDDGS used in our study came from a fermentation mixture of sorghum (95%) and rice hull (5%). The amino acid content (Table 3) of sDDGS ranged from 0.06–3.18%, indicating a low overall level of amino acids. The content levels of methionine, lysine, tryptophan, threonine, and arginine were 0.12, 0.41, 0.06, 0.45, and 0.42%, respectively, implying that sDDGS is deficient in essential amino acids for poultry. The crude protein and amino acid contents of sDDGS were higher than those of sorghum grain (Xiong *et al.*, 2013) because of the conversion of grain starch to ethyl alcohol and CO₂ during fermentation, which concentrated the remaining nutrients in the sDDGS. The levels of crude protein and ether extract in sDDGS were higher than those in corn, and were similar to those in wheat bran (Xiong *et al.*, 2013). In addition, Table 1 shows that sDDGS contains a low level of energy, with a total energy value of 17.87 MJ/kg.

Table 3. **Ingredients and chemical composition of the diets (% as fed)**

Item	Control	4% sDDGS	8% sDDGS	12% sDDGS	16% sDDGS
Ingredient					
Corn	51.50	53.23	55.48	57.82	60.10
Soybean meal	18.12	19.10	19.05	18.20	18.30
Fish meal	1.18	0.58	0.50	0.97	0.90
sDDGS	0.00	4.00	8.00	12.00	16.00
Alfalfa meal	21.00	15.72	10.60	5.71	0.50
Soybean oil	5.40	4.30	3.07	1.84	0.54
Lysine·HCl	0.11	0.14	0.15	0.16	0.18
DL-Methionine	0.21	0.22	0.21	0.22	0.23
L-Tryptophan	0.05	0.06	0.09	0.07	0.08
L-Threonine	0.00	0.00	0.01	0.01	0.00
L-Arginine·HCl	0.11	0.11	0.13	0.15	0.14
Salt	0.30	0.30	0.30	0.30	0.30
Limestone	0.37	0.56	0.76	0.95	1.03
Hydrophosphate	1.40	1.44	1.40	1.35	1.45
Mineral and vitamin premix ¹	0.25	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00	100.00
Composition					
Metabolizable energy (MJ/kg)	11.95	11.95	11.95	11.95	11.95
Crude protein	16.00	15.99	15.99	16.00	16.00
Crude fiber	6.60	6.60	6.59	6.60	6.60
Calcium	0.85	0.85	0.85	0.85	0.85
Phosphorous	0.60	0.60	0.60	0.60	0.63
Lysine	0.85	0.85	0.85	0.85	0.85
Methionine	0.45	0.45	0.44	0.45	0.46
Cystine	0.23	0.23	0.23	0.23	0.23
Threonine	0.61	0.61	0.61	0.61	0.60
Tryptophan	0.25	0.25	0.28	0.25	0.25
Arginine	1.00	1.00	1.00	1.00	0.99

¹ Identical to that in Table 2.

Digestibility of sDDGS in Geese

The digestibility of sDDGS by geese in terms of energy and amino acids was low (Table 4): the TME was 11.38 MJ/kg, and the TTTD of amino acids in sDDGS ranged from 43.16 to 80.92%. Among amino acids, the respective digestibilities of sDDGS methionine, lysine, tryptophan, threonine, and arginine for geese were 59.22, 43.16, 64.13, 58.59, and 59.94%. The digestibility of sDDGS has been estimated in previous studies of cattle (Lodge *et al.*, 1997) and pigs (Urriola *et al.*, 2009). However, to date, no data on the digestibility of sDDGS nutrients in poultry have been available. This means that the results of the current study will provide a reference for poultry feed formulation with sDDGS. sDDGS is a potential source of feedstuff for geese diets, but should be supplemented with high-energy or protein-rich ingredients.

Effect of sDDGS on Performance of Geese Aged 35 to 70 Days

The inclusion of sDDGS in the diet did not affect ($P > 0.05$) daily average weight gain (Table 5). These results are similar to those reported by Barekain *et al.* (2013b), who found that body weight gain in the broiler chicken from 1 to 35 days was unaffected by inclusion of up to 30% sDDGS in the diet. As shown in Table 5, the average daily feed intake

Table 4. **Metabolizable energy and amino acid digestibility of sDDGS in geese**

Item	Value ¹
True metabolizable energy (MJ/kg)	11.38
True total tract digestibility of amino acids (% DM)	
Methionine	59.22
Lysine	43.16
Valine	61.61
Leucine	69.98
Isoleucine	61.88
Threonine	58.59
Arginine	59.94
Phenylalanine	67.07
Histidine	56.15
Glycine	55.14
Proline	65.10
Serine	68.17
Cystine	80.92
Alanine	73.47
Glutamate	55.14
Tyrosine	70.23
Aspartate	59.60
Tryptophan	64.13

¹ Values are the means of 12 geese.

Table 5. Effect of sDDGS on performance of Sichuan white geese from 35 days to 70 days of age¹

Item	Control	4% DDGS	8% DDGS	12% DDGS	16% DDGS	SEM ²	P value
Weight gain (g/d per bird)	50.1	49.3	52.9	51.0	49.7	0.52	0.211
Feed intake (g/d per bird)	209.8 ^c	214.3 ^{bc}	229.1 ^{ab}	237.3 ^a	239.3 ^a	3.09	0.001
Feed/gain (g:g)	4.20 ^b	4.35 ^b	4.49 ^{ab}	4.50 ^{ab}	4.81 ^a	0.06	0.011

^{a-c} Means within a column with different superscripts are significantly different ($P < 0.05$).

¹ Values are the means of seven replicates of nine geese.

² SEM, stand error of the mean.

Table 6. Effect of sDDGS on carcass characteristics of Sichuan white geese at 70 days of age^{1,2}

Item	Control	4% sDDGS	8% sDDGS	12% sDDGS	16% sDDGS	SEM ³	P value
Breast meat (%)	7.5	7	7.7	7.9	7.6	0.16	0.523
Leg meat (%)	10.8	10.4	10.7	11.2	10.4	0.17	0.597
Subcutaneous fat + skin (%)	14.5	15.1	15.7	14.9	14.4	0.26	0.538
Abdominal fat (%)	2	2.1	1.9	2	2.2	0.05	0.412

¹ Values are the means of seven replicates of two birds.

² The yield is calculated using the following equation: Yield = (breast meat, leg meat, subcutaneous fat + skin or abdominal fat weight) / live body weight at processing × 100.

³ SEM, standard error of the mean.

and feed-to-gain ratio of geese responded linearly to incremental dietary sDDGS incorporation ($P < 0.05$). Birds that were fed up to at least 8% sDDGS had higher ($P < 0.05$) average daily feed intake than geese fed the control diet, and the feed-to-gain ratio in geese fed diets containing 16% sDDGS was higher than in the control and the 4% sDDGS groups (Table 5). These results indicate that dietary inclusion of sDDGS increased feed intake and impaired the feed/gain ratio of the birds. These results are similar to those reported for broiler chickens by Berekatain *et al.* (2013b), who found that inclusion of 10–30% sDDGS in diets significantly increased feed intake and the feed/gain ratio in broiler chickens from 1 to 35 days. DDGS consists of a greater proportion of soluble nonstarch polysaccharides (NSP) (28.6 g soluble NSP/kg dry matter, 184.9 g insoluble NSP/kg dry matter) than the respective native grains; the presence of NSP increases digesta viscosity (Smits and Anison, 1996) and reduces the feed passage rate (Van der Klis *et al.*, 1993), leading to lower growth rates and a higher feed/gain ratio. By contrast, xylanase supplementation in broiler chicken diets containing 30% sDDGS can improve the feed conversion ratio (Berekatain *et al.*, 2013a, b), implying that appropriate supplementation with NSP enzymes could be beneficial to the feed efficiency of poultry diets containing sDDGS. In addition, the 5% rice hull content of sDDGS in the present study would have increased the indigestible dietary fiber and increased the feed/gain ratio. Our results suggest that up to 12% sDDGS can be included in the diet of geese aged 35–70 days without negative effects on

body weight gain and the feed-to-gain ratio. Based on the broken-line regression model, the optimal dietary inclusion level of sDDGS for average daily feed intake was 12.86% (as fed) of diet [$y = 239.3 - 2.4325 \times (12.8551 - x)$, $R^2 = 0.95$, $P = 0.0248$] in Sichuan white geese aged from 35 to 70 days.

In the present study, the yields of breast meat and leg meat were not affected ($P > 0.05$) by dietary sDDGS level, and no differences ($P > 0.05$) were observed for subcutaneous fat and skin, or abdominal fat across the five sDDGS treatments (see Table 6). This implies that dietary sDDGS inclusion up to 16% did not affect carcass yield. However, the dietary inclusion portion of sDDGS should be limited to avoid a negative effect on carcass yields. Dietary inclusion of DDGS (15 and 30%) did not affect dressing percentage and leg quarters percentage (to body weight) in broiler chickens aged 0–42 days, while a high level of incorporation (30%) reduced the ratio of breast to body weight in broiler chickens aged 0–42 days (Wang *et al.*, 2007). In addition, Lukaszewicz and Kowalczyk (2014) reported that inclusion of 15% DDGS decreased the weight of breast muscle, leg muscle, and skin with subcutaneous fat, but did not affect their percentages relative to live body weight in chickens aged 0–42 days.

sDDGS contains low levels of gross energy, crude protein, and amino acids, and a high level of crude fiber. The TME and TTTD of amino acids by geese were low. The average daily feed intake increased with increasing levels of sDDGS incorporation in the diet, and the optimal dietary inclusion level of sDDGS for average daily feed intake was 12.86% of diet based on our broken-line regression analysis. However,

high levels (16%) of dietary sDDGS impaired the feed/gain ratio. Generally, sDDGS has potential for use as a valuable feedstuff for geese, but it should be supplemented with a high-energy or protein-rich ingredient. For improvements in growth performance and carcass yield, sDDGS levels below 12% can be included in the diets of geese from 35 to 70 days of age.

Acknowledgments

This work was supported by the Special Fund for Agro-Scientific Research in the Public Interest (201303143), and the Earmarked Fund for China Agriculture Research System (CARS-42).

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