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Short communication

Effects of corn distillers dried grains with solubles and xylanase on growth performance and digestibility of diet components in broilers

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ABSTRACT

The objective of this study was to investigate the effect of corn distillers dried grains with solubles (cDDGS) and xylanase in corn-based diets on growth performance and digestibility of diet components in broiler chickens. The experiment was a 3×4 factorial design with diets containing 3 levels of cDDGS (0, 100 and 200 g/kg) and 4 levels of xylanase (0, 1200, 2400 and 3600 U/kg). The diets were fed to 720 Cobb 500 chicks for 42 days. Excreta was collected at 18–21 days to measure coefficients of total tract apparent digestibility (CTTAD) and ileal digesta was collected at 42 days to measure coefficients of ileal apparent digestibility (CIAD). Dietary cDDGS caused poor ($P<0.05$) feed conversion ratio (FCR) of broilers from 1 to 21 and 22 to 42 days, but increased ($P<0.05$) feed intake (FI) at 1–21 days. Inclusion of xylanase increased ($P<0.05$) FI by 4–5% at 1–21 days, and did not affect ($P\geq0.05$) FCR in either period. In the two growing periods, cDDGS decreased ($P<0.05$) the CTTAD of dry matter (DM), and the CIAD of DM and hemicelluloses, whereas xylanase increased ($P<0.05$) the digestibility of DM and hemicellulose by 5% and 20%, respectively. There were significant interactions ($P<0.05$) between cDDGS and xylanase for BWG and energy digestibility. In comparison with the 100 g/kg cDDGS diet, the inclusion of 200 g/kg cDDGS led to poorer ($P<0.05$) FCR at 22–42 days, and lower ($P<0.05$) CTTAD of DM at 18–21 days. There were no differences ($P\geq0.05$) in most growth parameters between the doses of xylanase at 1200, 2400 and 3600 U/kg. Xylanase at 2400 U/kg increased ($P<0.05$) CTTAD of DM compared with the lower dose, but 3600 U/kg xylanase showed no further improvement ($P\geq0.05$) on digestibility measurements. The results suggest that supplementing xylanase to diets containing cDDGS can improve growth performance and digestibility of diet components in broilers.

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Abbreviations: BWG, body weight gain; cDDGS, corn distillers dried grains with solubles; CIAD, coefficient of ileal apparent digestibility; CP, crude protein; CTTAD, coefficient of total tract apparent digestibility; DM, dry matter; FCR, feed conversion ratio; FI, feed intake; ME, metabolisable energy; NSP, non-starch polysaccharides.

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1. Introduction

Corn distillers dried grains with solubles (cDDGS) is a by-product of the ethanol industry. During the fermentation process starch in the corn grain is converted into ethanol and CO_2, with the cDDGS consequently having increased levels of non-starch polysaccharides (NSP), protein and fat (Cromwell et al., 1993; Belyea et al., 2004). Xylan is the predominant component of NSP in cDDGS (Widyaratne and Zijlstra, 2007). Based on the reported results, cDDGS is an acceptable ingredient in poultry diets and can be safely fed at 60 g/kg in starter broiler diets, and at 120–150 g/kg in grower–finisher broiler diets (Lumpkins et al., 2004; Świątkiewicz and Koreleski, 2008).

Historically, xylanase has been widely used to reduce the anti-nutritional effects of NSP and improve the nutritional values of energy and protein in wheat-based diets (Selle et al., 2009). Nowadays, xylanase is used increasingly in corn-based diets (Beg et al., 2001), sometimes in combination with other enzyme activities. However, there are few reports on the effects of different levels of cDDGS with xylanase addition on growth performance and digestibility of diet components in broilers fed corn-based diets. Therefore, the objective of this study was to investigate the effects of cDDGS and microbial xylanase on growth performance and digestibility of diet components in broilers fed corn-based diets from 1 to 42 days of age.

2. Materials and methods

2.1. Experimental diets

The experiment was a 3×4 factorial design with 3 levels of cDDGS at 0, 100 and 200 g/kg, and supplementation with a commercial xylanase (Danisco Animal Nutrition, Wiltshire, UK) at 0, 1200, 2400 and 3600 U/kg which is based on the minimum guaranteed xylanase activity in the product. The components of cDDGS (Huaxing Ethanol Ltd., Mengzhou, Henan, China) were dry matter (DM) 901 g/kg, crude protein (CP) 283 g/kg, crude fibre 71 g/kg, neutral detergent fibre 385 g/kg, acid detergent fibre 153 g/kg and apparent metabolisable energy (AME) 9.4 MJ/kg. The diets were based on corn and soybean meal and fed as mash throughout the experiment. The AME levels of the diets were 11.7 and 12.5 MJ/kg from 1 to 21 and 22 to 42 days of age, respectively, which were lower than typical commercial diet specifications. All experimental diets were maintained isocaloric and isonitrogenous. TiO_2 was used as an external marker to determine the apparent faecal and ileal digestibility of diet components. The definition of xylanase activity (U) is the amount of enzyme which liberates 0.5 μmol of reducing sugar (expressed as xylose equivalents) from a cross-linked oat spelt arabinoxylan substrate at pH 5.3 and 50 °C in 1 min. The compositions of the basal diets are shown in Table 1.

2.2. Broiler management

A total of 720 Cobb 500 chicks, 1-day-old, were randomly allocated to 12 treatments, each of which had 6 cages of 10 chicks (male:female, 1:1) per cage. All chicks were raised in four-layered cages (per cage 1.0 m×1.8 m) and given *ad libitum* access to diets and water, with continuous lighting and controlled ventilation. The temperature was maintained at 32 °C for the first week and then gradually reduced until a temperature of 22 °C was achieved by the fourth week. Body weight and diet consumption were recorded weekly on a cage basis. At day 7 and 21, the birds were inoculated with Newcastle disease virus and infectious bronchitis vaccines (Yikang Biological Products Co., Taizihe, Liaoyang, China) by intranasal and intraocular administration. All procedures were approved by Henan University of Science and Technology Institutional Animal Care and Use Committee.

2.3. Sample collection

At days 18–21, the total amount of excreta per cage replicate was collected and mixed, of which 10% was freeze-dried for the determination of the coefficient of total tract apparent digestibility (CTTAD) of diet components. Care was taken during the collection of excreta samples to avoid contamination from feathers and other foreign materials. At day 42, six birds (male:female, 1:1) per replicate were randomly selected and euthanized by electrocution. A section of ileum was removed by cutting from the Meckel's diverticulum to the ileo-caecal junction. A 50 ml syringe full of room-temperature deionised water was inserted into one end of the ileum to carefully flush out the digesta in the gut into a 10 cm diameter Petri-dish (Liu et al., 2007). The digesta from each replicate were pooled and freeze-dried to calculate the coefficient of ileal apparent digestibility (CIAD) of diet components.

2.4. Chemical analyses

The components in the samples were determined according to the standard AOAC methods (1990) for total P (964.06), Ca (935.13), CP (976.05), crude fibre (962.09) and crude fat (920.39). Gross energy was measured in an Oxygen Bomb Calorimeter (Model 6300, PARR, Moline, IL). Dry matter was determined by drying a 2 g sample at 70 °C to a constant mass. The contents of neutral detergent fibre and hemicellulose and acid detergent fibre were measured as described by Van Soest et al. (1991). The concentrations of TiO_2 in samples were determined using the method by Short et al. (1996). The apparent metabolisable

Table 1
Compositions of corn-based diets.[a]

	Days 1–21			Days 22–42		
Ingredient (g/kg)						
Corn	647.7	587.1	550.4	690.3	614.3	574.2
Soybean meal	160.0	157.0	60.0	84.0	86.0	39.0
cDDGS	0	100.0	200.0	0	100.0	200.0
Corn gluten meal	50.0	0	30.0	29.0	0	0
Rapeseed meal	42.0	56.0	76.0	89.0	87.0	76.0
Pig meat meal	40.0	40.0	30.0	60.0	40.0	40.0
Meat and bone meal	20.0	18.0	7.4	12.0	13.0	4.3
Mixed oil	0	0	0	7.0	22.0	27.0
Limestone	13.5	15.0	18.7	7.6	9.4	16.0
L-Lysine	7.5	7.9	9.0	5.0	5.7	7.6
DL-Methionine	1.4	1.7	1.0	0.9	7.6	0.9
Salt	1.9	1.3	2.1	0.2	0	0
Choline chloride	0.8	0.8	0.4	0	0	0
L-Threonine	0.2	0.2	0	0	0	0
Premix[b]	10.0	10.0	10.0	10.0	10.0	10.0
TiO_2	5.0	5.0	5.0	5.0	5.0	5.0
Chemical analyses (g/kg)						
Crude protein (determined)	200	201	200	181	181	180
Crude fibre (determined)	30	36	37	31	35	35
Hemicellulose (determined)	64	83	100	65	82	102
AME (MJ/kg, determined)[c]	11.7	11.7	11.7	12.5	12.5	12.5
Ca	9.8	9.9	9.8	9.0	9.0	9.2
Total P	6.0	6.1	6.1	5.5	5.7	5.5
Non-phytate P	4.0	4.0	4.0	3.5	3.5	3.5
Methionine	4.7	4.7	4.7	4.0	4.0	4.0
Methionine + cysteine	7.1	7.1	7.1	6.7	6.7	6.7
Lysine	12.0	12.0	12.0	9.5	9.5	9.5

[a] Factorial arrangement with 3 levels of corn distillers dried grains with solubles (cDDGS) and 4 levels of xylanase (0, 1200, 2400 or 3600 U/kg; Danisco Animal Nutrition, Wiltshire, UK).

[b] Provides (/kg of diet): vitamin A (retinyl acetate), 8000 IU; cholecalciferol, 1000 IU; vitamin E (DL-α-tocopheryl acetate), 20 IU; vitamin K, 0.5 mg; thiamin, 2.0 mg; riboflavin, 8.0 mg; D-pantothenic acid, 10 mg; niacin, 35 mg; pyridoxine, 3.5 mg; biotin, 0.18 mg; folic acid, 0.55 mg; vitamin B_{12}, 0.010 mg; manganese, 120 mg; iodine, 0.70 mg; iron, 100 mg; copper, 8 mg; zinc, 100 mg; selenium, 0.30 mg.

[c] Mean of 12 conventional broilers (Cobb 500, male:female, 1:1) at 26–30 days old.

energy was measured using 12 conventional broilers (Cobb 500; male:female, 1:1) at 26–30 days old (Deng et al., 2009). The apparent faecal and ileal digestibility of diet components was calculated as described by Camden et al. (2001).

2.5. Statistical analyses

Data were analyzed using a general linear model procedure of SAS (SAS Institute, 2002). Two-way ANOVA was used to assess main effects of cDDGS and xylanase and their interactions. One-way ANOVA was used for specific contrasts including cDDGS 100 *vs*. 200 g/kg, and xylanase 1200 *vs*. 2400 *vs*. 3600 U/kg. Differences of variables were separated using Duncan's multiple-range test at P<0.05 level of significance. Values in the tables were means and pooled S.E.M.

3. Results

3.1. Performance of broilers

Diets containing cDDGS caused a deterioration (P<0.05) in feed conversion ratio (FCR) in the two periods (Table 2). However, dietary cDDGS increased (P<0.05) feed intake (FI) at 1–21 days. Inclusion of xylanase in the diet increased (P<0.05) FI by 4% at 1–21 days, but had no effect (P≥0.05) on FCR in the two periods. The significant interactions (P<0.05) between cDDGS and xylanase were found on BWG in both periods and on FI in the second period. Diets containing cDDGS at 200 g/kg had no effect (P≥0.05) on the performance at 1–21 days, but decreased (P<0.05) FCR at 22–42 days, compared with the diet containing 100 g/kg cDDGS. Increasing xylanase dose from 1200 to 2400 or 3600 U/kg had no further improvement (P≥0.05) in FI, BWG or FCR in either period.

3.2. Coefficient of total tract apparent digestibility at 18–21 days

Corn DDGS decreased (P<0.05) the CTTAD of DM by 2%, and had no effect (P≥0.05) on hemicelluloses (Table 3). The diets supplemented with xylanase at 1200–3600 U/kg increased (P<0.05) the CTTAD of hemicellulose by 20%. Significant interactions (P<0.05) between cDDGS and xylanase were obtained (P<0.05) on the CTTAD of CP and energy. Diets containing cDDGS at 200 g/kg had no effect (P≥0.05) on the CTTAD of hemicelluloses, but decreased (P<0.05) DM digestibility, compared

Table 2
Effects of corn distillers dried grains with solubles (cDDGS) and xylanase on the growth performance of broilers.

Treatment		Days 1–21			Days 22–42		
cDDGS (g/kg)	Xylanase[a] (U/kg)	FI (g/bird)	BWG (g/bird)	FCR	FI (g/bird)	BWG (g/bird)	FCR
0	–	860	621	1.39	3515	1563	2.25
	+1200	872	613	1.43	3390	1586	2.26
	+2400	882	621	1.42	3545	1621	2.19
	+3600	887	605	1.47	3555	1590	2.24
100	–	865	590	1.47	3374	1427	2.37
	+1200	897	616	1.46	3401	1505	2.26
	+2400	899	605	1.49	3662	1596	2.30
	+3600	912	621	1.47	3559	1641	2.17
200	–	854	564	1.51	3286	1374	2.40
	+1200	907	616	1.47	3508	1488	2.36
	+2400	901	602	1.50	3515	1481	2.37
	+3600	908	607	1.50	3473	1477	2.35
S.E.M.		7.4	9.5	0.020	36.2	26.2	0.044

Main effect	Days 1–21			Days 22–42		
	FI (g/bird)	BWG (g/bird)	FCR	FI (g/bird)	BWG (g/bird)	FCR
cDDGS						
0	875	615	1.43	3551	1590	2.24
100	893	608	1.47	3499	1542	2.27
200	892	598	1.50	3445	1455	2.37
Xylanase						
0	860	592	1.46	3392	1455	2.34
1200	892	615	1.45	3500	1526	2.30
2400	894	609	1.47	3574	1566	2.29
3600	902	611	1.48	3521	1569	2.25

P-value	Days 1–21			Days 22–42		
	FI (g/bird)	BWG (g/bird)	FCR	FI (g/bird)	BWG (g/bird)	FCR
cDDGS	**	*	**	**	**	**
Xylanase	**	*	NS	**	**	NS
cDDGS×xylanase	NS	*	NS	**	**	NS
cDDGS 100 *vs.* 200	NS	NS	NS	NS	**	**
Xylanase 1200 *vs.* 2400	NS	NS	NS	NS	NS	NS
Xylanase 2400 *vs.* 3600	NS	NS	NS	NS	NS	NS

BWG, body weight gain; FI, feed intake; FCR, feed conversion ratio.
NS, $P \geq 0.05$.
[a] Danisco Animal Nutrition, Wiltshire, UK.
* $P<0.05$.
** $P<0.01$.

with the diet at 100 g/kg cDDGS. In contrast with xylanase at 1200 U/kg, the dose at 2400 U/kg increased ($P<0.05$) the digestibility of DM by 2%, but did not affect ($P \geq 0.05$) the digestibility of hemicellulose. There were no differences ($P \geq 0.05$) between 2400 and 3600 U/kg xylanase in the digestibility of diet components.

3.3. Coefficient of ileal apparent digestibility at 42 days

Diets containing cDDGS decreased ($P<0.05$) the CIAD of DM and hemicellulose by 2% and 3%, respectively, but increased ($P<0.05$) CP digestibility (Table 3). Inclusion of xylanase increased ($P<0.05$) the CIAD of DM, CP and hemicellulose by 5, 5 and 21%, respectively. There was an interaction ($P<0.05$) between cDDGS and xylanase on the CIAD of energy. In comparison with the diet containing 100 g/kg cDDGS, the higher cDDGS diet decreased ($P<0.05$) the CIAD of CP, but did not affect the digestibility of DM and hemicellulose. Increasing the dose of xylanase from 1200 to 3600 U/kg of diet, gave no significant CIAD responses ($P \geq 0.05$).

4. Discussion

4.1. Corn DDGS and performance

During the processing of corn in the dry-grind ethanol industry, starch in the whole corn kernel is fermented, resulting in two main co-products, ethanol and cDDGS. There are 2–3 times the levels of NSP, protein and fat in cDDGS compared

Table 3
Effects of corn distillers dried grains with solubles (cDDGS) and xylanase on coefficients of total tract apparent digestibility (CTTAD) and ileal apparent digestibility (CIAD) for broilers.

Treatment		CTTAD at 18–21 days				CIAD at 42 days			
cDDGS (g/kg)	Xylanase[a] (U/kg)	DM (%)	CP (%)	HC (%)	Energy (MJ/kg)	DM (%)	CP (%)	HC (%)	Energy (MJ/kg)
0	–	85	83	39	13.17	82	77	40	13.01
	+1200	87	84	47	13.55	83	78	46	13.24
	+2400	88	84	45	13.73	85	80	47	13.20
	+3600	88	85	45	13.28	83	79	50	13.29
100	–	83	83	37	12.87	78	77	39	12.52
	+1200	85	87	45	13.31	82	81	46	13.18
	+2400	88	88	46	13.51	85	81	48	13.39
	+3600	87	83	47	13.79	83	81	48	13.21
200	–	79	85	37	12.40	77	74	38	12.18
	+1200	83	86	46	12.97	82	78	45	13.04
	+2400	85	87	44	13.32	82	79	46	13.13
	+3600	85	87	45	13.32	82	79	46	13.15
S.E.M.		0.9	0.8	1.0	0.124	1.0	0.8	0.9	0.109

Main effect	CTTAD at 18–21 days				CIAD at 42 days			
	DM (%)	CP (%)	HC (%)	Energy (MJ/kg)	DM (%)	CP (%)	HC (%)	Energy (MJ/kg)
cDDGS								
0	87	84	44	13.43	83	78	46	13.18
100	86	85	44	13.37	82	80	45	13.08
200	83	86	43	13.00	81	78	44	12.87
Xylanase								
0	82	84	38	12.81	79	76	39	12.57
1200	85	86	46	13.28	82	79	46	13.15
2400	87	86	45	13.52	84	80	47	13.24
3600	87	85	46	13.47	83	80	48	13.21

P-value	CTTAD at 18–21 days				CIAD at 42 days			
	DM (%)	CP (%)	HC (%)	Energy (MJ/kg)	DM (%)	CP (%)	HC (%)	Energy (MJ/kg)
cDDGS	**	**	NS	**	*	**	**	**
Xylanase	**	**	**	**	**	**	**	**
cDDGS × xylanase	NS	**	NS	*	NS	NS	NS	*
cDDGS 100 *vs*. 200	**	NS	NS	*	NS	**	NS	NS
Xylanase 1200 *vs*. 2400	*	NS	NS	*	NS	NS	NS	NS
Xylanase 2400 *vs*. 3600	NS	NS	NS	NS	NS	NS	NS	NS

CP, crude protein; DM, dry matter; HC, hemicellulose.
NS, $P \geq 0.05$.
[a] Danisco Animal Nutrition, Wiltshire, UK.
* $P<0.05$.
** $P<0.01$

to corn grain (Cromwell et al., 1993; Belyea et al., 2004). Increasing inclusions of cDDGS in the diet of intensively reared monogastric animals will help to use the growing quantities of by-products, but the maximum inclusion level of cDDGS in the diet remains to be defined. Lumpkins et al. (2004) reported that a corn-based diet containing 60 g/kg cDDGS did not affect BWG, 120 g/kg cDDGS numerically reduced BWG by 15 g/chick, and 180 g/kg cDDGS statistically depressed BWG by 27 g/chick as well as causing a deterioration in FCR in starter broilers. For grower and finisher broilers, the content of cDDGS in the diet can be increased up to 120–150 g/kg without compromising performance (Lumpkins et al., 2004; Świątkiewicz and Koreleski, 2008).

In contrast, Wang et al. (2007) found that a corn-based diet containing 50–250 g/kg of cDDGS did not influence BWG for 14, 35 and 49-day-old broilers, however, FI was increased and FCR was poor in the diet containing 250 g/kg cDDGS for 35 and 49-day-old broilers. In the present study, diets containing cDDGS without xylanase addition did not affect FI, but the diet containing 200 g/kg cDDGS decreased BWG at 1–21 days, and with the increased cDDGS, FI and BWG significantly decreased at 22–42 days. These results indicated that anti-nutritional factors such as NSP from the high cDDGS diet most likely limited the growth performance of broilers. Additionally, the growth performance was 15–20% lower than the standards of Cobb 500 broilers in the present study, which would be mainly caused by the relatively low AME control diet.

4.2. Xylanase and performance

Corn DDGS contains more than 250 g/kg total NSP, of which almost 90% is insoluble (Świątkiewicz and Koreleski, 2007). Xylans are the predominant component of hemicellulose in cDDGS (Cowieson, 2005; Świątkiewicz and Koreleski, 2007;

Widyaratne and Zijlstra, 2007). Consequently, a diet based on corn and cDDGS provides good levels of substrate for xylanase, and it is therefore of interest to study its potential benefits in such diets (Beg et al., 2001). However, there are few reports on the relationship between dietary cDDGS and xylanase supplementation on the growth performance of broilers. In the present study, there were significant interactions between cDDGS and xylanase on BWG in both growth periods and FI in the second period. These results indicated that the effect of xylanase may be dependent on the levels of dietary cDDGS, and this needs further study.

4.3. Apparent coefficients of total tract and ileal digestibility

In the absence of xylanase in the present study, the high cDDGS diet decreased the CTTAD of DM by 5% at 18–21 days. Overall, the high cDDGS diet reduced the CTTAD of DM at 18–21 days, which mainly caused the lowered CTTAD of energy. Interestingly, cDDGS did not affect the CTTAD of hemicellulose and CP, suggesting that the high level of DDGS (200 g/kg cDDGS) in the basal diet and its associated high levels of NSP may also decrease the digestibility of other diet components, such as starch and fat. Given the variability in cDDGS quality, much more information on the nutritive value of cDDGS will be required by the broiler industry in order to maximize its use. Batal and Dale (2006) reported a true ME range from 10.42 to 13.35 MJ/kg of cDDGS, and Fastinger et al. (2006) found a range from 10.37 to 12.72 MJ/kg. Parsons et al. (2006) reported a true ME value ranging from 2603 to 3051 kcal/kg (10.89–12.76 MJ/kg), so achieving a reduction in variability in feeding value for cDDGS in broiler diets is highly important.

Inclusion of xylanase in the diet can break down NSP in cDDGS and consequently improve utilisation of diet components. In the present study, the digestibility of hemicellulose and energy increased by 20% and 620 kJ/kg, respectively. These were similar to reports that diets rich in NSP, supplemented with NSP-hydrolyzing enzymes, improved the digestibility of DM and apparent MEn in poultry (Pan et al., 1998; Lázaro et al., 2003; Świątkiewicz and Koreleski, 2007). However, Min et al. (2009) reported no significant improvement in energy digestibility from adding 1–4 times the recommended level of two commercial enzyme products for growing broilers fed corn-based diets containing 300 g/kg cDDGS. In the present study, the largest effect of xylanase on the growth and digestibility response was obtained at a dose of 2400 U/kg in both basal diets, indicating that such a dose of this particular xylanase may be adequate for the levels of cDDGS added in this trial.

In summary, the high NSP and low energy contents of cDDGS limit its use in the diet of broilers, although there are relatively high contents of protein and fat in cDDGS that may be potentially beneficial. Adding an effective xylanase to a diet containing cDDGS can reduce these negative effects on growth performance and digestibility of diet components and consequently allow increased inclusions of cDDGS in broiler diets.

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