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Nutritional value of distillers dried grains with solubles from corn and sorghum and xylanase in diets for pigs

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ABSTRACT - Two experiments were conducted to evaluate the digestibility and energy of distillers dried grains with solubles (DDGS) from corn and sorghum with or without xylanase enzyme in diets for pigs. The values of dry matter (DM), organic matter (OM), crude protein (CP), mineral matter (MM), ether extract (EE), neutral detergent fiber (NDF), gross (GE), digestible (DE), metabolizable energy (ME), and digestibility coefficients (DC) were determined. In the experiment 1, we used eight barrows of 26.15±3.45 kg with repeated measures in three periods of five days of collection. The treatments consisted of a reference diet (RD); RD with 200 g kg^{-1} corn DDGS or sorghum DDGS; and RD with 400 g kg^{-1} corn DDGS or sorghum DDGS. Corn DDGS showed higher values of DE, ME, and DC of EE, GE, and CP. Inclusions of 400 g kg^{-1} of the test ingredients resulted in higher values of DE and ME and trend for higher DC of DM, OM, and CP. In experiment 2, nine barrows weighing 34.91±1.46 kg were fed RD, 200 g kg^{-1} corn DDGS or 200 g kg^{-1} corn DDGS plus xylanase enzyme. The inclusion of xylanase did not influence the digestibility and energy values in diets containing corn DDGS. Values of DE and ME of corn DDGS were 3,477 and 3,277 kcal kg^{-1}, respectively, for the substitution of 200 g kg^{-1} and 3,761 and 3,068 kcal kg^{-1} for the substitution of 400 g kg^{-1} RD. For sorghum DDGS, DE and ME values were 3,030 and 2,863 kcal kg^{-1}, respectively, for replacement of 200 g kg^{-1} and 3,398 and 3,296 kcal kg^{-1} for substitution of 400 g kg^{-1} RD. Levels of up to 400 g kg^{-1} do not influence the DE and ME of the diets but impair the digestibility coefficient of DM, OM, CP, EE, MM, and NDF. The use of xylanase enzyme in diets containing 200 g kg^{-1} of corn DDGS does not affect the digestibility of the diets.

Keywords: digestibility, DDGS, digestible energy, metabolizable energy

Introduction

With increasing ethanol production from corn in Brazil, the supply of distillers dried grains with solubles (DDGS) for inclusion in animal diets is growing. However, because the variability in composition and digestibility is directly related to the difference in the raw material composition and production process, it is necessary to know the nutrient and energy availability of these co-products for a precise formulation of diets for pigs.

In the production of ethanol from corn and sorghum, grain starch is fermented, while fiber, protein, lipids, and minerals of the grain make up the DDGS. Variation in DDGS composition occurs due to genetic variation of the cereal source used (Belyea et al., 2010), variation in nitrogen fertilization, grain drying, presence of fungi, proportion of solubles added before drying (Li et al., 2015), among other factors.

Additionally, the inclusion level of DDGS as test ingredient in the digestibility experiments has ranged from 100 to 200 g kg⁻¹ (Hanson et al., 2012); 150 and 250 g kg⁻¹ (Lammers et al., 2015); 300 g kg⁻¹ (Urriola et al., 2010); and 200, 400, and 600 g kg⁻¹ DDGS (Corassa et al., 2017), and can be a source of variation in the determination of digestibility coefficients and energetic values.

The fiber of cereal grains is not converted into ethanol during the fermentation process, so diets containing DDGS could be supplemented with enzymes that hydrolyze non-starch polysaccharides (NSP) as a way of improving nutritional value (Swiatkiewicz et al., 2016). Expressive amounts of xylans and other NSP have been recorded in DDGS (Kim et al., 2008; Swiatkiewicz and Koreleski, 2007); however, the impact of the use of enzymes such as xylanase on nutrient digestibility has not been constant (Tsai et al., 2017).

These observations are consistent with the hypotheses that digestibility of DDGS from corn and sorghum differs according to the raw material, inclusion level used in the digestibility study, and use of xylanase.

The objectives of this study were to determine the digestibility coefficients and digestible and metabolizable energy values of corn and sorghum DDGS with different inclusion levels in the diet and determine the effect of xylanase enzyme on DDGS digestibility.

Material and Methods

The experiments were carried out in Sinop, Mato Grosso, Brazil (11° 51' 41" S, 55° 28' 57" W). The experimental procedures were approved by the local Ethics Committee on the Use of Animals, under case no. 23108.700673/14-4.

In experiment 1, eight barrows of the same genetic line, with initial mean weight of 26.15±3.45 kg, were housed in metabolic cages, with repeated measures in three periods of five days of collection. The experiment was performed in a randomized block design using the weight of the animals to form the blocks, each animal being an experimental unit. The experiment consisted of five diets, with four replicates for the reference diet and five replicates for the other diets.

Before the onset of the experiment, the animals were adapted to the cages for two days, followed by three experimental periods constituting five days of feed intake followed by five days of total collection of feces and urine.

The experimental diets were a reference diet (RD) based on corn and soybean meal (Table 1) formulated to meet recommendations of Rostagno et al. (2011); 200 g kg⁻¹ corn DDGS + 800 g kg⁻¹ RD; 400 g kg⁻¹ corn DDGS + 600 g kg⁻¹ RD; 200 g kg⁻¹ sorghum DDGS + 800 g kg⁻¹ RD; and 400 g kg⁻¹ sorghum DDGS + 600 g kg⁻¹ RD, according to methodology of Sakomura and Rostagno (2016).

The DDGS came from an alcohol distillery (Libra Alcohol Distillery Ltda, São José do Rio Claro, MT, Brazil). The DDGS from corn contained 315.3 g kg⁻¹ crude protein (CP), 4,949 kcal kg⁻¹ gross energy (GE), 84.8 g kg⁻¹ ether extract (EE), and 468.4 g kg⁻¹ neutral detergent fiber (NDF). The DDGS from sorghum contained 260.9 g kg⁻¹ CP, 4,345 kcal kg⁻¹ GE, 82.1 g kg⁻¹ EE, and 661.2 g kg⁻¹ NDF.

The dry matter (DM), CP, mineral matter (MM), EE, NDF, and GE were determined to obtain the chemical composition of the diets (Table 2) and DDGS according to Silva and Queiroz (2002).

In the adaptation period, diets were given ad *libitum*, and leftovers were quantified. Diets were duly weighed and supplied twice a day (07.30 and 17.30 h). From the data of feed intake during the

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adaptation period and based on the metabolic weight ($LW^{0.60}$), the amounts of feed given to each animal in the collection period were calculated according to the lower feed intake per kilogram of metabolic weight.

Fecal and urine collections were performed at 07.30 h. Feces were collected, counted, weighed, homogenized, and then little samples of 200 g kg^{-1} of the total were stored in plastic bags, identified, and stored (−10 °C) until the end of the collection period.

The urine was filtered through a filter cloth coupled to the urine collecting box funnel and collected in plastic buckets with 10 mL of 1:1 HCl. Total urine volume of each animal was measured through a 0.5-mL graduated cylinder, from which 200 mL L^{-1} aliquots were taken and stored in a freezer.

After the sampling period, fecal samples were thawed and dried in a forced-ventilation oven at 60 °C for 72 h to promote pre-drying for analytical determination of DM, CP, MM, EE, NDF, and GE, according to Silva and Queiroz (2002). The organic matter (OM) content was determined by the difference between the DM and MM contents. Total nitrogen and energy determination of urine were made from thawed and homogenized samples.

Table 1 - Composition and calculated nutritional values of the reference diet (as-fed basis)

Item	Reference diet
Ingredient (g kg^{-1})	
Corn	604.8
Soybean meal	302.6
Rice bran	30.0
Soybean oil	18.9
Limestone	5.2
Dicalcium phosphate	17.5
Vitamin-trace mineral premix[1]	10.0
Salt	4.6
L-lysine HCl	1.5
Chromium oxide	5.0
Total	1000.0
Calculated nutrient content (g kg^{-1})	
Metabolizable energy (kcal kg^{-1})	3,230
Crude protein	189.9
Calcium	7.2
Available phosphorus	3.6
Sodium	2.0
Digestible lysine	10.1

[1] Provided per kg of diet: vitamin A, 13,750 IU; vitamin B1, 2 mg; vitamin B2, 1.25 mg; vitamin B6, 4 mg; vitamin B12, 4.5 mcg; vitamin D3, 3000 IU; vitamin E, 75 IU; vitamin K3, 6.25 mg; nicotinic acid, 50 mg; pantothenic acid, 30 mg; folic acid, 0.625 mg; cobalto, 1.25 mg; copper, 25 mg; iron, 150 mg; zinc, 200 mg; manganese, 75 mg; selenium, 0.7 mg; iodine, 2 mg; coline, 250 mg; biotin, 25 mcg.

Table 2 - Chemical composition of dietary treatments (g kg $^{-1}$, dry-matter basis)

Item	RD	Corn DDGS		Sorghum DDGS	
		200	400	200	400
Dry matter	955	956	946	957	953
Organic matter	935	943	956	945	954
Crude protein	173	178	210	177	194
Ether extract	79	81	82	72	64
Mineral matter	66	57	44	55	46
Neutral detergent fiber	430	450	460	470	500
Gross energy (kcal kg^{-1})	4,198	4,321	4,489	4,287	4,425

RD - reference diet; DDGS - distillers dried grains with solubles.

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The apparent total tract digestibility (DC) and metabolizability coefficients (MC), digestible nutrient contents, and digestible and metabolizable energy values were determined based on the methodology of Sakomura and Rostagno (2016).

The experiment was conducted in a 2×2+1 factorial completely randomized block design, with two sources of DDGS (corn and sorghum), two inclusion levels of DDGS (200 and 400 g kg⁻¹), and one reference diet. The results were tested by analysis of variance, and the effects broken down into three orthogonal contrasts: 1 = reference diet versus other diets, 2 = corn DDGS versus sorghum DDGS, and 3 = 200 g kg⁻¹ versus 400 g kg⁻¹ of DDGS inclusion. The statistical model used was:

$$Y_{ijk} = \mu + S_i + L_j + B_k + S_i \times L_j + \varepsilon_{ijk},$$

in which Y_{ijk} = observation referring to the effect source $_i$ of DDGS, at level $_j$ of DDGS, to block $_k$; μ = overall mean; S_i = source (corn or sorghum DDGS); L_j = inclusion level of DDGS (200 or 400 g kg⁻¹); B_k = block; $S_i \times L_j$ = interaction between sources and levels; and ε_{ijk} = random error associated with source and level. The Mixed procedure of SAS (Statistical Analysis System, version 6.0) was used considering <0.05 as significance level and 0.10 as a trend of significance.

In experiment 2, nine barrows of the same genetic line and with an initial mean weight of 34.91±1.46 kg were individually distributed in metabolic cages. The experiment was performed in a randomized block design, consisting of three treatments and three replicates, each animal being an experimental unit. The animals were housed in metabolic cages with seven days for adaptation to diets and cages and five days for data collection, comprising a total period of twelve days. The experimental procedures were identical to those adopted in experiment 1.

The treatments consisted of a RD based on corn and soybean meal (Table 1), made to meet the recommendations of Rostagno et al. (2011); 200 g kg⁻¹ corn DDGS + 800 g kg⁻¹ RD; and 200 g kg⁻¹ corn DDGS + 800 g kg⁻¹ RD + 0.1 g kg⁻¹ xylanase (16,000 BXU kg⁻¹).

The statistical model used was

$$Y_{ijk} = \mu + D_i + X_j + \varepsilon_{ijk},$$

in which, Y_{ijk} = observation regarding the effect of feed $_i$ containing (200 g kg⁻¹) DDGS with xylanase $_j$; μ = overall mean; D_i = diet with 200 g kg⁻¹ DDGS, X_j inclusion of xylanase; and ε_{ijk} = random error associated with DDGS and xylanase. The Mixed procedure of SAS was used considering <0.05 as significance level and 0.10 as a trend of significance.

Results

There was no interaction effect between source and inclusion level for the variables under study, except for CP and EE digestibility. Pigs fed RD expressed the highest values of DE, DC, ME, and MC in comparison with pigs fed the other diets, while those receiving diets with corn DDGS also expressed

Table 3 - Energy diet values with different levels and sources of DDGS for pigs (Exp. 1)

| Item | RD | Corn DDGS (g kg⁻¹) | | Sorghum DDGS (g kg⁻¹) | | Significance | | | | SEM |
		200	400	200	400	RD vs others	Source (S)	Level (L)	S×L	
GE (kcal kg⁻¹)	4,198	4,321	4,489	4,287	4,425	-	-	-	-	
DE (kcal kg⁻¹)	3,809	3,752	3,805	3,673	3,667	0.0112	0.0003	0.3497	0.3986	25.2
DC (g kg⁻¹)	907	868	847.6	856	828	<0.0001	0.0132	0.0003	0.5976	5.65
ME (kcal kg⁻¹)	3,702	3,625	3,679	3,554	3,559	0.0130	0.0042	0.3181	0.5305	29.8
MC (g kg⁻¹)	882	839	819	829	804	<0.0001	0.0681	0.0034	0.7083	6.65
DE- DDGS (kcal kg⁻¹)	-	3,477	3,761	3,030	3,398	-	0.0004	0.0028	0.7173	94.2
ME- DDGS (kcal kg⁻¹)	-	3,277	3,609	2,863	3,296	-	0.0007	0.0004	0.7185	88.5

RD - reference diet; DDGS - distillers dried grains with solubles; GE - gross energy; DE - digestible energy; DC - digestibility coefficient; ME - metabolizable energy; MC - metabolizability coefficient; SEM - standard error of the mean.

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superiority in these parameters and trend (P = 0.0681) for higher MC compared with animals fed sorghum DDGS (Table 3). The inclusion level of 200 g kg^{-1} of DDGS presented higher values of DC and MC compared with the 400 g kg^{-1} level, but ME and DE were not influenced.

We observed higher DC of EE, GE, and CP in corn DDGS compared with sorghum DDGS, while the 400 g kg^{-1} level expressed higher DC of NDF and GE compared with the 200 g kg^{-1} inclusion level (Table 4).

The RD had higher DC values for DM, OM, CP, EE, MM, and NDF compared with the other diets (Table 5). Diets containing inclusion of corn DDGS generated higher DC values for CP and EE but did not differ in DM, OM, and MM compared with those containing sorghum DDGS. Diets containing sorghum DDGS had higher DC values for NDF compared with those with corn DDGS. The inclusion of 200 g kg^{-1} DDGS in the diets generated higher DC values in all the parameters of the diets compared with the 400 g kg^{-1} inclusion.

Table 4 - Apparent total tract digestibility coefficients of corn and sorghum DDGS for pigs with different DDGS levels (Exp. 1)

Digestibility coefficient (g kg^{-1})	Corn DDGS		Sorghum DDGS		Significance			SEM
	200	400	200	400	Source (S)	Level (L)	S×L	
Dry matter	712	745	666	719	0.1271	0.0700	0.6740	26.7
Organic matter	714	747	668	722	0.1164	0.0552	0.6416	25.8
Crude protein	825	863	573	669	<0.0001	0.0539	0.3895	39.1
Ether extract	730	750	579	603	0.0020	0.5956	0.9902	49.8
Mineral matter	587	582	533	553	0.3633	0.8679	0.7880	53.7
Neutral detergent fiber	600	661	644	704	0.1004	0.0262	0.9920	30.1
Gross energy	703	752	632	699	0.0122	0.0167	0.7060	26.6

DDGS - distillers dried grains with solubles; SEM - standard error of the mean.

Table 5 - Apparent total tract digestibility coefficients of the experimental diets for pigs with different DDGS sources and levels (Exp. 1)

Digestibility coefficient (g kg^{-1})	RD	Corn DDGS		Sorghum DDGS		Significance				SEM
		200	400	200	400	RD vs others	Source (S)	Level (L)	S×L	
Dry matter	907	870	844	864	836	<0.0001	0.1972	<0.0001	0.8094	5.42
Organic matter	915	877	850	870	843	<0.0001	0.1782	<0.0001	0.8323	5.25
Crude protein	904	884	878	836	804	<0.0001	<0.0001	0.0326	0.1560	8.55
Ether extract	901	875	857	849	800	0.0004	0.0008	0.0052	0.2960	10.6
Mineral matter	796	755	712	751	704	<0.0001	0.5972	0.0006	0.8178	11.2
Neutral detergent fiber	919	856	816	867	836	<0.0001	0.0364	<0.0001	0.7548	6.80

RD - reference diet; DDGS - distillers dried grains with solubles; SEM - standard error of the mean.

Table 6 - Apparent total tract digestibility content of the experimental diets for pigs with different DDGS sources and levels (Exp. 1)

Digestibility content (g kg^{-1})	RD	Corn DDGS		Sorghum DDGS		Significance				SEM
		200	400	200	400	RD vs others	Source (S)	Level (L)	S×L	
Dry matter	866	832	799	826	797	<0.0001	0.5015	<0.0001	0.9737	5.16
Organic matter	856	827	813	822	804	<0.0001	0.1904	0.0043	0.6819	5.02
Crude protein	157	158	184	148	156	0.0221	<0.0001	<0.0001	0.2503	1.64
Ether extract	72	71	70	61	51	<0.0001	<0.0001	<0.0001	0.3705	0.77
Mineral matter	52	43	31	41	32	<0.0001	0.4399	<0.0001	0.1548	0.51
Neutral detergent fiber	395	385	375	407	418	0.7216	<0.0001	0.9464	0.0557	3.24

RD - reference diet; DDGS - distillers dried grains with solubles; SEM - standard error of the mean.

The RD presented higher values of digestible fractions of DM, EE, CP, MM, and OM compared with the other diets but did not differed as to the digestible NDF content (Table 6). The digestible fractions of DM, OM, and MM of the experimental diets were not influenced by DDGS source; however, CP and EE values were higher for diets containing corn DDGS compared with those with sorghum DDGS, whereas digestible NDF data showed an inverse behavior (Table 6). The inclusion of 200 g kg^{-1} DDGS resulted in higher values of digestible fractions of DM, OM, MM, and EE compared with the 400 g kg^{-1} inclusion, data of digestible CP presented an inverse behavior but did not change values of digestible NDF.

The DDGS values of DE and ME were not influenced by the inclusion of xylanase. Values of energy, digestibility coefficients, and digestible fractions of the diets were not influenced by the treatments (Tables 7, 8, and 9). However, a higher digestible MM value was found for RD compared with the other diets (Table 9).

Table 7 - Energy values of diets with DDGS and xylanase (XYL) for pigs (Exp. 2)

Item	RD	Corn DDGS	Corn DDGS + XYL	Significance	SEM
Gross energy (kcal kg^{-1})	4,198	4,321	4,349	-	-
Digestible energy (DE; kcal kg^{-1})	3,897	3,922	3,921	0.9033	25.5
Digestibility coefficient (g kg^{-1})	928	908	901	0.2353	5.94
Metabolizable energy (ME; kcal kg^{-1})	3,769	3,753	3,761	0.9653	25.5
Metabolizability coefficient (g kg^{-1})	898	868	865	0.1162	5.94
DE- DDGS (kcal kg^{-1})	-	4,021	4,019	0.9770	145.3
ME- DDGS (kcal kg^{-1})	-	3,686	3,728	0.9890	147.8

RD - reference diet; DDGS - distillers dried grains with solubles; SEM - standard error of the mean.

Table 8 - Apparent total tract digestibility coefficients of the experimental diets for pigs with DDGS and xylanase (XYL) (Exp. 2)

Digestibility coefficient (g kg^{-1})	RD	Corn DDGS	Corn DDGS + XYL	Significance	SEM
Dry matter	929	909	904	0.2444	5.83
Organic matter	935	913	909	0.1963	5.54
Crude protein	930	913	908	0.4098	6.54
Ether extract	929	917	910	0.6714	8.43
Mineral matter	853	842	830	0.6868	10.6
Neutral detergent fiber	929	895	886	0.0841	6.73

RD - reference diet; DDGS - distillers dried grains with solubles; SEM - standard error of the mean.

Table 9 - Apparent total tract digestibility content of the experimental diets for pigs with DDGS and xylanase (XYL) (Exp. 2)

Digestibility content (g kg^{-1})	RD	Corn DDGS	Corn DDGS + XYL	Significance	SEM
Dry matter	887	869	862	0.2416	5.54
Organic matter	876	861	860	0.4305	5.43
Crude protein	161	163	162	0.8584	1.13
Ether extract	74	74	74	0.9144	0.74
Mineral matter	56a	48b	47b	0.0020	0.63
Neutral detergent fiber	399	403	399	0.8567	3.04

RD - reference diet; DDGS - distillers dried grains with solubles; SEM - standard error of the mean.
Means in the same row followed by different letters differ from each other by the Tukey test (P<0.05).

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Discussion

The Brazilian corn DDGS of this study show the gross energy value (4,949 kcal kg^{-1}) lower than the mean values reported by Anderson et al. (2012) (5,076 to 5,550 kcal kg^{-1}) but close to other Brazilian DDGS analyzed by Corassa et al. (2017) (4,780 kcal kg^{-1}). The gross energy of sorghum DDGS evaluated in this study (4,345 kcal kg^{-1}) was lower than in the samples evaluated by Jacela et al. (2010) (5,108 kcal kg^{-1}) and by Stein et al. (2016) (5,302 kcal kg^{-1}). Values of DE and ME determined for corn DDGS were higher than those of sorghum DDGS, which was also evidenced by Feoli et al. (2008) and are related to higher DC of CP, EE, and GE. Characteristics of the grains used as raw material may have influenced the composition of the co-product, and corn has higher energy value compared with sorghum.

The energy content of pig feed is closely related to its chemical composition. Analyzing the ether extract of the corn and sorghum DDGS, values of 84.8 and 82.1 g kg^{-1}, respectively, were observed, justifying the difference in the energy value between the sources. The Brazilian DDGS of this study present average oil content, based on NRC (2012) classification that considers >100 g kg^{-1} as high, 60 to 90 g kg^{-1} as medium, and <40 g kg^{-1} as low oil content. The oil content of DDGS is an important variable, because it was related to differences in growth performance of pigs (Graham et al., 2014).

On the other hand, it is well established that dietary fiber negatively affects energy and nutrient utilization by pigs and results in increased fecal output and nutrient excretion (Urriola et al., 2010). The increase in the levels of insoluble fiber in the diet increases the rate of passage of the digesta through the gastrointestinal tract (GIT) and can be due to the physical stimulation of the insoluble fiber on the GIT walls. Therefore, the action of microorganisms on these fibers in the small intestine can create a physical barrier to the performance of certain digestive enzymes, reducing the diet digestibility (Silva, 2015).

The reduction in DC (Table 7) and the digestible fraction (Table 8) of OM, DM, MM, NDF, and EE with increasing DDGS inclusion is probably related to the fiber fraction in the tested ingredients, in which this concentration is almost three times higher than that of the original grains (Pedersen et al., 2014). Quantities above 600 g kg^{-1} NDF were observed in the DDGS of the present study, contributing to differences in DDGS energy digestibility as also observed by Corassa et al. (2017) and Anderson et al. (2012).

The use of high fiber content in pig diets may be a critical factor, especially when given to animals that do not possess a suitable GIT. Nevertheless, fiber can cause deleterious effects on the digestibility coefficients of nutrients, and Gomes et al. (2007) concluded that fibrous diets can promote changes in the absorption rate of nutrients, especially amino acids and minerals. Moreover, the dietary fiber concentration may also affect feed intake, since the increase in fiber content may limit the physical ability of the intestines to digest more feed (Wu et al., 2016).

The observation of higher NDF content in sorghum DDGS compared with corn DDGS in this study corroborates the results of Sotak et al. (2014). However, regardless of the source, it was observed that DDGS inclusion in the diets resulted in an increase in NDF content and worsening in diet DC compared with the diet with corn and soybean meal. The present results are similar to a study that evaluated inclusions of 200, 400, and 600 g kg^{-1} of corn DDGS and reported a decline in the DC of NDF as the DDGS inclusion increased (Corassa et al., 2017).

The results of this study also show the influence of the inclusion level of the tested feeds on the determination of the digestibility. The higher DC values of NDF and GE and the tendency for DM, OM, and CP presented in the two DDGS sources with 400 g kg^{-1} inclusion compared with the 200 g kg^{-1} inclusion suggest that the higher use of this feed, the greater its inclusion. In this sense, Sakomura and Rostagno (2016) inferred that the higher the proportion of feed in the test diet, the greater the precision in the determination, as long as the characteristics of the ingredients are respected.

When considering the reduction in the digestibility of diets and improvement in the DC of DDGS with higher inclusions of the test ingredient, it is understood that the magnitude of the differences of DC between the diets was smaller than the magnitude of the differences between the inclusion levels of the

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test ingredient. This is due to the calculation method of DC, which considers the difference between the DC of the test diet and the RD, dividing it by the inclusion level of the test ingredient, adding this value to the DC of the RD. This same calculation is used to determine the digestible and metabolizable energy value according to Sakomura and Rostagno (2016).

The effect of the inclusion level of the test ingredient on the digestibility was also reported by Bolarinwa and Adeola (2016), who evaluated the diets with barley and wheat at levels of 0, 300, and 600 g kg^{-1}, and observed a decreasing linear effect in values of DE and ME and DC of DM for barley. However, Verussa et al. (2017) observed that the DC of OM and DM increased linearly as the inclusion of glycerin increased with 50, 100, and 150 g kg^{-1}. Inclusion levels of 200, 400, and 600 g kg^{-1} corn DDGS tested by Corassa et al. (2017) resulted in differences in DC and digestible fractions of the diet due to DDGS inclusions. In any case, the differences between the studies are related to the characteristics of the evaluated ingredients.

The DM digestibility values of the diets containing 200 g kg^{-1} DDGS were higher than the values reported by Urriola et al. (2010) using 300 g kg^{-1} inclusion but close to those of Hanson et al. (2012), who used 100 and 200 g kg^{-1} inclusion, suggesting that high levels of DDGS can reduce DM digestibility of the diets. Dietary fiber negatively affects DE and ME and nutrient utilization by pigs, resulting in increased fecal output and nutrient excretion (Noblet and Shi, 1994). The concentration of fiber and other chemical components in DDGS observed in the experiments is mainly due to the difference in the composition of the original grains used to produce ethanol (NRC, 2012). However, the observation of equality of DC of NDF between corn and sorghum DDGS (Table 4), together with the difference in this parameter in the diets containing the two sources (Table 5), suggest that the chemical constitutions of this fiber fraction of both are close and that differences between the sources are quantitative.

The addition of xylanase enzyme in a diet containing DDGS did not affect any of the parameters of digestibility and energy values evaluated in this study, contrary to the initial hypothesis. Similar to the present study, Jones et al. (2010) evaluated xylanase levels in diets based on corn and soybean meal and with 300 g kg^{-1} corn DDGS to pigs and concluded that xylanase supplementation did not alter the energy performance and digestibility coefficient of the diets. Moreover, Moran et al. (2016) stated that xylanase supplementation had limited potential to enhance nutrient digestibility of pigs fed DDGS-based diets. In this sense, Weiland and Patience (2016), evaluating 0 and 300 g kg^{-1} DDGS and 0 and 4 g kg^{-1} xylanase, observed that DDGS decreased DM digestibility, and xylanase inclusion did not significantly impact DM digestibility or DE value of the diet for pigs at 46 kg body weight; however, at 70 kg, xylanase inclusion increased DM digestibility, concluding that xylanase did not affect DM digestibility or DE in the smallest pigs and improved both in the heaviest pigs.

Nevertheless, Ndou et al. (2015) observed a reduction of negative impacts on nutrient digestibility when compared with the control diet without the enzyme in diets with 300 g kg^{-1} DDGS. Likewise, Tsai et al. (2017) observed increased DM, NDF, acid detergent fiber, and hemicellulose digestibility when using xylanase in diets containing 300 g kg^{-1} corn DDGS, while Barnes et al. (2011) found that xylanase addition increased apparent fecal ADF digestibility of growing-finishing pigs fed diets with 150 or 300 g kg^{-1} corn DDGS.

The results of research on enzymes are often contradictory, but adequacy of factors such as amount of substrate and adequate dosage of enzymes has been suggested (Jones et al., 2010) to evidence biologically favorable responses. However, few studies quantified the content of fiber fraction in corn DDGS, registering 160 g kg^{-1} cellulose, 80 g kg^{-1} xylan, 50 g kg^{-1} arabinan (Kim et al., 2008), 265 g kg^{-1} total NSP (35.5 g kg^{-1} soluble and 235 g kg^{-1} insoluble NSP), and 215 g kg^{-1} arabinoxylans, and 3.2 g kg^{-1} β-glucans (Swiatkiewicz and Koreleski, 2007).

In a recent review, Swiatkiewicz et al. (2016) stated that the efficacy of enzymes used in pig diets with DDGS is not consistent and that factors such as activity of the enzymes used, age and physiological stage of the animals, level of DDGS used, chemical composition, and composition of diets can influence. According to these authors, the use of xylanase alone without the use of other exogenous enzymes such as proteases, amylase, and beta-glucanase does not produce a response similar to those obtained with

a combination of the enzymes. However, Kerr et al. (2013) showed a small and inconsistent effect on nutrient digestibility using mixtures of commercial NSP-containing enzymes, and none of the products improved performance of pigs fed diets with 300 g kg^{-1} corn DDGS. Therefore, further studies evaluating the use of enzymes should be carried out to improve the digestibility of DDGS-containing diets.

The lowest concentration of MM in DDGS-containing diets is due to the isomeric substitution method of the RD with the test ingredient used in this study, since 200 g kg^{-1} of the RD with the highest concentration of minerals is withdrawn compared with the test ingredient added.

Conclusions

Metabolizable energy of corn distillers dried grains with solubles is 3,277 and 3,609 kcal kg^{-1} and 3,296 and 2,863 kcal kg^{-1} of sorghum distillers dried grains with solubles with 200 and 400 g kg^{-1} inclusion, respectively.

Levels up to 400 g kg^{-1} do not influence the digestible and metabolizable energy of the diets but impair the digestibility coefficient of organic matter, dry matter, ether extract, crude protein, neutral detergent fiber, and mineral matter.

Corn distillers dried grains with solubles show better digestibility than sorghum distillers dried grains with solubles, while 200 g kg^{-1} inclusion indicate better digestibility coefficients than 400 g kg^{-1}.

The use of xylanase enzyme in diets containing 200 g kg^{-1} distillers dried grains with solubles does not affect the digestibility of the diets.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: A. Corassa and A.P.S. Ton. Data curation: A. Corassa, J.L. Stuani, A.P.S. Ton, M. Sbardella and D.B.C. Gonçalves. Formal analysis: A. Corassa, J.L. Stuani, A.P.S. Ton, C. Kiefer, M. Sbardella, C.O. Brito, A.B. Amorim and D.B.C. Gonçalves. Funding acquisition: A. Corassa, A.P.S. Ton and M. Sbardella. Investigation: A. Corassa, J.L. Stuani, A.P.S. Ton, C. Kiefer, M. Sbardella, C.O. Brito, A.B. Amorim and D.B.C. Gonçalves. Methodology: A. Corassa, J.L. Stuani, A.P.S. Ton, C. Kiefer, M. Sbardella, C.O. Brito, A.B. Amorim and D.B.C. Gonçalves. Project administration: A. Corassa, J.L. Stuani, M. Sbardella, C.O. Brito and A.B. Amorim. Resources: A. Corassa. Software: A. Corassa. Supervision: A. Corassa. Validation: A. Corassa and C. Kiefer. Visualization: A. Corassa and C. Kiefer. Writing-original draft: A. Corassa, J.L. Stuani, A.P.S. Ton, C. Kiefer, M. Sbardella, C.O. Brito and A.B. Amorim. Writing-review & editing: A. Corassa, A.P.S. Ton, C. Kiefer, M. Sbardella, C.O. Brito and A.B. Amorim.

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