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Short communication

The effect of feeding wheat distillers dried grain with solubles on growth performance and nutrient digestibility in weaned pigs

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ABSTRACT

The effects of substituting soybean meal with wheat distillers dried grain with solubles (DDGS) as an energy and amino acid source on growth performance and dietary nutrient digestibility were evaluated in 240 weaned pigs with an initial body weight (BW) of 6.2 ± 1.2 kg. Five pelleted wheat-based diets containing 0, 50, 100, 150, or 200 g wheat DDGS/kg were formulated to contain 10.0 MJ/kg net energy (NE) and 1.15 g standardised ileal digestible (SID) lysine (Lys)/MJ NE and were fed for 4 wk. For d 0–28, increasing dietary inclusion of wheat DDGS quadratically reduced BW gain ($P<0.001$) mainly due to a quadratically reduced ($P<0.001$) feed intake but also a reduced ($P<0.001$) feed efficiency. At d 28, pigs fed 50, 100, 150 and 200 g wheat DDGS/kg were 0.1, 0.1, 0.4 and 5.5 kg lighter ($P<0.001$) than pigs fed 0 g wheat DDGS/kg. In conclusion, weaned pigs fed diets formulated to equal NE and SID amino acids can be fed up to 100 g wheat DDGS/kg without reducing final body weight (BW) and up to 150 g wheat DDGS/kg with limited reductions in growth performance. Despite similar DE content among diets, inclusion of 200 g wheat DDGS/kg of drastically reduced growth performance of weaned pigs.

1. Introduction

To meet the demands of legislation requiring the use the gasoline blended with ethanol, wheat instead of maize is used for ethanol production in some countries with cooler climates such as Canada, France and the UK. Production of ethanol from wheat has increased the availability of the co-product wheat distillers dried grains with solubles (DDGS). Wheat DDGS has a higher gross energy content (Nyachoti et al., 2005), a higher protein and fibre content and a drastically reduced starch content compared to wheat grain (Widyaratne and Zijlstra, 2007; Cozannet et al., 2010b). This nutritional profile provides an opportunity to use wheat DDGS primarily as a protein feedstuff in livestock feeding to mitigate feed cost, which is the largest variable cost of swine production.

Initially, results of feeding wheat DDGS were not positive in Canada. The growth performance of grower-finisher pigs fed 100 g wheat DDGS/kg or more was reduced (Thacker, 2006), even when diets were formulated to equal digestible energy (DE) and standardised ileal digestible (SID) amino acid content (Widyaratne and Zijlstra, 2007). However, wheat DDGS used in

Abbreviations: ADFI, average daily feed intake; ADG, average daily gain; BW, body weight; ATTD, apparent total tract digestibility; CP, crude protein; DDGS, distillers dried grains with solubles; DE, digestible energy; DM, dry matter; G:F, feed efficiency (ADG/ADFI); Lys, lysine; NE, net energy; SID, standardised ileal digestible.

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Table 1
Ingredient composition and analysed nutrient content of experimental diets.

Ingredient (g/kg diet)	Wheat DDGS (g/kg diet)				
	0	50	100	150	200
Wheat	570.7	568.6	567.2	565.3	564.0
Soybean meal	200.0	150.0	100.0	50.0	–
Wheat DDGS[a]	–	50.0	100.0	150.0	200.0
Lactose	50.0	50.0	50.0	50.0	50.0
Canola oil	50.0	50.0	50.0	50.0	50.0
Soy protein concentrate	44.0	44.0	44.0	44.0	44.0
Herring fish meal	44.0	44.0	44.0	44.0	44.0
Limestone	9.1	9.8	10.5	11.0	11.5
Acid-insoluble ash[b]	8.0	8.0	8.0	8.0	8.0
Mono/dicalcium phosphate	8.5	8.0	7.0	6.5	5.5
Vitamin premix[c]	5.0	5.0	5.0	5.0	5.0
Mineral premix[d]	5.0	5.0	5.0	5.0	5.0
Salt	5.0	5.0	5.0	5.0	5.0
L-Lysine HCl	–	1.3	2.6	3.9	5.2
L-Threonine	0.2	0.6	0.9	1.3	1.7
DL-Methionine	0.2	0.3	0.3	0.4	0.4
L-Tryptophan	–	0.1	0.2	0.3	0.4
Choline chloride, 60 g/kg	0.3	0.3	0.3	0.3	0.3
Analysed composition (g/kg DM)					
Moisture (g/kg)	100	98	100	100	102
Crude protein	239	245	246	249	241
Crude fat	77	81	75	83	77
Crude fibre	23	25	26	27	29
Ash	66	72	65	65	59
ADF	45	45	48	50	52
NDF	128	157	171	176	177
Gross energy (MJ/kg)	19.3	19.3	19.4	19.5	19.7
Density (kg/hL)	70.1	68.3	67.3	65.9	64.0

[a] Terra Grain Fuels, Belle Plaine, SK, Canada.
[b] Celite 281, World Minerals Inc. (Santa Barbara, CA).
[c] Supplied per kilogram of diet: 17,500 IU of vitamin A, 200 IU of vitamin D, 11 IU of vitamin E, 12.5 mg of niacin, 9 mg of pantothenic acid, 0.3 mg of folacin, 3.0 mg of riboflavin, 1.5 mg of pyridoxine, 0.5 mg of vitamin K, 0.5 mg of biotin and 15 mg of vitamin B_{12}.
[d] Supplied per kilogram of diet: 80 mg of Zn, 5 mg of Cu, 80 mg of Fe, 3 mg of Mn, 0.14 mg of I and 0.25 mg of Se.

these early studies had been overheated during drying resulting in reduced lysine (Lys) availability (Zijlstra and Beltranena, 2009), the first limiting amino acid for swine. Recently, ethanol processing plants with improved fermentation and drying technologies produce a wheat DDGS of a higher quality that has been termed 'new generation' (Whitney and Shurson, 2004). Therefore, the inclusion of wheat DDGS in diets for pigs should be re-evaluated. We selected to use the weaned pig, because this is a more sensitive model for feedstuff evaluation than the grower-finisher pig. Growth performance data regarding the feeding of wheat DGDS in weaned pigs has not been published.

The hypothesis tested in the present study was that pigs offered diets containing 50–200 g wheat DDGS/kg and formulated to an equal net energy (NE) and SID amino acid content would have a growth performance and dietary nutrient digestibility similar to pigs fed diet without wheat DDGS. The objectives were to determine whether a dose response existed for growth performance and apparent total tract digestibility (ATTD) coefficients of dietary energy and protein in weaned pigs fed diets containing 0 up to 200 g wheat DDGS/kg.

2. Materials and methods

2.1. Experimental design and diet

The animal protocol for the study was approved by the University of Alberta Animal Care and Use Committee for Livestock and followed principles established by the Canadian Council on Animal Care (CCAC, 2009). The experiment was conducted at the Swine Research and Technology Centre of the University of Alberta (Edmonton, AB, Canada).

In total, 240 pigs (Duroc × Large White/Landrace F_1; Hypor, Regina, SK, Canada) were weaned at 19 ± 1 d of age, selected based on BW gain during the first 7 d post weaning and BW on d 7 after weaning (6.7 ± 1.0 kg) and divided within gender into heavy and light BW. One heavy and one light barrow and gilt were placed randomly into one of 60 pens, for 4 pigs per pen. After weaning, pigs were fed commercial phase 1 and 2 diets (Unifeed, Edmonton, AB, Canada) for 7 d.

A wheat-based control diet and four diets containing 50, 100, 150 or 200 g wheat DDGS/kg were formulated by replacing soybean meal with wheat DDGS (Terra Grain Fuels, Belle Plaine, SK, Canada). The main dietary ingredients were wheat, soybean meal, lactose, soy protein concentrate and herring fish meal (Table 1). Diets without antibiotics were formulated to provide 10.0 MJ/kg NE and 1.15 g SID Lys/MJ NE with other amino acids formulated as an ideal ratio to Lys (threonine,

0.65; methionine, 0.35; tryptophan, 0.22; isoleucine, 0.63; NRC, 1998) using established NE (Sauvant et al., 2004) and SID AA (NRC, 1998) values. For the wheat DDGS, a content of 8.61 MJ/kg NE and 2.00 g/kg SID Lys were used for diet formulation, values based on measurements in our laboratory (data not shown). Premixes were added to meet or exceed mineral and vitamin requirements (NRC, 1998). Eight g/kg of acid-insoluble ash (Celite 281; World Minerals, Santa Barbara, CA, USA) was included in diets as an indigestible marker. Diets were mixed and steam pelleted at 70 °C (70 hp; CPM, Crawfordsville, IN, USA).

The study was a completely randomised design with 60 pens in three nursery rooms. Each pen was fed one of five diets during the 4-wk study, starting 7 d post weaning for a total of 12 observations per diet. Pens (1.1 × 1.5 m) were equipped with a 4-space self-feeder, nipple drinker and plastic slatted flooring. Pigs had free access to feed and water during the entire 4-wk study.

Weekly, individual pigs were weighed to monitor BW gain and the amount of feed consumed was determined. Measured BW changes and feed disappearance were used to calculate average daily gain (ADG), average daily feed intake (ADFI) and feed efficiency (G:F; calculated as ADG/ADFI) for the pen. Freshly voided faeces were collected from 0800 to 1600 h by grab sampling from pen floors on d 15 and 16. Faeces were pooled by pen and frozen at −20 °C. Upon completion of the growth trial, faeces were thawed, homogenised, sub-sampled and freeze-dried.

2.2. Chemical analyses

Wheat DDGS, diets and freeze-dried faeces were ground through a 1-mm screen in a centrifugal mill (Retsch GmbH, Haan, Germany). Wheat DDGS was analysed for crude protein (CP), crude fat, ADF, NDF, starch, ash, Ca and P [Association of Official Analytical Chemists (AOAC), 2006]. Wheat DDGS was analysed for amino acids (method 982.30E; AOAC, 2006) and available Lys (method 975.44; AOAC, 2006). Faeces and diets were analysed for dry matter (DM) by drying at 135 °C for 2 h (method 930.15; AOAC, 2006), CP [N × 6.25; method 988.05; (AOAC, 2006)], acid-insoluble ash (McCarthy et al., 1974) and gross energy using an adiabatic bomb calorimeter (model 5003; Ika-Werke GMBH & Co. KG, Staufen, Germany). Based on the results of chemical analyses, the coefficients of ATTD of CP, gross energy and DM were calculated using the acid-insoluble ash concentration of faeces relative to feed using the indicator method (Adeola, 2001).

Table 2
Analysed composition of wheat DDGS[a] used in the experimental diets.

Composition	g/kg DM
Moisture	83
Crude protein	463
Crude fat	56
ADF	154
NDF	427
Starch	23
Ash	63
Calcium	1.1
Phosphorus	11.1
Indispensable amino acid	
Arginine	20.1
Histidine	10.2
Isoleucine	16.6
Leucine	30.0
Lysine	11.7
Methionine	7.1
Phenylalanine	22.2
Threonine	13.1
Tryptophan	4.3
Valine	20.9
Dispensable amino acid	
Alanine	17.7
Aspartic acid	21.6
Cysteine	10.0
Glutamic acid	113.0
Glycine	19.2
Proline	38.5
Serine	17.5
Tyrosine	13.5
Available lysine	9.7

[a] Terra Grain Fuels, Belle Plaine, SK, Canada.

Table 3
Apparent total tract digestibility (ATTD) coefficients of nutrients and DE content of diets resulting from feeding increasing levels of wheat DDGS in substitution for soybean meal to weaned pigs[a].

Variable	Wheat DDGS (g/kg diet)					SEM	P-value	
	0	50	100	150	200		Linear	Quadratic
ATTD								
Crude protein	0.798	0.804	0.784	0.786	0.788	0.005	0.011	0.406
Gross energy	0.842	0.845	0.833	0.830	0.827	0.003	<0.001	0.846
Dry matter	0.847	0.850	0.839	0.836	0.834	0.003	<0.001	0.852
DE content, MJ/kg	14.6	14.7	14.6	14.6	14.6	0.05	0.436	0.541

[a] Least-squares means based on 12 pen observations of 4 pigs each per diet.

2.3. Statistical analyses

Pen was considered the experimental unit. Growth performance was analysed as repeated measures using the MIXED procedure of SAS (SAS, 2003). Diet was the fixed effect and pen was the random effect in the statistical model; initial BW was used as a covariate. Digestibility coefficients were analysed using the same model excluding period. Two single degree of freedom orthogonal contrasts tested the linear and quadratic effects of wheat DDGS inclusion. To test the hypotheses, $P<0.05$ was considered significant.

3. Results

The wheat DDGS sample contained 463 g/kg CP, 11.7 g/kg Lys and 9.7 g/kg available Lys on a DM basis (Table 2). All pigs remained on test for entire study and signs of disease were not observed.

Increasing dietary wheat DDGS linearly decreased ($P<0.05$; Table 3) the diet apparent total tract digestibility coefficients of CP, gross energy and DM. The DE content was not different among diets (Table 3).

For d 0–28, increasing inclusion of wheat DDGS quadratically decreased ($P<0.001$; Table 4) ADFI, ADG and G: F. Specifically, for d 0–28, pigs fed 50 and 100 g wheat DDGS/kg had a similar ADFI, ADG and G:F than pigs fed 0 g wheat DDGS/kg, whereas pigs fed 200 g wheat DDGS/kg had a 36% reduced ADFI, 49% reduced ADG and 23% reduced G:F. Reductions in ADFI, ADG and G:F to wheat DDGS were similar for individual weeks.

Overall, increasing the inclusion of wheat DDGS quadratically reduced ($P<0.001$) final BW of weaned pigs. At d 28, pigs fed 50, 100, 150 and 200 g wheat DDGS/kg were 0.1, 0.1, 0.4 and 5.5 kg lighter ($P<0.001$), respectively, than pigs fed 0 g wheat DDGS/kg that had a final BW of 17.3 kg.

Table 4
Growth performance of weaned pigs fed diets with increasing level of wheat DDGS in substitution for soybean meal[a].

Variable	Wheat DDGS (g/kg)					SEM	P-value	
	0	50	100	150	200		Linear	Quadratic
ADFI (g/d)								
Day 0–7	226	227	232	205	191	7	0.001	0.029
Day 8–14	444	421	433	402	318	14	<0.001	0.004
Day 15–21	638	622	620	598	360	24	<0.001	<0.001
Day 22–28	847	861	840	839	496	26	<0.001	<0.001
Day 0–28	539	533	531	511	341	13	<0.001	<0.001
ADG (g/d)								
Day 0–7	202	204	206	171	105	1	<0.001	<0.001
Day 8–14	294	292	299	280	169	14	<0.001	<0.001
Day 15–21	438	421	425	423	196	21	<0.001	<0.001
Day 22–28	568	587	568	574	293	21	<0.001	<0.001
Day 0–28	375	376	375	362	191	11	<0.001	<0.001
G:F								
Day 0–7	0.89	0.89	0.89	0.83	0.55	0.04	<0.001	0.001
Day 8–14	0.66	0.69	0.69	0.70	0.53	0.02	0.004	<0.001
Day 15–21	0.69	0.68	0.68	0.72	0.56	0.04	0.080	0.053
Day 22–28	0.67	0.68	0.67	0.69	0.61	0.04	0.259	0.179
Day 0–28	0.73	0.73	0.73	0.73	0.56	0.02	<0.001	<0.001

[a] Least-squares means based on 12 pen observations of 4 pigs each per diet.

4. Discussion

Few studies have characterised the effects of dietary inclusion of wheat DDGS on diet nutrient digestibility and growth performance in grower pigs (Thacker, 2006; Widyaratne and Zijlstra, 2007; Widyaratne et al., 2009) and none in weaned pigs. In the present study, the ADG of weaned pigs was reduced by increasing wheat DDGS inclusion that was caused mostly by a reduced ADFI and also a reduced G:F. Interestingly in the present study, the reduction in nutrient digestibility was linear and did not coincide with the quadratic reduction in growth performance indicating that nutrient digestibility was not a main factor reducing growth performance. Pigs could maintain BW up to 100 g wheat DDGS/kg, 150 g/kg inclusion caused a 0.4 kg reduction in BW, whereas an inclusion of 200 g wheat DDGS/kg caused BW to plummet.

The main effect observed was a reduced ADFI with an increased inclusion of wheat DDGS, especially at an inclusion of 200 g/kg. Inclusion of wheat DDGS may have reduced ADFI for several reasons (Nyachoti et al., 2004). First, increasing wheat DDGS inclusion from 0 to 200 g/kg linearly reduced ($R^2 = -0.99$) the density of the feed by 8.6%. Therefore, pigs had to increase the bulk volume of intake thereby reaching a physical limitation in gut size (Bach Knudsen and Hansen, 1991). Finally, increasing the inclusion of wheat DDGS may have altered taste or smell of the diet progressively reducing diet palatability.

Heat processing may reduce amino acid digestibility and availability and introduce variation in quality of wheat DDGS (Cozannet et al., 2010a,b). The processing of the wheat DDGS used in the present study was indeed milder than previous studies. Chemically defined Lys availability was 83% and Lys as a percentage of CP was 2.53%. Both criteria were much higher than the 1.62% (Widyaratne and Zijlstra, 2007) and 2.17% (Widyaratne et al., 2009), respectively, measured previously. However, the Lys data indicate that still some Lys damage occurred during DDGS production, because wheat grain Lys as a percentage of CP of 2.7% is expected (NRC, 1998). Therefore, the possibility that overheating of wheat DDGS altered the taste or smell of the diet at the higher inclusions of wheat DDGS and thereby reduced palatability and ADFI cannot be excluded (Whitney and Shurson, 2004).

5. Conclusion

In conclusion, the data indicate that weaned pigs fed diets formulated to equal NE and SID amino acids can be fed up to 100 g wheat DDGS/kg without reducing final BW and up to 150 g wheat DDGS/kg with limited reductions in growth performance. Despite similar DE content among diets, inclusion of 200 g wheat DDGS/kg of drastically reduced ADFI, ADG and G:F of weaned pigs.

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