Growth performance of nursery pigs fed diets containing increasing levels of corn distiller's dried grains with solubles originating from a modern Midwestern ethanol plant[1]

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ABSTRACT: Two experiments were conducted to determine the effects of including distiller's dried grains with solubles in nursery diets on growth performance, and to establish maximum inclusion rates for corn distiller's dried grains with solubles originating from modern, "new-generation" ethanol plants (built since 1990). Ninety-six crossbred pigs (BW = 6.18 ± 0.14 kg) were blocked by gender and ancestry, and pigs within each block were randomly assigned to one of six dietary treatments (four pigs/pen, four pens/dietary treatment) in each of two growth performance experiments. Dietary treatments provided 0, 5, 10, 15, 20, or 25% distiller's dried grains with solubles during Phases 2 and 3 of a three-phase nursery feeding program for early-weaned pigs. Pigs in Exp. 1 were slightly older (19.0 vs. 16.9 d of age) and heavier (7.10 vs. 5.26 kg) at the beginning of the experiment compared to pigs in Exp. 2. All pigs in both experiments were provided a commercial pelleted Phase 1 diet for the first 4 d after weaning and were then switched to their respective experimental Phase 2 diets, which were fed for 14 d, followed by their respective Phase 3 experimental diets, which were fed for a subsequent 21-d feeding period. Experimental diets were formulated to contain equivalent apparent ileal digestible lysine (1.35 and 1.15%), apparent ileal digestible methionine + cystine (0.80 and 0.65%), ME (3,340 and 3,390 kcal/kg), calcium (0.95 and 0.80%), and total phosphorus (0.80 and 0.70%) within Phases 2 and 3, respectively. Overall growth rate, ending body weight, and feed conversion were similar among pigs regardless of dietary distiller's dried grains with solubles level for both experiments. In Exp. 1, feed intake was not affected by dietary treatment ($P > 0.10$). In Exp. 2, however, increasing the level of distiller's dried grains with solubles linearly decreased feed intake ($P < 0.02$) during Phase 2 and tended to decrease voluntary feed intake ($P < 0.09$) over the length of the experiment. These results suggest that the corn distiller's dried grains with solubles used in this study can be included in Phase 3 diets for nursery pigs at dietary levels of up to 25% without negatively affecting growth performance after a 2-wk acclimation period. Including high levels of corn distiller's dried grains with solubles in diets for pigs weighing less than 7 kg in BW, however, may negatively influence feed intake and growth.

Key Words: Distiller's Dried Grains with Solubles, Growth, Nursery, Swine

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Introduction

Corn distiller's dried grains with solubles (**DDGS**) is a co-product of the dry-mill ethanol industry. The physical appearance, chemical composition, and nutrient digestibility of DDGS can vary considerably depending on source and processing and drying procedures (Cromwell et al., 1993). Recent research results have indicated that corn DDGS originating from "new-generation" (built after 1990) ethanol plants located in the upper Midwest has higher levels of apparent ileal digestible amino acids (Whitney et al., 2000), metabolizable energy (Spiehs et al., 1999), and available phosphorus (Whitney et al., 2001) than values published by NRC (1998). These plants use improved enzymes and yeasts, compared with more than 20 yr ago, which increase starch conversion to ethanol and use lower temperature drying techniques that improve the nutritional value of DDGS for swine (R. Doyal, personal communication).

Similar growth performance has been observed in pigs fed DDGS at levels of up to 10% (Cromwell et al., 1985) or 20% (Combs and Wallace, 1969) of the diet, whereas others have reported a reduction in growth performance (Wahlstrom and Libal, 1980) and dry mat-

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ter, protein, and fat digestibility (Combs and Wallace, 1969). As a result of these studies, nutritionists have adhered to a conservative recommended maximal inclusion level of 5% DDGS in starter pig diets (Newland and Mahan, 1990; Miller et al., 1987). Current nutrient specifications and recommended inclusion rates are based on studies that have evaluated DDGS produced from older dry mill ethanol plants. Additionally, these studies were conducted using pigs that were 4 wk of age or more at weaning, compared to current practice of early weaning (<3 wk of age) in the United States. This study was conducted to determine whether including increasing levels of corn DDGS, originating from a new-generation ethanol plant, in conventional starter diets results in similar growth performance when diets are formulated on a basis of equivalent metabolizable energy and apparent digestible amino acid.

Materials and Methods

Animals and Dietary Treatments

The experimental protocol used in this study was approved by the University of Minnesota Institutional Animal Care and Use Committee. Two experiments were conducted using two consecutive weaning groups of early-weaned pigs. In Exp. 1, 96 crossbred pigs initially weighing 7.10 ± 0.07 kg were allotted to dietary treatments immediately following weaning at an average of 19.0 d of age. In Exp. 2, 96 crossbred pigs initially weighing 5.26 ± 0.07 kg were allotted to dietary treatments immediately following weaning at an average of 16.9 d of age. Pigs for both experiments were blocked by gender and randomly allotted within each block to 1 of 24 pens (four pigs/pen). Equal numbers of gilts (n = 2) and barrows (n = 2) were allotted to each pen. Littermates were stratified across treatments. Experimental diets were formulated to contain corn distiller's dried grains with solubles (DDGS) at inclusion levels of 0, 5, 10, 15, 20, or 25% of the diet (four replications/dietary treatment). A three-phase nursery feeding program (four replications/dietary treatment) was used for each experiment, with all pigs receiving the same commercial Phase 1 diet (Ultra Wean Plus, Land O'Lakes Inc., Inver Grove Heights, MN) during the first 4 d postweaning. Pigs were switched to their assigned Phase 2 experimental diets on d 4 after weaning and remained on these diets for 14 d. On d 18, respective Phase 3 experimental diets were then fed for the final 21 d of each experiment.

Diet composition and analyzed nutrient content of experimental diets were the same for both experiments (Tables 1 and 2). Diets within each phase were formulated to contain equivalent levels of apparent ileal digestible Lys and Met + Cys, ME, calcium, total phosphorus, vitamins, and trace minerals. Diets were formulated using energy values (Spiehs et al., 1999), total amino acid and mineral levels (Whitney et al., 1999), and apparent ileal amino acid digestibility coefficients (Whitney et al., 2000) for new-generation corn DDGS. The ME value used for DDGS was 3,350 kcal/kg on an as-fed basis, whereas apparent ileal digestible Lys, Met + Cys, Thr, and Trp levels were estimated at 0.39%, 0.57%, 0.55%, and 0.13%, respectively. Dietary apparent ileal digestible Lys levels were set at 1.35 and 1.15%, whereas apparent ileal digestible Met + Cys levels were formulated to be 0.80 and 0.65% for Phases 2 and 3, respectively, as suggested by NRC (1998). Apparent ileal digestible Thr and Trp levels were formulated in all diets to meet a minimum ratio of 58 and 18% of digestible Lys, respectively. In addition, vitamins and trace minerals were provided to exceed NRC (1998) nutrient recommendations.

Corn DDGS was provided by AL-CORN Clean Fuel (Claremont, MN). Analyzed composition of the DDGS (as-fed basis) was: 89.60% DM, 27.87% crude protein, 10.1% crude fat, 6.6% crude fiber, 0.09% calcium, 0.56% phosphorus, 0.74% Lys, 0.47% Met, 0.98% Thr, and 0.24% Trp. The DDGS from this ethanol plant is similar in quality to DDGS from several modern (built after 1990) dry-mill ethanol plants located in the upper Midwest region of the United States. Improved batch fermentation procedures, including improved enzyme and yeast additions, are used during the ethanol extraction process, resulting in increased starch removal and ethanol yield. Additionally, corn is delivered to these plants from a smaller geographical region and may contribute to reduced variability in nutrient content of DDGS than that produced by older plants (Shurson et al., 2000). Because most of the starch is converted to ethanol during fermentation, the resulting proportion of protein, oil, and fiber is 2 to 3 times more concentrated in DDGS compared with corn (Shurson et al., 2003). Nutrient content of the corn used to produce DDGS can greatly affect DDGS nutrient content, and therefore differences in DDGS based on geographical area may be expected.

Pigs were housed in pens that measured 1.2 m × 1.2 m, providing 0.36 m^2 of space per pig. Unlimited access to water and feed was provided via one nipple waterer and a four-hole self-feeder in each pen. Environmental temperature was controlled and maintained at 27°C for the first 11 d of each experiment and then was reduced to 25 and 23°C during each of the next two 14-d periods, respectively. Pigs were monitored twice daily to ensure they were healthy, and that waterers and feeders were functioning properly.

Measurements

Pig body weights were measured initially and on d 4, 18, and 39 of each experiment. Feed disappearance was measured on d 4, 18, and 39 of each experiment. Growth rate, feed intake, and feed efficiency were calculated for each of the three nursery phases. Feed samples were collected from each batch of feed at the time of manufacture and were stored in a freezer at –20°C until subsequent nutrient analysis could be performed. Subsamples were sent to laboratories for analysis of amino

Table 1. Composition of the experimental nursery phase 2 diets (as-fed basis)[a]

	DDGS inclusion level, %					
Item	0	5	10	15	20	25
Ingredient, %						
Corn	50.13	45.33	40.52	35.72	30.91	26.11
Soybean meal (47% CP)	23.43	23.24	23.06	22.87	22.69	22.50
DDGS[b]	0.00	5.00	10.00	15.00	20.00	25.00
Dried whey	15.00	15.00	15.00	15.00	15.00	15.00
Select menhaden fish meal	6.00	6.00	6.00	6.00	6.00	6.00
Choice white grease	2.50	2.55	2.60	2.65	2.70	2.75
Dicalcium phosphate	1.18	1.03	0.87	0.72	0.56	0.41
Limestone	0.35	0.45	0.56	0.66	0.77	0.87
Vitamin/trace mineral premix[c]	0.45	0.45	0.45	0.45	0.45	0.45
Antibiotic[d]	0.13	0.13	0.13	0.13	0.13	0.13
Zinc oxide	0.28	0.28	0.28	0.28	0.28	0.28
Salt	0.30	0.30	0.30	0.30	0.30	0.30
L-Lysine	0.15	0.15	0.15	0.15	0.15	0.15
DL-Methionine	0.10	0.09	0.08	0.07	0.06	0.05
Analyzed composition						
Dry matter, %	92.50	92.90	93.10	92.80	93.60	93.80
Crude protein, %	21.50	22.20	23.27	25.04	26.24	26.96
Lysine, %	1.34	1.35	1.35	1.38	1.38	1.37
Methionine, %	0.43	0.44	0.46	0.46	0.46	0.45
Threonine, %	0.78	0.84	0.90	0.95	0.97	0.99
Tryptophan, %	0.27	0.23	0.26	0.27	0.28	0.27
ME, kcal/kg[e]	3,306	3,298	3,302	3,287	3,327	3,329
Calcium, %	0.87	1.02	1.04	0.98	0.86	0.90
Phosphorus, %	0.65	0.79	0.75	0.76	0.73	0.66

[a]Diets were formulated to contain 3,340 kcal/kg of ME, 1.35% apparent digestible lysine, 0.80% apparent digestible methionine & cystine, 0.95% Ca, and 0.80% total P.

[b]Distiller's dried grains with solubles (Al-Corn Clean Fuel, Claremont, MN). Analyzed composition (as-fed basis): 89.6% DM, 27.87% crude protein, 10.1% crude fat, 6.6% crude fiber, 0.74% lys, 0.47% met, 0.98% thr, 0.24% trp, 0.56% calcium, and 0.56% phosphorus.

[c]Suppled per kg of premix: 1,466,667 IU vitamin A as retinyl acetate, 246,000 IU vitamin D_3, 6,138 IU vitamin E as DL-α-tocopherol acetate, 979 mg vitamin K as menadione dimethylpyrimidinol bisulfite, 1,467 mg riboflavin, 8,800 mg niacin, 5,867 mg pantothenic acid as D-calcium pantothenate, 6.6 mg vitamin B_{12}, 141 mg iodine as EDDI, 99 mg selenium as sodium selenite, 59,840 mg zinc as zinc oxide, 59,840 mg iron as ferrous sulfate, 3,960 mg copper as copper sulfate, and 1,980 mg manganese as manganese oxide.

[d]Provided 27.5 mg carbadox/kg of complete feed.

[e]Calculated from equation by Noblet and Perez (1993):

$$\text{DE, kcal/kg} = 4{,}151 - (122 \times \%\ \text{Ash}) + (23 \times \%\ \text{CP}) + (38 \times \%\ \text{EE}) - (64 \times \%\ \text{crude fiber})$$

$$\text{ME, kcal/kg} = \text{DE} \times [1.003 - (0.0021 \times \%\ \text{CP})].$$

acid levels (University of Missouri, Columbia, MO) and proximate analysis (Iowa Testing Labs, Eagle Grove, IA). Metabolizable energy values of diets were calculated based on proximate analysis values using equations from Noblet and Perez (1993).

Statistical Analysis

A completely randomized design was used in both experiments. Pen was the experimental unit. Evaluation of ADG, ADFI, and G/F data during each experimental phase, along with initial age and weight, were analyzed statistically using the GLM procedure of SAS (1989). Additionally, ADG, ADFI, and G/F for the entire period when experimental diets were fed (Phases 2 and 3) were analyzed using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC) with repeated measures in time. Body weight after the initial 4-d preexperimental period was used as a covariate in all statistical analysis. Least statistical squares means are reported. Orthogonal comparisons across DDGS level were conducted to determine linear or quadratic trends for increasing DDGS level in the diet.

Results

Experiment 1

Experimental period (Phases 2 and 3) growth performance least squares means are presented in Table 3. Health was excellent, with all animals remaining on test for the entire study. Pigs were similar in initial age (19.0 ± 0.1 d), initial body weight (7.10 ± 0.03 kg), and body weight at the beginning of the experimental Phase 2 period (7.68 ± 0.06) across dietary treatments. Time ($P < 0.01$) effects were noted for ADG and ADFI during the experimental period between Phase 2 and 3, but no time × treatment interactions were observed throughout the experiment ($P > 0.10$). Dietary treatment did not significantly affect growth rate during the

Table 2. Composition of the experimental nursery phase 3 diets (as-fed basis)[a]

	DDGS inclusion level, %					
Item	0	5	10	15	20	25
Ingredient, %						
Corn	61.53	56.96	52.39	47.81	43.24	38.67
Soybean meal (47% CP)	32.62	32.2	31.77	31.35	30.92	30.50
DDGS[b]	0.00	5.00	10.00	15.00	20.00	25.00
Choice white grease	2.35	2.40	2.45	2.50	2.55	2.60
Dicalcium phosphate	1.67	1.52	1.37	1.22	1.07	0.92
Limestone	0.56	0.66	0.77	0.87	0.98	1.08
Vitamin/trace mineral premix[c]	0.45	0.45	0.45	0.45	0.45	0.45
Antibiotic[d]	0.13	0.13	0.13	0.13	0.13	0.13
Copper sulfate	0.10	0.10	0.10	0.10	0.10	0.10
Salt	0.40	0.40	0.40	0.40	0.40	0.40
L-Lysine	0.15	0.15	0.15	0.15	0.15	0.15
DL-Methionine	0.04	0.03	0.02	0.02	0.01	0.00
Analyzed composition						
Dry matter, %	92.10	93.10	93.50	92.80	93.40	93.30
Crude protein, %	21.82	22.70	23.89	24.05	24.99	25.65
Lysine, %	1.31	1.29	1.32	1.29	1.28	1.30
Methionine, %	0.37	0.36	0.36	0.39	0.37	0.37
Threonine, %	0.80	0.82	0.86	0.88	0.89	0.92
Tryptophan, %	0.25	0.25	0.24	0.25	0.25	0.26
ME, kcal/kg[e]	3,295	3,351	3,333	3,318	3,335	3,336
Calcium, %	0.72	0.62	0.75	0.69	0.74	0.66
Phosphorus	0.58	0.55	0.60	0.56	0.59	0.56

[a]Diets were formulated to contain 3,390 kcal/kg of ME, 1.15% apparent digestible lysine, 0.65% apparent digestible methionine & cystine, 0.80% Ca, and 0.70% total P.
[b]Distiller's dried grains with solubles (Al-Corn Clean Fuel, Claremont, MN). Analyzed composition (as-fed basis): 89.6% DM, 27.87% crude protein, 10.1% crude fat, 6.6% crude fiber, 0.74% Lys, 0.47% Met, 0.98% Thr, 0.24% Trp, 0.56% calcium, and 0.56% phosphorus.
[c]Supplied per kg of premix: 1,466,667 IU vitamin A as retinyl acetate, 246,400 IU vitamin D_3, 6,138 IU vitamin E as DL-α-tocopherol acetate, 979 mg vitamin K as menadione dimethylpyrimidinol bisulfite, 1,467 mg riboflavin, 8,800 mg niacin, 5,867 mg pantothenic acid as D-calcium pantothenate, 6.6 mg vitamin B_{12}, 141 mg iodine as EDDI, 99 mg selenium as sodium selenite, 59,840 mg zinc as zinc oxide, 59,840 mg iron as ferrous sulfate, 3,960 mg copper as copper sulfate, and 1,980 mg manganese as manganese oxide.
[d]Provided 27.5 mg carbadox/kg of complete feed.
[e]Calculated from equation by Noblet and Perez (1993):
DE (kcal/kg) = 4,151 − (122 × % Ash) + (23 × % CP) + (38 × % EE) − (64 × % crude fiber)
ME (kcal/kg) = DE × [1.003 − (0.0021 × % CP)].

Table 3. Effects of increasing level of dietary corn distiller's dried grains with solubles on growth rate, feed intake, feed conversion, and body weight during a 35-d nursery period (Exp. 1)[a]

	Distiller's dried grains with solubles inclusion rate, %								Contrast	
Item	0	5	10	15	20	25	SEM	$P > F$	Linear	Quadratic
Initial age, days	18.88	19.25	18.94	18.94	18.69	19.13	0.12	0.86	0.87	0.85
Initial wt, kg	7.12	7.11	6.97	7.13	7.14	7.15	0.03	0.51	0.47	0.29
Phase 2 (d 0–14)										
ADG, g/d	261	237	265	220	236	247	6.9	0.51	0.42	0.50
ADFI, g/d	402	387	390	395	384	376	8.6	0.98	0.50	0.77
G/F	0.67	0.62	0.69	0.57	0.61	0.66	0.02	0.76	0.72	0.60
Phase 3 (d 14–35)										
ADG, g/d	626	613	607	591	658	613	9.0	0.42	0.78	0.57
ADFI, g/d	992	989	1,009	965	1,058	1,039	16.5	0.71	0.28	0.63
G/F	0.63	0.62	0.62	0.61	0.62	0.59	0.01	0.96	0.48	0.79
Phases 2 and 3 (d 0–35)										
Start wt, kg	7.87	7.75	7.47	7.57	7.67	7.75	0.06	0.48	0.57	0.08
End wt, kg	24.72	23.97	22.86	23.06	24.83	24.10	0.31	0.42	0.96	0.13
ADG, g/d[b]	480	463	470	442	489	466	7.3	0.58	0.91	0.51
ADFI, g/d[b]	756	748	761	737	789	774	11.9	0.90	0.50	0.72
G/F	0.65	0.62	0.65	0.59	0.62	0.62	0.01	0.93	0.55	0.76

[a]Each value represents a mean of four pens with four pigs each treatment.
[b]Time effect between phases ($P < 0.01$).

Table 4. Effects of increasing level of dietary corn distiller's dried grains with solubles on growth rate, feed intake, feed conversion, and body weight during a 35-d nursery period (Exp. 2)[a]

	Distiller's dried grains with solubles inclusion rate, %								Contrast	
Item	0	5	10	15	20	25	SEM	*P* > *F*	Linear	Quadratic
Initial age, days	16.83	16.67	17.06	16.63	17.06	1706	0.06	0.10	0.12	0.43
Initial wt, kg	5.25	5.17	5.27	5.20	5.24	5.26	0.02	0.59	0.72	0.59
Phase 2 (d 0–14)										
ADG, g/d	261	265	223	226	204	213	11.1	0.57	0.09	0.66
ADFI, g/d	329	375	306	289	303	283	9.5	0.05	0.02	0.99
G/F	0.78	0.71	0.73	0.79	0.65	0.67	0.03	0.70	0.34	0.82
Phase 3 (d 14–35)										
ADG, g/d	544	545	564	516	571	522	10.6	0.65	0.71	0.65
ADFI, g/d	843	837	895	772	871	796	15.4	0.08	0.33	0.53
G/F	0.65	0.65	0.65	0.66	0.66	0.65	0.01	0.94	0.65	0.61
Phases 2 and 3 (d 0–35)										
Start wt, kg	5.79	5.55	5.67	5.54	5.89	5.60	0.06	0.45	0.99	0.61
End wt., kg	20.78	20.84	20.64	19.69	20.55	19.63	0.28	0.62	0.19	0.93
ADG, g/d[b]	431	433	427	400	425	398	7.3	0.63	0.18	0.92
ADFI, g/d[c]	637	652	659	579	644	591	6.7	0.08	0.09	0.62
G/F[d]	0.70	0.67	0.68	0.71	0.66	0.66	0.01	0.55	0.35	0.65

[a]Each value represents a mean of four pens with four pigs each per treatment.
[b]Time effect between phases ($P < 0.01$).
[c]Time ($P < 0.01$) and time × treatment ($P < 0.06$) effects.
[d]Time effect between phases ($P < 0.07$).

14-d Phase 2 period ($P > 0.10$). Feed intake and G/F were similar regardless of level of DDGS in the diet. Pigs did not appear to have problems adjusting to any level of DDGS in the diet based on the absence of differences in ADFI as level of DDGS increased. During Phase 3, ADG, ADFI, and G/F were not affected by increasing level of DDGS in the diet ($P > 0.10$), resulting in a similar ending body weight that averaged 23.9 kg ($P > 0.10$). Overall, growth performance, feed intake, and feed efficiency were unaffected by dietary treatment ($P > 0.10$) over the entire 35-d experimental period (Table 3). Additionally, increasing level of DDGS did not linearly affect any of the overall responses measured in Exp. 1 ($P > 0.10$).

Experiment 2

Experimental period growth performance results are presented in Table 4. During the course of the study, two pigs were removed due to poor health within the first 10 d of the experiment. Although pigs were randomly assigned to dietary treatments, average initial age tended to be different ($P < 0.10$), but initial body weight was similar (5.26 ± 0.07 kg) across dietary treatments. The difference in initial age appeared to be of minimal importance because body weight was similar across dietary treatments at the end of the preexperimental Phase 1 period ($P > 0.10$), when experimental diets with differing levels of DDGS were fed. Time effects were observed for ADG and ADFI ($P < 0.01$), and G/F ($P < 0.06$). There was a time × treatment interaction ($P < 0.05$) for ADFI, but not for ADG or G/F. Increasing level of DDGS in the diet linearly decreased ADFI ($P < 0.05$) during Phase 2. Similarly, increasing DDGS level in the diet tended to linearly depress ADG ($P < 0.09$), but G/F was unaffected by dietary treatment. During Phase 3, ADG, G/F, and ending body weight were similar across dietary treatments ($P > 0.10$). No linear or quadratic trends for ADG, ADFI, or G/F with increasing DDGS level were observed ($P > 0.10$). Overall ADG and G/F during Phases 2 and 3 combined were unaffected by dietary treatment ($P > 0.10$). Increasing level of DDGS tended to linearly decrease voluntary feed intake ($P < 0.09$).

Discussion

Cromwell et al. (1993) indicated that the odor and color of DDGS seem to correlate well with the nutritional value of the feedstuff for nonruminants. The authors collected DDGS from seven beverage-alcohol and two fuel-alcohol manufacturers, evaluated the physical characteristics and chemical composition of each source, and evaluated the nutritional value using one pig (initial weight = 16 kg) and two chick growth assays. Dark-colored DDGS was lower in nutritional value than light-colored DDGS using growth rate and feed conversion as response criteria. Dark-colored DDGS had a burnt or smoky odor, suggesting that darkness of color was at least partially caused by an overheating of DDGS during the drying process. Additionally, Lys concentration of DDGS appeared to be positively correlated with lightness of color ($r^2 = 0.67$, $P < 0.05$). Lysine and CP content of DDGS were not highly correlated with each other ($r = 0.43$, $P = 0.43$), similar to the low correlation observed between CP and Lys in corn (Reese and Lewis, 1989). The corn DDGS used in the present two experiments was light golden in color and had a sweet and slightly fermented smell, thereby suggesting that it was high in nutritional quality. Additionally, the Lys (0.74 vs. 0.62%) and crude fat (10.1 vs. 8.4%) concentrations of the corn DDGS were greater than that reported in NRC (1998).

Combs and Wallace (1969) reported responses in growth performance similar to those of Exp. 1. Nursery pigs were fed diets containing 0, 10, or 20% DDGS. Thirty-six pigs, initially weighing 7.5 kg, were fed the experimental diets over a 6-wk period. Compared to the corn-soybean meal control, including 10 or 20% DDGS did not affect growth rate, feed intake, or feed conversion. The authors also measured dry matter, protein, and ether extract digestibility, but they observed decreases in all three response criteria when the 20% DDGS diet was fed. Therefore, a 10% maximal inclusion rate of DDGS was suggested for starter diets. Growth rate, feed intake, and feed efficiency in Exp. 1 were similar regardless of dietary DDGS level during Phases 2 and 3, but nutrient digestibility was not measured.

Two experiments were conducted by Cromwell et al. (1985) to evaluate the effect of DDGS inclusion in weanling pig diets, with or without antibiotic supplementation, on growth performance during a 4-wk experimental period. Pigs were 4 wk of age, and initially weighed 12.3 and 8.6 kg for Exp. 1 and 2, respectively. Both experiments utilized a 2 × 2 factorial arrangement of treatment groups, evaluating DDGS inclusion (0 or 10%) in corn-soybean meal diets in the presence or absence of antibiotics (100 g of chlortetracycline, 100 g of sulfamethazine and 50 g of penicillin per ton of diet). Diets were formulated to be isolysinic (0.95% lysine), and the energy concentration of DDGS was assumed to be similar to that of corn, thereby providing equivalent energy density in the experimental diets. Feeding DDGS in the absence of antibiotic supplementation tended to reduce average daily gain ($P < 0.10$). Feeding DDGS with antibiotic supplementation, however, resulted in similar growth rate compared to pigs fed corn-soybean meal diets. The current experiments included antibiotic supplementation, and, therefore, a lack of reduction in growth performance response at high levels of DDGS inclusion during Exp. 1 may have been partially due to the presence of antibiotic.

The results observed during Exp. 2 are consistent with those reported by Wahlstrom and Libal (1980), who examined growth performance in nursery pigs when fed diets containing 10, 20, or 30% DDGS compared to a corn-soybean meal control. Experimental diets were formulated to be equivalent in crude protein (19.6%) and total lysine (1.05%) but were not isocaloric. One hundred twenty pigs initially weighing 8.1 kg and approximately 4 wk of age were utilized over the 4-wk study. Growth rate was reduced significantly as the level of DDGS in the diet increased. Feed intake and feed efficiency were unaffected by dietary treatment, although both decreased numerically with increasing DDGS level. The reduction in growth rate may be partially explained by the reduction in energy concentration that would be expected as level of DDGS in the diet increased. This may also explain the trend toward poor feed conversion. The authors indicated that DDGS inclusion seemed to negatively affect palatability and that the increased fiber content may have reduced growth performance. Because only one experimental period was examined, it is not known whether the reductions in growth performance observed were more substantial during the initial 2 wk of the experiment, as was observed in the current study, or if negative impacts were sustained throughout the 4-wk experimental period. However, the initial reduction in feed intake and growth rate observed during Phase 2 of Exp. 2 appears to indicate that an adaptation period is required for increasing levels of DDGS in the diet for young nursery pigs.

Distiller's dried grains with solubles contains a high level of crude protein, and the amino acid profile is not ideal relative to the pig's requirements (Whitney et al., 1999). Therefore, including increasing levels of DDGS increases the crude protein content of the diet, with a large concomitant increase in level of nonessential amino acids (Tables 1 and 2), and will increase nitrogen in swine manure when fed to pigs as a partial substitute for corn and soybean meal (Shurson et al., 2000). Several studies (Henry et al., 1992; Henry, 1995; Hahn et al., 1995) have indicated that feed intake can be reduced in growing pigs fed diets with significant imbalances in amino acids or increased nonessential amino acid levels in the diet. This may partially explain the decreased feed intake with increasing dietary levels of DDGS observed in this study.

Excess amino acids absorbed above the requirement for maintenance and protein synthesis must be deaminated. Therefore, diets containing improperly balanced amino acids are less efficiently utilized, diverting energy to fat synthesis and synthesis of urea to excreted excess nitrogen. Additionally, increasing the level of fiber in the diet has been implicated with reducing nutrient digestibility (Ewan, 2001). Energy utilization did not seem to be greatly affected by level of DDGS in the diet in Exp. 1 and 2, as indicated by similar feed efficiency levels observed. Our group has previously estimated the ME value of the same source of DDGS used in this experiment at 3,350 kcal/kg on an as-fed basis (Spiehs et al., 1999). The high fat content of DDGS (10.1%) used in these experiments may have offset the increases in fiber and excess nitrogen that occur with increasing level of dietary DDGS inclusion. Addition of fat to diets increases energy density, reduces feed intake, and increases efficiency of energy utilization (Azain, 2001).

Previous research conducted on the same source of DDGS used in this experiment indicated improved apparent ileal digestibility of many amino acids compared with NRC (1998) values (Whitney et al, 2000). Eight crossbred pigs (38.8 kg) were randomly allotted to and limit-fed one of four dietary treatments: control (90% corn-soybean meal), 30% DDGS, 60% DDGS, and 90%

DDGS in two 4×4 Latin square designs. All pigs were fitted with a simple T-cannula inserted at the ileocecal junction of the small intestine. Apparent ileal Lys, Met, Thr, and Trp digestibility coefficients of DDGS were determined to be 53.6, 58.5, 55.2, and 63.6%, resulting in apparent digestible AA levels of 0.44, 0.32, 0.62, and 0.15%, respectively. This compares to apparent ileal Lys, Met, Thr, and Trp levels of 0.29, 0.37, 0.52, and 0.13% calculated from NRC (1998).

These results suggest that pigs weighing less than 7 kg may require an adaptation period before being fed diets high in DDGS. Although feed intake appeared to be slightly depressed with increased dietary DDGS level, growth rate remained similar over the entire experimental period. The source of DDGS used in this experiment, and the ME and digestible amino acid values used to formulate the diets, seemed to support adequate performance when DDGS replaced a portion of the corn, soybean meal, and dicalcium phosphate in late nursery diets at inclusion levels up to 25%.

Implications

The corn distiller's dried grains with solubles used in this experiment seems to be an acceptable amino acid, energy, and phosphorus source for weaned pigs weighing more than 7 kg and can be included in Phase 2 and 3 nursery diets at levels up to 25% without negatively affecting feed intake, growth rate, or feed conversion. Pigs that are younger or smaller, however, seem to require an adaptation period before including substantial levels of distiller's dried grains with solubles in the diet. Nutrient quantity and quality (digestibility) of distiller's dried grains with solubles can vary considerably, depending on the type of grain used, along with fermentation, processing, and drying conditions and procedures. The use of high-quality corn distiller's dried grains with solubles will allow feeding diets containing up to 25% distiller's dried grains with solubles, while supporting satisfactory growth performance in nursery pigs.

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