Effects of Feeding Distillers Dried Grains with Solubles to Finishing Swine on Animal Performance, Manure Characteristics, and Odorous Emissions

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Summary and Implications

Seventy-two finishing pigs were used to evaluate the effects of distillers dried grains with solubles (DDGS) on pig performance, manure characteristics, and odorous emissions. Three diets containing 0, 5, and 10% DDGS were fed during six 4-wk feeding periods. Week 1 served as a dietary adjustment period. Animals were housed in two feeding rooms (six pigs per room) with one treatment per room. A new group of animals (average initial Body Weight = 85.8 kg) was used for each feeding period. Diets were replicated four times. Rooms were equipped with individual shallow manure storage pits that were cleaned once weekly (day 7). On day 4 and 7 of each week manure pit samples and air samples in 10-liter Tedlar bags for olfactometry analysis were collected from each room. Dynamic dilution triangular forced-choice olfactometry was conducted using the Ac'scent International Olfactometer (St. Croix Sensory, Stillwater, MN) located in the Iowa State University Engineering Department of Agricultural and Biosystems. No differences in animal performance, as measured by average daily gain and feed efficiency, were observed ($P > .05$). Greater feed disappearance ($P < .10$) was observed from animals fed 10% DDGS. A nonsignificant trend of increasing odor, in terms of odor dilution threshold, was observed with increasing dietary concentration of DDGS ($P = .16$). A nonsignificant trend for increasing odor with increasing DDGS demonstrates the potential for diet formulation to improve odor. This increase in odor was likely due to the increased levels of dietary crude protein, amino acids, and elemental sulfur that were observed with increasing DDGS in the diets. Diet manipulation as a means to reduce odor needs to be investigated further.

Introduction

The odor associated with swine manure is produced by the anaerobic breakdown of undigested feed components in the manure (4,6,7). Abatement may occur, to some extent, by diet modification. By increasing nutrient use and decreasing nutrient excretion, less substrate should be available for bacterial breakdown and thus less odor may be produced (5,9).

The current study was undertaken to examine dietary manipulation as a means to reduce odor. The DDGS replaced corn and soybean meal at varying levels in diets fed to finishing pigs to determine the effect on swine manure odor. Air samples from the swine facilities were analyzed by olfactometry.

Materials and Methods

Facility description. The experiment, conducted at the Iowa State University Swine Nutrition and Management Research Center outside of Ames, IA, was divided into six, 24-d periods, beginning March 15, 1999, and ending August 26, 1999. A total of 72 crossbred finishing pigs (average initial body weight = 85.8 kg) is used over the duration of the trial; 12 new pigs fed during each of the six periods. Two environmentally controlled, mechanically ventilated feeding rooms, 3.81 m × 3.96 m, were available for the experiment. Within the room, six finishing pigs were housed in a 2.44 m × 2.44 m pen with woven-wire flooring. Average room temperature during the course of the experiment was 22.7°C (range: 10.0°C to 34.4°C). Two 0.36–m exhaust fans provided the ventilation for each room. Each feeding room was equipped with a shallow manure storage pit under the pen. The pits were emptied using a pull-plug drain. Due to the limited manure storage that was available, the pits were drained and rinsed each Thursday (day 7).

Nutrition study. Isolysinic diets were formulated to contain equal metabolizable energy to lysine ratios. The control diet was a basal corn–soybean ration and contained no DDGS. The two dietary treatments included either 5 or 10% DDGS. The DDGS replaced both corn and soybean meal in an attempt to more closely meet the nutrient requirements of the animal because DDGS contains an intermediate amount of energy, protein, and essential amino acids (Table 1). Three diets were fed in each room on a rotating basis. Pigs were allowed access to feed and water *ad libitum*. Feed disappearance was recorded. To track performance, animals were individually weighed at the beginning and end of a feeding period. Animals were assigned to treatment groups based on weight and gender, providing a similar animal profile between rooms within a feeding period. A feed sample was collected for proximate analysis from each batch of feed that was mixed. Feed samples were analyzed for amino acid content by CN Laboratories (Courtland, MN). Analysis for crude protein, fiber, energy, and sulfur content was conducted by the Dairy One Forage Testing Laboratory (Ithaca, NY).

Olfactometry. Air samples were collected during the last 3 weeks of each 4 week period, thus allowing the first week for dietary acclimation. Samples were collected on Mondays and Thursdays (day 4 and 7) and were transported to the Iowa State University campus for analysis. A battery-powered Supelco 10 liter air sampler (Supelco, Bellefonte, PA, model 1062) was used to collect air samples in Tedlar bags. During sample collection, the air sampler was placed on the floor as close to the pit as possible.

A 10–liter air sample was collected from each room for analysis by olfactometry. Room air samples were analyzed using the Acscent International Olfactometer (St. Croix Sensory, Stillwater, MN) located in the Olfactometry and Air Quality Laboratory on the Iowa State University campus. The method of dynamic dilution triangular forced-choice olfactometry with an ascending concentration series was used to determine odor concentration (3). A minimum of eight trained human panelists comprises an odor panel.

Manure analysis. A composite manure sample was collected from the pit in each room, following manual mixing and agitation. All manure analyses were conducted in the Iowa State University Department of Animal Science. To determine the amount of total solids (dry matter), manure samples were oven dried in porcelain crucibles for 3 to 4 days at 55°C until a consistent dry weight was obtained (1), (method 2540B). Dried samples were ashed in a muffle furnace at 550°C for 5 hr to determine volatile solids content (organic matter); (1), (method 2540E). Sample chemical oxygen demand was determined using Hach digester tubes according to Hach method 8000 (Hach, Loveland, CO). The colorimetric reaction was measured using a spectrophotometer. Total phosphorus content was analyzed using procedures of the AOAC (2, method 7.123) involving a digestion procedure followed by colorimetric determination using molybdovanadate for color development. Total Kjeldahl nitrogen was determined using digestion with a selenium catalyst followed by distillation (2), (method 2.057).

Statistical analysis. Room served as the experimental unit in the incomplete randomized block design. Dietary influence on odor concentration and manure composition was evaluated statistically using the mixed procedure of SAS, version 6.01 (8). Fixed variables included room, diet, day, and panelist. Period was included as a random variable. Because only two rooms were available for the experiment, but three dietary treatments were considered, Diet was confounded within the room × period interaction. To relate human panelist response to manure characteristics, correlation procedures were used.

Results and Discussion

Animal performance. The three diets were subsampled with each batch that was mixed over the entire course of the feeding trial. A total of nineteen samples was sent to a commercial lab for individual analysis. Nutrient analyses were conducted on an as-fed basis (average diet dry matter content = 89.11%). Table 2 depicts dietary treatment compositions, pooled over time. Contrasts were used to identify any differences in nutrient composition among the three diets (Table 2).

Treatment effects were analyzed and dietary inclusion of DDGS resulted in no significant ($P > .05$, Table 3) differences in animal performance, as measured by average daily gain and feed efficiency. There was greater feed disappearance ($P < .10$) with 10% DDGS than with both 5 and 0% DDGS. No difference ($P > .10$) was observed in feed disappearance when comparing the 5% DDGS diet to the control. Diets were formulated to minimize performance differences and, rather, focus on manure odor differences that may result.

Diet effects on manure characteristics. Manure characteristics are depicted in Table 4. No significant differences due to diet were observed for total solids, volatile solids, chemical oxygen demand, total Kjeldahl nitrogen, or phosphorus content of manure ($P > .10$, Table 4). Day was a significant ($P < .05$) model variable for each of these parameters, but this was to be expected as the amount of manure accumulated and the storage time of the manure present increased from one sampling day to the next within each week. The first sampling day of each week reflected 4 days worth of manure storage and accumulation while the second sampling day represented seven. As the storage time of the manure increased, the anaerobic breakdown of the manure would have progressed. The solids would have been broken down and the dilution would have increased as wasted water from the drinkers and the sprinklers entered the pit. Nitrogen would have been lost through ammonia volatilization. The chemical oxygen demand would have decreased with increased storage time and extent of decomposition as well. Also, sampling error in collecting manure from the pits could have contributed to the differences observed, particularly with respect to day effects on phosphorus content (measured on a dry basis).

Diet effects on odor. Each olfactometry panelist's individual response, in terms of the log of odor dilution threshold, was analyzed using the mixed procedure of SAS with panelist as a fixed variable. There were no significant treatment effects upon odor dilution threshold ($P > .10$). However, a nonsignificant ($P = .16$) trend for increasing odor concentration with increasing dietary content of DDGS was identified using a linear contrast.

This trend was likely due to the increasing amount of protein, sulfur amino acids (methionine and cysteine), and elemental sulfur in the diets with DDGS. The excess protein in the diets would have been broken down anaerobically to volatile fatty acids, phenols, and indoles, which would have contributed to the odor perceived by the human panelists during olfactometry.

Odor dilution was affected by room ($P < .01$), day ($P < .01$), and panelist ($P < .01$). The room effect was possibly due to differences in the ventilation systems. room and period were confounded; therefore time or season may have influenced Room effect. Effects arising from the day of sampling and the human panelists involved in the olfactory evaluation were expected. Because the amount of manure in the storage pit increased from one sampling day to the next within a week, the odor generated from the manure would be expected to increase. As more manure was added to the pit each day, more substrate was available for breakdown by bacteria, thus greater concentrations of odorous compounds could have been generated. Also, the dissolved oxygen available may have decreased, and the resultant shift to anaerobic breakdown may have generated compounds of a more odorous nature, such as branched chain fatty acids.

A panelist effect upon odor dilution threshold was expected because of the inherent variability among human beings. Sensory perception of an odor is an individual response, differing from one person to the next. The date on which a panelist participated in the panel also was determined to have a significant ($P < .01$) influence on panelist response.

The proportion of total variability in the odor concentration measurements explained by differences between the panelists over the treatments was calculated to have an R^2 of .23. This low number indicates that only a quarter of the total variability in the olfactometry analysis can be accounted for by differences between the panelists. The olfactometry training process during which individuals are screened to ensure they are neither hypo- nor hypersensitive to odors minimizes the differences among the panelists. The variability among the panelists within the treatments across time had an R^2 of .12, suggesting that an individual panelist's response was consistent over time.

References

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Table 1. Composition of experimental diets,[1] kilograms of ingredient per kilograms complete diet (%)

Feedstuff	0% DDGS[2]	5% DDGS	10% DDGS
Corn	86.44	82.20	77.80
Soybean meal	11.26	10.50	9.90
DDGS	0.00	5.00	10.00
Limestone	1.00	1.00	1.00
Dicalcium phosphate	0.70	0.70	0.70
Salt	0.35	0.35	0.35
Vitamin and trace Mineral premix[3]	0.25	0.25	0.25
Total	100.00	100.00	100.00

[1] Diets fed to six finishing pigs (average initial body weight = 86 kg) per room during each 24-d period.

[2] DDGS , distillers dried grains with solubles, expressed as kilograms DDGS per kilograms diet.

[3] Supplied per kilograms of diet: vitamin A, 4,409 IU; vitamin D, 1,102 IU; riboflavin, 6.6 mg; pantothenic acid, 17.6 mg; niacin, 33 mg; vitamin B_{12}, 22 μg; zinc, 75 mg; iron, 87.5 mg; manganese, 30 mg; copper, 8.75 mg; and iodine, 0.1 mg

Table 2. Least squares means of nutrient composition of experimental diets for finishing pigs containing 0, 5, or 10% DDGS.[1]

Nutrient[2]	0% DDGS	5% DDGS	10% DDGS
CP (%)	12.09^{a}	12.51^{a}	13.34^{b}
ADF (%)	4.29^{a}	4.50^{a}	5.38^{b}
NDF (%)	8.16^{a}	9.56^{b}	10.66^{c}
NEG	0.58^{a}	0.57^{b}	0.57^{c}
Amino Acids			
Lys (%)	0.65	0.63	0.64
Trp (%)	0.12	0.11	0.12
Thr (%)	0.45^{a}	$0.46^{a,b}$	0.48^{b}
Val (%)	0.58^{a}	0.59^{a}	0.63^{b}
Leu (%)	1.18^{a}	1.24^{b}	1.34^{c}
Ile (%)	0.48^{a}	$0.49^{a,b}$	0.52^{b}
Phe (%)	0.60^{a}	0.61^{a}	0.65^{b}
Tyr (%)	0.49^{a}	0.50^{a}	0.54^{b}
Met (%)	0.24^{a}	0.24^{a}	0.26^{b}
Cys (%)	0.25^{a}	0.26^{a}	0.27^{b}
Minerals			
Ca (%)	0.64	0.65	0.63
P (%)	0.44^{a}	0.46^{b}	0.48^{b}
S (%)	0.12^{a}	0.13^{b}	0.15^{c}

[1] DDGS, distillers dried grains with solubles, expressed as kg DDGS per kg diet.

[2] CP, crude protein; ADF = acid detergent fiber, NDF = neutral detergent fiber, NEG = net energy for gain, all analyzed on as-fed basis.

[a,b,c] Means within a row with different superscripts differ ($P < .10$).

Table 3. Least squares means of animal performance measures over 24-d periods, as influenced by dietary inclusion of 0, 5, or 10% DDGS.[1]

	0% DDGS	5% DDGS	10% DDGS
Initial BW[2] (kg)	84.4	85.9	87.0
Final BW (kg)	103.0	105.3	105.9
ADG[3] (kg)	0.80	0.79	0.78
ADFD[4] (kg)	2.75^{a}	2.73^{a}	2.91^{b}
F:G[5]	0.29	0.30	0.26

[1] DDGS, distillers dried grains with solubles, expressed as kilograms DDGS per kilograms diet.

[2] BW, body weight.

[3] ADG, average daily gain.

[4] ADFD, average daily feed disappearance per pig, calculated as total feed into room per period divided by six pigs per room and 24 d per period.

[5] F:G, feed-to-gain ratio.

[a,b] Means within a row with different superscripts differ ($P < .10$).

Table 4. Composition of manure from finishing pigs fed diets containing 0, 5, or 10% DDGS.[1]

Parameter[2]	0% DDGS		5% DDGS		10% DDGS	
	Day[3] 4	Day 7	Day 4	Day 7	Day 4	Day 7
TS (%)	19.36^{a}	14.78^{b}	20.63^{a}	15.68^{b}	19.35^{a}	17.10^{b}
VS (%)	16.41^{a}	12.17^{b}	17.32^{a}	13.34^{b}	16.14^{a}	14.32^{b}
P (% TS)	1.96	1.94	2.09^{a}	1.74^{b}	2.10^{a}	1.97^{b}
TKN (% TS)	2.75	2.71	2.77^{a}	2.69^{b}	2.93	2.91
COD (g/l)	217.54^{a}	163.03^{b}	230.54^{a}	154.30^{b}	238.70^{a}	187.40^{b}

[1] DDGS, distillers dried grains with solubles, expressed as kg DDGS per kilograms diet.

[2] TS, total solids, kg solids/kg wet manure; VS, volatile solids, kg solids/kg wet manure; P, phosphorus, dry matter basis; TKN, total Kjeldahl nitrogen, dry matter basis; COD, chemical oxygen demand, as-is basis.

[3] Day, day of sampling each week, either day 4 or day 7.

[a,b] Superscripts indicate differences between samples collected on day 4 and day 7 ($P < .05$); no diet differences were observed.

Table 5. Least squares means of detectable dilution ratios of collected room air samples when finishing pigs were fed diets containing 0, 5, or 10% DDGS[1]

		Log odor dilution	
	0% DDGS	5% DDGS	10% DDGS
Period 1[2]			
Day 4	5.08	4.80	-
Day 7	5.21	5.02	-
Period 2			
Day 4	-	5.68	5.37
Day 7	-	5.81	5.59
Period 3			
Day 4	4.70^{a}	-	5.28^{a}
Day 7	6.13^{b}	-	6.03^{b}
Period 4			
Day 4	-	5.27	5.16^{a}
Day 7	-	5.40	6.09^{b}
Period 5			
Day 4	5.39^{a}	-	5.35
Day 7	5.82^{b}	-	5.66
Period 6			
Day 4	5.11^{a}	5.11^{a}	-
Day 7	5.78^{b}	6.01^{b}	-

[1] DDGS, distillers dried grains with solubles, expressed as kilograms DDGS per kilogram diet.

[2] Empty cells reflect not all diets fed during each period due to facility limitations.

[a,b] Different superscripts indicate within diet, day was significant ($P < .10$).