Dried skim milk as a replacement for soybean meal in growing-finishing diets: Effects on growth performance, apparent total-tract nitrogen digestibility, urinary and fecal nitrogen excretion, and carcass traits in pigs[1,2]

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ABSTRACT: Two trials were conducted to determine the replacement nutritive value of dried skim milk for growing-finishing pigs. In a three-phase feeding trial, 180 growing composite barrows (40.8 ± 2.9 kg BW) were allotted to three dietary treatments. Each phase lasted 28 d. Treatment 1 comprised a basal corn–soybean meal diet supplemented with crystalline AA to contain true ileal digestible concentrations (as-fed basis) of 0.83, 0.66, and 0.52% Lys; 0.53, 0.45, and 0.40% Thr; and 0.51, 0.45, and 0.42% sulfur amino acids (SAA; Met + Cys) in Phases 1, 2, and 3, respectively. Treatments 2 and 3 were the basal diets with 5 and 10% (as-fed basis) dried skim milk added. The three diets at each phase were formulated to have the same quantities of DE, true ileal digestible Lys, Thr, Trp, SAA, Ca, and available P. Pigs were housed 10 per pen (six pens/treatment), allowed ad libitum access to feed, and slaughtered at 121.6 ± 9.3 kg BW. No differences were detected between pigs fed the basal diet and the dried skim milk diets or between pigs fed the 5 and 10% dried skim milk diets, respectively, in 84-d ADG ($P = 0.84$ or $P = 0.71$), ADFI ($P = 0.54$ or $P = 0.91$), and G:F ($P = 0.80$ or $P = 0.97$), in hot carcass weight ($P = 0.66$ or $P = 0.74$), 45-min postmortem LM pH ($P = 0.90$ or $P = 0.53$), 10th-rib backfat thickness ($P = 0.24$ or $P = 0.77$), LM area ($P = 0.13$ or $P = 0.63$), weights of belly ($P = 0.43$ or $P = 0.70$), trimmed wholesale cuts ($P = 0.18$ to 0.85 or $P = 0.06$ to 0.53), and ham components ($P = 0.25$ to 0.98 or $P = 0.32$ to 0.63). In the N balance trial, four littermate pairs of finishing gilts (82.9 ± 2.0 kg BW) were assigned within pair to the basal or the 10% dried skim milk (as-fed basis) finishing diet. Daily feed allowance was 2.6× maintenance DE requirement and was given in two equal meals. Total fecal collection from eight meals and a 96-h urine collection began on d 14 when gilts weighed 92.1 ± 2.2 kg BW. No differences were found between dietary treatments in gilt's daily N intake ($P = 0.33$) and the daily output of urinary urea ($P = 0.88$), urinary N ($P = 0.97$), fecal N ($P = 0.69$), and total manure ($P = 0.62$), as well as apparent total-tract N digestibility ($P = 0.84$) and N retention ($P = 0.84$). It is concluded that growing-finishing pigs fed diets containing 10% dried skim milk would have growth performance, carcass traits, and N digestibility and use similar to those fed typical corn–soybean meal diets.

Key Words: Carcass Traits, Dried Skim Milk, Growing-Finishing Pigs, Growth, Nitrogen Digestibility, Urinary Nitrogen Excretion

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Introduction

Dried skim milk's high AA quality makes it an excellent protein supplement for pigs (Pond and Maner, 1984); however, dried skim milk is normally too expensive, and it is used primarily for human consumption and in calf milk replacers (Mahan, 2003). When its price is uncommonly low, dried skim milk would be a good substitute for soybean meal in pig diets. A possibility exists that the U.S. government may release, at a very low price, its surplus dried skim milk to assist growing-finishing pig producers suffering economic hardship created by recent drought.

The quantity of feed consumed by growing-finishing pigs is many times that eaten by nursery pigs. So, a greater effect on the feed cost and profitability of swine operations would result from using inexpensive dried skim milk to replace soybean meal in growing-finishing diets rather than nursery diets. Nonetheless, dried

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[2]Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the USDA.

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skim milk is very powdery, and difficulties in feed preparation and animal feeding can be encountered with too much dried skim milk in the diets. Little information is available in the literature on the use of dried skim milk, particularly the proper dietary inclusion rate, for growing-finishing pigs.

This study was conducted to determine effects of dried skim milk as a partial replacement of soybean meal on growth performance, carcass traits, apparent total-tract N digestibility, and N excretion in urine and feces in growing-finishing pigs.

Materials and Methods

Animal, Diets, and Management

The experimental protocol was reviewed and approved by the Animal Care and Use Committee of the U.S. Meat Animal Research Center (MARC). The pigs used in the experiment were the composite offspring of Duroc, Landrace, and Large White breeds. The experiment consisted of two trials: a feeding trial and a N balance trial.

Feeding Trial. A total of 180 growing barrows (8 to 11 wk of age; 40.8 ± 2.9 kg BW) was used in two replicates. For each replicate, 90 pigs were stratified by weight into 30 outcome groups. Within each three-pig outcome group, one pig was randomly allotted to Treatment 1, one to Treatment 2, and one to Treatment 3. Adjustments were made to distribute littermates across different treatments. The pigs were housed 10 pigs per pen in an environmentally regulated growing-finishing building. Each pen measured 1.7 × 5.7 m, with a 40% slotted floor, and was equipped with two nipple waterers. Because of the limited slaughtering capacity and the need to slaughter 30 pigs in the same day (10 pigs from each treatment), dietary treatments for Replicates 1 and 2 began 1 and 2 wk, respectively, after pigs were moved into the growing-finishing building. For each replicate, there were three 10-pig pens per dietary treatment. Pigs were fed in a three-phase regimen (growing, growing-finishing, and finishing), and each phase lasted 4 wk. For Treatment 1, pigs were fed a 15.6% CP corn–soybean meal-based diet supplemented with crystalline AA to contain true ileal digestible concentrations of 0.83% lysine, 0.53% threonine, 0.26% methionine, 0.25% cystine, and 0.15% tryptophan during the growing phase. A 13.4% CP diet supplemented with crystalline AA to contain true ileal digestible concentrations of 0.66% lysine, 0.45% threonine, 0.23% methionine, 0.22% cystine, and 0.12% tryptophan was fed during the growing-finishing phase. And an 11.9% CP diet supplemented with crystalline AA to contain true ileal digestible concentrations of 0.52% lysine, 0.40% threonine, 0.22% methionine, 0.20% cystine, and 0.10% tryptophan was fed during the finishing phase. All basal diets were formulated to meet or exceed nutrient requirements recommended by NRC (1998). For Treatments 2 and 3, respectively, 5 and 10% (as-fed basis), dried skim milk was added to the basal diet primarily at the expense of soybean meal. The three test diets at each feeding phase were formulated (as-fed basis) to contain the same quantities of DE, CP, true ileal digestible lysine, threonine, tryptophan, and sulfur amino acids (methionine + cystine), Ca, and available P (Table 1).

On d 0 of the test, a fresh fecal sample was obtained by rectal massage from all 10 pigs in the first pen of each treatment. The shedding of microbial pathogens, including *Escherichia coli* O157:H7, was determined in fresh fecal sample. These fresh fecal samples were also used to measure production of volatile organic compounds. Volatile odor compounds measured were primarily short- and branched-chain VFA (C_2 through C_6), alcohols (C_2 through C_4), and aromatic ring-containing compounds (principally phenol and cresol) similar to the volatile odor compounds observed in the headspace of swine manure slurries by Zhan et al. (1997). After fecal sampling, all pigs were weighed and allowed ad libitum access of their designated growing diets. Pigs and feeders were weighed every 14 d. On d 28, 56, and 84 before weighing the pigs, a fresh fecal sample was obtained by rectum massage from the same pigs that were sampled on d 0. After being weighed on d 28 and 56, pigs were given their designated growing-finishing and finishing diets, respectively.

Pigs were slaughtered at 121.6 ± 9.3 kg BW in six groups of 30 pigs each. Each slaughter group comprised 10 pigs from each dietary treatment. The length on test when pigs were slaughtered ranged from 86 to 98 d. On the day of slaughter, pigs were weighed and their backfat thickness at the 10th rib was obtained ultrasonically (Renco Lean-Meater, Renco Corp., Minneapolis, MN). Pigs were killed by exsanguination after electric stunning. The time of stunning was recorded for each pig. The carcass was skinned, eviscerated, split into two halves, washed, weighed for hot carcass weight, and then kept in a cooling room at 0°C. At 45 min after stun, the pH value of the LM was obtained through the intercostal space at the 10th- and 11th-rib interface, using a Type Argus χ Sentron pH meter (Sentron Inc., Gig Harbor, WA). The carcass was chilled at 0°C for 24 to 72 h before being weighed, LM area at the 10th- and 11th-rib interface was traced, and primal cuts were separated. The Boston butt, picnic shoulder, loin, and ham were trimmed to 0.635-cm fat cover and weighed. The trimmed ham was further dissected to measure lean, bone, and fat contents.

Nitrogen Balance Trial. Four pairs of littermate Duroc, Landrace, and Large White composite finishing gilts were used. The gilts were housed in individual 1.2 × 1.2 m pens equipped with nipple waterers to provide water at all times. The room temperature was maintained at 21°C with 24-h lighting. The gilts were trained to enter individual rectangular metabolism cages to consume a basal finishing diet within a 30-min period twice daily (0800 and 1500). The metabolism cage had adjustable sides and back (81 cm tall), and a 46 cm ×

Table 1. Composition of basal and dried skim milk (DSM) diets for feeding trial (as-fed basis)

	Growing			Growing-finishing			Finishing		
		DSM			DSM			DSM	
Item	Basal	5%	10%	Basal	5%	10%	Basal	5%	10%
Ingredient, %									
Corn	76.98	76.16	75.38	83.19	82.72	81.59	87.19	86.54	85.49
Soybean meal 48% CP	19.00	15.71	12.33	13.35	9.61	6.34	9.58	6.07	2.78
Dried skim milk	—	5.00	10.00	—	5.00	10.00	—	5.00	10.00
Soybean oil	1.09	0.54	—	0.92	0.40	—	1.00	0.46	—
Dicalcium phosphate	1.00	0.77	0.56	0.88	0.66	0.44	0.67	0.45	0.22
Limestone	0.76	0.75	0.73	0.55	0.53	0.66	0.57	0.56	0.68
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin premix[a]	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Trace mineral premix[b]	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Choline chloride[c]	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Antibiotic[d]	0.10	0.10	0.10	0.10	0.10	0.10	0.025	0.025	0.025
L-Lysine·HCl	0.200	0.150	0.096	0.163	0.137	0.071	0.106	0.060	0.008
L-Threonine	0.038	0.018	—	0.033	0.019	—	0.035	0.019	—
DL-Methionine	0.026	0.004	—	0.021	0.011	—	0.028	0.016	—
Calculated composition[e]									
DE, Mcal/kg	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.5
CP, %	15.65	15.65	15.65	13.43	13.30	13.30	11.93	11.88	11.88
Ca, %	0.62	0.62	0.62	0.50	0.50	0.55	0.45	0.45	0.50
Total P, %	0.53	0.52	0.50	0.49	0.47	0.45	0.43	0.42	0.40
Available P, %	0.24	0.24	0.24	0.21	0.21	0.21	0.17	0.17	0.17
True ileal digestible									
Lysine, %	0.83	0.83	0.83	0.66	0.67	0.66	0.52	0.52	0.52
Sulfur AA, %	0.51	0.50	0.51	0.45	0.45	0.45	0.42	0.42	0.42
Threonine, %	0.53	0.53	0.53	0.45	0.45	0.45	0.40	0.40	0.40
Tryptophan, %	0.15	0.16	0.16	0.12	0.12	0.13	0.10	0.10	0.11

[a]Supplied the following per kilogram of diet: retinyl acetate, 4,400 IU; cholecalciferol, 880 IU; dl-α-tocopheryl acetate, 35 IU; menadione sodium bisulfite complex, 4.4 mg; niacin, 44 mg; d-calcium pantothenate, 24.2 mg; riboflavin, 8.8 mg; and vitamin B_{12}, 44 μg.

[b]Supplied the following per kilogram of diet: Fe (as ferrous sulfate heptahydrate), 150 mg; Cu (as copper sulfate pentahydrate), 9 mg; Mn (as manganese oxide), 40 mg; Zn (as zinc oxide), 150 mg; I (as calcium iodate), 0.2 mg; Se (as sodium selenate), 0.3 mg; and $CaCO_3$ as carrier.

[c]Contained 60% choline.

[d]Supplied 55 ppm chlortetracycline in growing and growing-finishing diets, and 33 ppm bacitracin methylene disalicylate in finishing diets.

[e]Based on chemical composition of feed ingredients published by NRC (1998).

122 cm flat expanded metal floor, which was 81 cm above the room floor. Underneath the expanded metal floor were tracks for a full-length screen and a funnel tray. The metabolism cage also had a 46 cm × 122 cm sheet-metal floor, which was 21 cm above the room floor.

The gilts were given a daily feed allowance to provide 2.6× maintenance DE in two equal meals. The daily maintenance DE requirement was equivalent to 110 kcal of DE/kg of $BW^{0.75}$ (NRC, 1998). Feed was mixed with water at a ratio of 1 g of feed:1 mL of water at feeding. After gilts had adapted to management, they were weighed 2 h after feeding, and their daily feed allowance was recalculated. The gilts were randomly assigned within a littermate pair to receive the basal finishing diet or the basal finishing diet with 10% (as-fed basis) dried skim milk added. The compositions of the basal finishing diet and the basal finishing diet with 10% dried skim milk added are shown in Table 2. The day gilts were assigned to treatments was designated as d 0 of the test. The BW of gilts on d 0 was 82.9 ± 2.0 kg.

Gilts were weighed on d 7 for recalculating their daily feed allowance. Starting on d 13, gilts were kept continuously in metabolism cages. Water was available to gilts at all times by completely filling the metabolism cage water bowl twice daily. At 0800 on d 14, gilts were given 2 g of ferric oxide (a red indigestible marker) mixed with 100 g of feed and 100 mL of water. After gilts had consumed the ferric oxide mixed feed, they were given the remainder of their morning meal. Gilts were weighed 2 h after feeding the marker, and their daily feed allowance was recalculated. The BW of gilts averaged 92.1 ± 2.2 kg. Gilts were then fitted with indwelling silicone-coated Foley urinary bladder catheters (Bard catheter, 16 French; C. R. Bard, Inc., Covington, GA). The bladder catheter was connected with sterile Tygon tubing to drain urine. The urine was collected continuously for 96 h starting at 1000 on d 15. Urine was allowed to flow through the catheter and Tygon tubing into a collection vessel containing 25 mL of 6*N* HCl solution. The urine excreted was measured daily

Table 2. Composition of basal and 10% died skim milk (DSM) diets for N balance trial (as-fed basis)

Item	Basal	10% DSM
Ingredient, %		
Corn	79.05	77.40
Soybean meal 48% CP	17.55	10.70
Dried skim milk	—	10.00
Soybean oil	1.00	—
Dicalcium phosphate	0.65	0.40
Limestone	0.80	0.65
Salt	0.30	0.30
Vitamin premix[a]	0.20	0.20
Trace mineral premix[b]	0.20	0.20
Choline chloride[c]	0.10	0.10
Antibiotic[d]	0.025	0.025
L-Lysine·HCl	0.125	0.050
L-Threonine	0.008	—
Calculated composition[e]		
DE, Mcal/kg	3.50	3.5
CP, %	15.00	15.00
Ca, %	0.55	0.55
Total P, %	0.46	0.46
Available P, %	0.18	0.21
True ileal digestible		
Lysine, %	0.74	0.75
Sulfur AA, %	0.45	0.45
Threonine, %	0.48	0.50
Tryptophan, %	0.14	0.15
Analyzed N concentration, %	2.53	2.45

[a]Supplied the following per kilogram of diet: retinyl acetate, 4,400 IU; cholecalciferol, 880 IU; dl-α-tocopheryl acetate, 35 IU; menadione sodium bisulfite complex, 4.4 mg; niacin, 44 mg; d-calcium pantothenate, 24.2 mg; riboflavin, 8.8 mg; and vitamin B_{12}, 44 μg.

[b]Supplied the following per kilogram of diet: Fe (as ferrous sulfate heptahydrate), 150 mg; Cu (as copper sulfate pentahydrate), 9 mg; Mn (as manganese oxide), 40 mg; Zn (as zinc oxide), 150 mg; I (as calcium iodate), 0.2 mg; Se (as sodium selenate), 0.3 mg; and $CaCO_3$ as carrier.

[c]Contained 60% choline.

[d]Supplied 33 ppm bacitracin methylene disalicylate in diet.

[e]Based on chemical composition of feed ingredients published by NRC (1998).

and a 10% aliquot was saved, pooled within pig, and stored at –20°C until analyses. At 0800 on d 18, ferric oxide was fed the second time. Total fecal collection from the eight meals (two meals daily for 4d, starting on d 14) was based on the marker-to-marker principle, and it began with the appearance of the first red feces and ended with the appearance of the second red feces. The use of the Foley bladder catheter for urine collection avoided contact between urine and feces. It also prevented urine from being contaminated with water wasted by gilts, and thereby allowed an accurate measurement of urinary output. Gilts were weighed at 1000 on d 22 when fecal collection was completed for all gilts. The BW for gilts fed the basal diet and the 10% dried skim milk diet were 91.0 kg and 93.2 kg on d 14 of the test, and 95.9 kg and 97.4 kg on d 22, respectively.

Chemical Analyses

The DM contents of the feed and feces were determined by drying them in a forced-air drying oven (105°C) until they reached a constant weight. This drying method was deemed appropriate because no urine could splash onto feces due to the catheterization of the urinary bladder in the gilts, and collected feces were urine-free. Feed and dried feces were then ground in a Thomas-Wiley mill (model 4, Arthur H. Thomas Co., Philadelphia, PA), subsampled, and analyzed for GE with a Parr adiabatic oxygen bomb calorimeter (model 1241, Parr Instrument Co., Moline, IL) and for N by the combustion method (AOAC, 1990) with Leco model CN-2000 carbon-nitrogen analyzer (Leco Corp., St. Joseph, MI). The urine samples were also analyzed for N and urea N (Marsh et al., 1965).

Statistical Analyses

Feeding Trial. The data for each 28-d phase and entire 84-d period were analyzed as a randomized complete block design with pen as the experimental unit and using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). The model included the effects of block (replication), dietary treatment, and block × treatment (error). Contrasts were used for treatment comparisons, including: 1) basal diet vs. diets containing dried skim milk (i.e., Treatment 1 vs. Treatments 2 and 3); and 2) 5% vs. 10% dried skim milk diets (i.e., Treatment 2 vs. Treatment 3).

Nitrogen Balance Trial. The data were analyzed as a randomized complete block design with individual pigs as the experimental unit and using the GLM procedure of SAS. The model included the effects of block (replication), dietary treatment, and block × treatment (error).

Results

Feeding Trial

Pig performance during intermediate phases was generally consistent with the overall trial result; therefore only data for the entire 84-d period are presented (Table 3). There were no differences between pigs fed the basal diet and the dried skim milk-supplemented diets in the initial (P = 0.80) and final (P = 0.81) BW. Also, no differences were detected between pigs fed the 5 and 10% dried skim milk diets in initial (P = 0.73) and final (P = 0.80) BW. Average daily gain did not differ between pigs fed the basal diets and the dried skim milk-supplemented diets (P = 0.84). No differences in ADG were found (P = 0.71) between pigs fed the 5 and 10% dried skim milk diets. The ADFI did not differ between pigs fed the basal diets and the dried skim milk-supplemented diets (P = 0.54), and no differences were found in ADFI between pigs fed the 5 and 10% dried skim milk diets (P = 0.91). There were also no differences in G:F between pigs fed the basal diets and the dried skim milk diets (P = 0.80), and no differences in G:F were detected between pigs fed the 5 and 10% dried skim milk diets (P = 0.97).

Data in Table 4 show that neither slaughter weight nor hot carcass weight was different between pigs fed

Table 3. Effect of dried skim milk (DSM) on growth performance of barrows[a]

Item	Basal	DSM		Root MSE	*P*-value for contrast comparisons	
		5%	10%		Basal vs. DSM	5 vs. 10% DSM
Initial BW, kg	40.6	40.6	41.2	2.9	0.80	0.73
Final BW, kg	114.5	114.6	115.1	2.9	0.81	0.80
ADG, kg	0.88	0.89	0.88	0.03	0.84	0.71
ADFI, kg (as-fed)	2.99	3.03	3.02	0.10	0.54	0.91
G:F	0.29	0.29	0.29	0.01	0.80	0.97

$P < 0.01$. **[Au: Not in table.]

[a]Values are means for six pens with 10 pigs per pen; length of test period was 84 d.

the basal diet and the dried skim milk diets ($P = 0.53$ or $P = 0.66$, respectively) or between pigs fed the 5 and 10% dried skim milk diets ($P = 0.89$ or $P = 0.74$, respectively). The 45-min postmortem LM pH values were also not different between pigs fed the basal diet and the dried skim milk diets ($P = 0.90$) or between pigs fed the 5 and 10% dried skim milk diets ($P = 0.53$). Neither the 10th-rib backfat thicknesses obtained ultrasonically from live pigs before slaughter nor the 10th-rib LM areas measured on carcasses differed between pigs fed the basal diet and the dried skim milk diets ($P = 0.24$ and $P = 0.13$, respectively) or between pigs fed the 5 and 10% dried skim milk diets ($P = 0.77$ and $P = 0.63$, respectively). The leaf fat weights and carcass lengths were not different between pigs fed the basal diet and the dried skim milk diets ($P = 0.99$ and $P = 0.30$, respectively) or between pigs fed the 5 and 10% dried skim milk diets ($P = 0.86$ and $P = 0.23$, respectively). The weights of left-side carcass did not differ between pigs fed the basal diet and the dried skim milk diets ($P = 0.64$) or between pigs fed the 5 and 10% dried skim milk diets ($P = 0.74$). There were no differences in weights of the untrimmed Boston butt, ham, picnic shoulder and loin, and the belly in the left-side carcass between pigs fed the basal diet and the dried skim milk diets ($P = 0.68$, $P = 0.63$, $P = 0.16$, $P = 0.60$, and $P = 0.43$, respectively) or between pigs fed the 5 and 10% dried skim milk diets ($P = 0.35$, $P = 0.90$, $P = 0.51$, $P = 0.79$, and $P = 0.70$, respectively). The weights of trimmed Boston butt, ham, picnic shoulder, and loin in the left-side carcass did not differ between pigs fed the basal diet and the dried skim milk diets ($P = 0.80$, $P = 0.85$, $P = 0.18$, and $P = 0.43$, respectively) or between pigs fed the 5 and 10% dried skim milk diets ($P = 0.06$, $P = 0.53$, $P = 0.49$, and $P = 0.51$, respectively). No differences in weights of ham lean, ham bone, and

Table 4. Effect of dried skim milk (DSM) on carcass measurements in barrows[a]

Item	Basal	DSM		Root MSE	*P*-value for contrast comparisons	
		5%	10%		Basal vs. DSM	5 vs. 10% DSM
Slaughter wt, kg	121.0	121.5	122.4	9.3	0.53	0.89
Hot carcass wt, kg	79.24	79.51	79.91	0.6	0.66	0.74
45-min LM pH	6.01	6.04	5.99	0.33	0.90	0.53
10th-rib backfat, cm	1.70	1.79	1.77	0.30	0.24	0.77
10th-rib LM area, cm^2	40.08	38.70	39.13	4.85	0.13	0.63
Leaf fat wt., kg	0.99	0.99	1.00	0.23	0.99	0.86
Carcass length, cm	82.2	82.3	82.9	2.7	0.30	0.23
Left-side carcass wt., kg	39.72	39.87	40.07	3.3	0.64	0.74
Untrimmed Boston butt, kg	5.39	5.38	5.47	0.54	0.68	0.35
Untrimmed ham, kg	10.11	10.16	10.18	0.84	0.63	0.90
Untrimmed picnic shoulder, kg	3.91	3.97	4.02	0.39	0.16	0.51
Untrimmed loin, kg	9.58	9.52	9.47	1.03	0.60	0.79
Belly, kg	8.31	8.39	8.45	0.89	0.43	0.70
Trimmed Boston butt, kg	4.36	4.30	4.45	0.44	0.80	0.06
Trimmed ham, kg	8.20	8.18	8.28	0.82	0.85	0.53
Trimmed picnic shoulder, kg	3.43	3.49	3.53	0.36	0.18	0.49
Trimmed loin, kg	7.45	7.31	7.40	0.77	0.43	0.51
Ham lean, kg	7.12	7.08	7.15	0.77	0.98	0.63
Ham bone, kg	1.29	1.30	1.32	0.11	0.25	0.32
Ham fat, kg	1.70	1.77	1.71	0.37	0.54	0.37

[a]Values are means for six pens with 10 pigs per pen.

Table 5. Effect of dried skim milk (DSM) on growth performance, apparent total-tract N digestibility, and N balance during the balance trial of finishing gilts

	DSM			
Item	Basal	10% DSM	Root MSE	*P*-value
No. of pigs	4	4		
Initial BW, kg	91.0	93.2	2.18	0.21
Final BW, kg	95.9	97.4	4.48	0.65
ADG, g[a]	613	528	291.2	0.70
ADFI, g (as-fed)[b]	2,293	2,429	85.5	0.07
G:F	0.263	0.217	0.121	0.61
N intake, g/d	58.0	59.6	2.15	0.33
Urine output, mL/d	5,176	5,852	1,640.4	0.58
Urine urea conc., mg/dL	917	845	278.1	0.73
Urine urea output, g/d	45.0	45.6	5.66	0.88
Urine urea N conc., mg/dL	429	395	129.9	0.73
Urine urea N output, g/d	21.0	21.3	2.64	0.88
Urine N conc., mg/dL	541	480	164	0.64
Urine N output, g/d	26.0	25.9	2.84	0.97
Fresh feces output, g/d	696	643	125.6	0.57
Fecal DM, %	34.2	34.2	3.62	0.99
Fecal DM output, g/d	238.0	219.9	32.78	0.49
Fecal N, % of DM	3.2	3.7	0.29	0.07
Fecal N output, g/d	7.6	8.1	1.70	0.69
Total manure, g/d	5,872	6,495	1,662.50	0.62
Total manure N, g/d	33.6	34.0	3.82	0.88
N digested, g/d	50.4	51.5	2.31	0.52
Apparent N digestibility, %	86.9	86.5	2.80	0.84
N retained, g/d	24.4	25.6	4.71	0.73
Apparent N retention, %	41.9	43.0	7.41	0.84

[a]Values are for an 8-d period.
[b]Daily feed intake was 2.6× maintenance DE requirement (NRC, 1998).

ham fat were found between pigs fed the basal diet and the dried skim milk diets (*P* = 0.98, *P* = 0.25, and *P* = 0.54, respectively) or between pigs fed the 5 and 10% dried skim milk diets (*P* = 0.63, *P* = 0.32, and *P* = 0.37, respectively).

No shedding of microbial pathogens, including *E. coli* O157:H7, was found in fecal samples obtained by rectal massage from pigs fed the basal diets, and diets containing 10% dried skim milk (data not shown). In addition, no differences were found among the three dietary treatments in the emissions of volatile odor compounds, including short- and branched-chain VFA (C_2 through C_6), alcohols (C_2 through C_4), and aromatic ring-containing compounds (principally phenol and cresol), from fresh feces, aged feces, and manure slurry obtained (data not shown).

Nitrogen Balance Trial

As showed in Table 5, the ADG, ADFI, and G:F over the 8-d period for feces and urine collection did not differ between gilts fed the basal diet and the 10% dried skim milk diet (*P* = 0.70, *P* = 0.07, and *P* = 0.61, respectively). The daily N intake for pigs fed the basal diet did not differ from those fed the 10% dried skim milk diet (*P* = 0.33). There were also no differences between pigs fed the basal diet and the 10% dried skim milk diet in daily urine output (*P* = 0.58), urine urea concentration (*P* = 0.73), daily urine urea output (*P* = 0.88), urine urea N concentration (*P* = 0.73), daily urine urea N output (*P* = 0.88), urine N concentration (*P* = 0.64), and daily urine N output (*P* = 0.97). Between pigs fed the basal diet and the 10% dried skim milk diet, no differences were found in daily fresh feces output (*P* = 0.57), fecal DM content (*P* = 0.99), daily fecal DM output (*P* = 0.49), fecal N concentration (DM basis; *P* = 0.07), daily fecal N output (*P* = 0.69), and daily total manure output (*P* = 0.62). No differences between pigs fed the basal diet and the 10% dried skim milk diet were detected in daily N digested (*P* = 0.52), apparent total-tract N digestibility coefficient (*P* = 0.84), daily N retention (*P* = 0.73), and apparent N retention coefficient (*P* = 0.84).

Discussion

In the current study, there was no dietary treatment difference in the ADFI of barrows allowed ad libitum access of feed. This suggests that growing-finishing barrows accepted readily the diets containing up to 10% dried skim milk compared with the basal corn soybean meal diets in a three-phase feeding regimen. The current study also demonstrates that growing-fishing barrows fed diets containing 5 or 10% dried skim milk would have growth performance similar to those fed the basal, corn–soybean meal diets when diets were formulated to contain the same amounts of DE, Ca, available P, and true ileal digestible lysine, threonine, methionine plus cystine, and tryptophan. The current study further shows that backfat thickness, LM area, the yield of untrimmed and trimmed primal cuts, ham lean, ham fat, and ham bone of pigs fed the dried skim milk diets were similar to those fed the basal diets. It was clearly shown that barrows fed the dried skim milk growing finishing diets should yield the same market value as those fed the corn–soybean meal diets. In the current study, the 45-min postmortem LM pH values were not different between pigs fed the basal diets and those fed dried skim milk diets, suggesting that dietary inclusion of 5 or 10% dried skim milk in growing-finishing diets would not cause a negative effect, such as PSE meat, on fresh pork quality in pigs (Berg et al., 2003).

The phenomenon whereby drying feces in a forced-air oven at temperatures over 70°C causes losses of volatile compounds such as N-containing volatile urinary urea (Adeola, 2001) exists only with feces contaminated with urine. However, feces of the current study were collected without any urine contamination because of catheterization of the urinary bladder in the gilts. Therefore, no loss of N from the urine-free feces would occur in the current study when the feces were dried at 105°C in a forced-air drying oven. The N values reported for the N balance trial of the current study should reflect true and accurate results. For finishing gilts fed the basal diet and the 10% dried skim milk diet in the N balance trial of the current study, the values of apparent total tract N digestibility did not differ and amounted to 86.9 and 86.5% of N intake, respectively. These values are close to the 87.8% value reported by Hansen and Lewis (1993) for finishing gilts fed corn–soybean meal diets. The apparent N retention values for finishing gilts fed the basal diet and the 10% dried skim milk diet in the current study were, respectively, 41.9 and 43.0% of N intake, with no treatment difference. These N retention values are within the 30 to 55% range normally observed in pigs fed commercial feedstuffs (Kornegay and Harper, 1997; NRC, 1998). The similar apparent total-tract N digestibility and apparent N retention for finishing gilts fed the basal diet and those fed the 10% dried skim milk diet in the current study indicates no negative effect on N excretion from dietary inclusion of 10% dried skim milk would occur in pig operations. These results from the N balance trial support the feeding trial on dietary suitability of dried skim milk for growing-finishing pigs.

In addition to nutrient excretion, ammonia release and odor production are also major challenges facing the swine industry (Kerr, 2003; Yen, 2003). Ammonia is released from the rapid hydrolysis of urinary urea by fecal urease (Stevens et al., 1989). Thus, the quantity of ammonia release is directly associated with urinary urea output by pigs. In the current study, daily urinary urea output did not differ between gilts fed the basal diet and those given the 10% dried skim milk diet (45.0 and 45.6 g/d, respectively). Although no determination of ammonia release was made in the current study, the almost identical daily urinary urea output for the two dietary treatments would suggest no negative effect on ammonia release from feeding the 10% dried skim milk diet in finishing gilts. In the feeding trial of the current study, determinations were conducted on the emission of volatile odor compounds from fresh feces, aged feces, and manure slurry on d 0, 28, 56, and 84 of the trial. Volatile odor compounds measured were primarily short- and branched-chain VFA (C_2 through C_6), alcohols (C_2 through C_4), and aromatic ring-containing compounds (principally phenol and cresol) similar to the volatile odor compounds observed in the headspace of swine manure slurries by Zhan et al. (1997). Our unpublished observations showed no difference in the emission of volatile odor compounds was found among the three dietary treatments. This further strengthens our contention that feeding 5 or 10% dried skim milk would not jeopardize environment as compared with typical corn-soybean meal diets.

There is an increasing concern in the general public about the food safety relating to gut microbial shedding. Dried skim milk contains 50% lactose on DM basis (Mahan, 2003). The inclusion of 5 or 10% dried skim milk in the current study increased lactose content in the diets. Lactose may alter gastrointestinal microbial function via shifts in microbial populations, specifically species of *E. coli* and *Lactobacillus* (Szilagyi, 2002). Certain *Lactobacillus* spp. have been shown to decrease shedding of *E. coli* O157:H7 in cattle (Brashears et al., 2003). In the feeding trial of the current study, the shedding of microbial pathogens was determined in fecal sample obtained by rectal massage. Our unpublished observations indicated that *E. coli* O157:H7 was not found in pigs fed the basal diets, and dietary inclusion of 10% dried skim milk did not result in shedding. These findings illustrate that inclusion of dried skim milk in growing-finishing diets would not likely cause unwanted effects on gut microbiota in pigs and the safety of pork.

Taken together, data from the current study indicate that up to 10% of dried skim milk can be used to partially replace soybean meal in diets for growing-finishing pigs. However, the price of dried skim milk will determine the feasibility of dietary inclusion of dried skim milk in growing-finishing diets. Dried skim milk can be released at lower prices by the U.S. government to assist pork producers suffering economic hardship created by drought or other conditions.

Literature Cited

Adeola, O. 2001. Digestion and balance techniques in pigs. Page 903–916 in Swine Nutrition. 2nd ed. A. J. Lewis and L. L. Southern, ed. CRC Press, Boca Raton, FL.

AOAC. 1990. Official Methods of Analysis. 15th ed. Assoc. Offic. Anal. Chem., Arlington, VA.

Berg, E. P., K. R. Maddock, and M. L. Linvelle. 2003. Creatine monohydrate supplemented in swine finishing diets and fresh pork quality: III. Evaluating the cumulative effect of creatine monohydrate and alpha-lipoic acid. J. Anim. Sci. 81:2469–2474.

Brashears, M. M., D. Jaroni, and J. Trimble. 2003. Isolation, selection, and characterization of lactic acid bacteria for a competitive exclusion product to reduce shedding of *Escherichia coli* O157:H7 in cattle. J. Food Prot. 66:355–363.

Hansen, B. C., and A. J. Lewis. 1993. Effects of dietary protein concentration (corn:soybean meal ratio) and body weight on nitrogen balance of growing boars, barrows, and gilts: Mathematical descriptions. J. Anim. Sci. 71:2110–2121.

Kerr, B. J. 2003. Dietary manipulation to reduce environmental impact. Page 139–159 in Proc. 9th Int. Symp. Digest. Physiol. Pigs. Vol. 2. Banff, AB, Canada.

Kornegay, E. T., and A. E. Harper. 1997. Environmental nutrition: Nutrient management strategies to reduce nutrient excretion of swine. Prof. Anim. Sci. 13:99–111.

Mahan, D. C. 2003. Feeding milk products to swine. Pages 141–156 in Proc. 3rd Natl. Symp. Altern. Feeds for Livest. Poult. M. L. Eastridge, ed. Ohio State Univ., Columbus.

Marsh, W. H., B. Fingerhut, and H. Miller. 1965. Automated and manual direct methods for the determination of blood urea. Clin. Chem. 11:624–627.

NRC. 1998. Nutrient Requirements of Swine. 10th ed. Natl. Acad. Press, Washington, DC.

Pond, W. G., and J. H. Maner. 1984. Swine Production and Nutrition. AVI Publ. Co. Inc., Westport, CT.

Stevens, R. J., R. J. Laughlin, and J. P. Frost. 1989. Effect of acidification with sulfuric acid on the volatilization of ammonia from cow and pig slurry. J. Agric. Sci. 113:389–395.

Szilagyi, A. 2002. Review article: Lactose—A potential prebiotic. Aliment. Pharmacol. Ther. 16:1591–1602.

Yen, J. T. 2003. Nutritional strategies to reduce nutrient excretion and odor in pig operations. Page 327–329 in Proc. XI Cong. de la AMENA y I del CLANA, Cancun, Mexico.

Zahn, J. A., J. L. Hatfield, Y. S. Do, A. A. DiSpirito, D. A. Laird, and R. L. Pfeiffer. 1997. Characterization of volatile organic emissions and wastes from a swine production facility. J. Environ. Qual. 26:1687–1696.