Effects of sodium metabisulfite additives on nursery pig growth

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ABSTRACT: Sodium metabisulfite (**SMB**)-based feed additive efficacy was evaluated in three nursery pig growth experiments where pigs were fed diets containing low deoxynivalenol (<1.5 mg/kg; **DON**) concentrations. Pigs were weaned at approximately 22 d of age and randomly allotted to pens with one pen of 27 gilts and one pen of 27 barrows per feeder; thus, feeder was the experimental unit. In experiment 1, a total of 2,268 pigs were used in a 35-d trial with 21 feeders per treatment. Experimental treatments included a control diet or the control with 0.50% SMB-based Product 1 (Defusion; Provimi, Brookville, OH) fed in phase 1 and 0.25% fed in phases 2 and 3, then all pigs were fed a control diet for the last week of the study. Pigs fed Product 1 had greater ($P < 0.05$) ADG, ADFI, and G:F compared with pigs fed the control diet from days 0 to 28. However, from days 28 to 35, the opposite response was observed with pigs fed the control diet having greater ADG and G:F than pigs previously fed Product 1. Despite this response, pigs fed Product 1 were heavier ($P < 0.05$) on day 35 than control-fed pigs. In experiment 2, a total of 4,320 pigs were used in a 42-d trial. Pigs were fed a control diet or diets with SMB-based either Product 1 or Product 2 (NutriQuest, Mason City, IA) at different concentrations and durations. Among the various treatments, Product 1 or Product 2 concentrations ranged from 0.50% initially to 0.25%, 0.15%, or none the last week of the study. Overall, pigs fed either of the additives at the highest concentrations and for the longest period of time had greater ($P < 0.05$) ADG and ADFI compared with pigs fed the control diet, with those fed lower concentrations or shorter durations being intermediate. In experiment 3, a total of 2,808 pigs were used in a 28-d trial with 13 feeders per treatment. All pigs were fed a common diet for 7 d after weaning. Pigs were then fed either a control diet (without any SMB-containing product) or a diet containing Product 1 (0.50% and 0.25% from days 0 to 21 and 21 to 28, respectively) or SMB (0.50% and 0.25% from days 0 to 21 and 21 to 28, respectively) or 0.25% SMB from days 0 to 28. Overall, pigs fed Product 1 or high-SMB diets had greater ($P < 0.05$) ADG compared with pigs fed low-SMB or control diets. In conclusion, results of these experiments indicate that in diets with low DON concentrations, these SMB-based products increased ADG compared with control diets.

Key words: deoxynivalenol, nursery pig, preservative, sodium metabisulfite

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INTRODUCTION

Deoxynivalenol (**DON**), or vomitoxin, is a mycotoxin found in cereal grains and is produced by the *Fusarium* genus. The DON concentration of cereal grains can vary from year to year, based on the degree of stress the plant is exposed to during the growing season, such as poor soil fertility, harsh weather conditions, and insect damage. Swine are sensitive to DON with exposure to concentrations greater than 1 mg/kg resulting in decreased feed intake and growth, whereas exposure to higher concentrations can result in complete feed refusal and vomiting (Rotter et al., 1996; Forsyth et al., 1977; Eriksen and Pettersson, 2004). Although not approved by U.S. Food and Drug Administration as DON-detoxifying agents, sodium metabisufite (**SMB**)-based feed additives have been used in diets with high DON concentrations with positive results. A positive relationship between growth performance and the addition of SMB-containing feed additives in swine diets with greater than 3 mg/kg of DON has been reported (Mahan et al., 2010; Patience et al., 2014; Frobose et al., 2015). However, limited research is available to document growth performance of nursery pigs fed diets containing SMB-based feed additives and with relatively little to no DON. Therefore, the objective of these experiments was to determine the effects of SMB-based feed additives in low-DON-containing diets on the growth performance of nursery pigs weighing approximately 6 to 25 kg.

MATERIALS AND METHODS

General

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in these studies. Experiments were conducted at a commercial research facility located in North Central Ohio. Each pen (2.3 × 2.7 m) initially contained 27 barrows or gilts and a double-sided five-hole stainless-steel fence line feeder. Therefore, the experimental unit was the feeder. Each pen also contained a cup-waterer and access to feed and water were provided on an ad libitum basis. Feed additions to each individual pen were made and recorded by an electronic feeding system (Dry Exact; Big Dutchman, Inc., Holland, MI). Experimental diets were manufactured at the Hord Elevator (Bucyrus, OH). Feed samples were collected from six feeders per treatment per phase, pooled, and subsampled for chemical analysis. Pens of pigs were weighed and feed disappearance was recorded every 7 d to determine ADG, ADFI, and G:F.

Experiment 1

In the first experiment, an SMB-containing product was evaluated (Defusion; Provimi, Brookville, OH). This product (Product 1) is a commercially available feed preservative that is a blend of SMB (92%), organic acids, fermentation products, and supplemental vitamins and amino acids.

A total of 2,268 pigs (PIC 337 × 1050; initial BW 6.8 kg) were used in a 35-d growth trial. Pigs were weaned at approximately 22 d of age and were randomly sorted into 1 of 84 pens (42 pens of barrows, 42 pens of gilts) with one pen of gilts and one pen of barrows per fence line feeder. A pair of pens (one adjoining feeder) were blocked by BW and weaning date and then randomly assigned to one of two dietary treatments in a randomized complete block design with 21 feeders per treatment. Dietary treatments included a control diet or the control with 0.50% Product 1 in phase 1 and 0.25% in phases 2 and 3 (Table 1). From days 28 to 35, all pigs were fed a common diet without Product 1. For phase 1, pigs were offered 0.68 kg feed, which lasted from day 0 to approximately day 5. Then phase 2 diets were provided until day 21, phase 3 diets were fed from days 21 to 28 with all pigs receiving a control diet without Product 1 from days 28 to 35.

Experiment 2

In the second experiment, a custom-made SMB-containing product was evaluated (Product 2; NutriQuest, Mason City, IA). Product 2 is a custom-made preservative and anticaking agent that contains SMB (92%), bentonite, and mineral oil. This product was compared with Product 1 used in the first experiment.

A total of 4,320 pigs (PIC 337 × 1050; initial weight 6.2 kg) were used in a 42-d growth trial. Pigs were weaned at approximately 22 d of age and were randomly sorted into 1 of 160 pens (80 pens of barrows, 80 pens of gilts) with one pen of gilts and one pen of barrows per fence line feeder. A pair of pens (one adjoining feeder) were blocked by BW and weaning date, and then randomly assigned to one of five dietary treatments that were fed for 35 d in a randomized complete block design. Dietary treatments included: 1) a control diet; 2) the control diets with 0.50% Product 1 fed for 7 d followed by 0.25% Product 1 from days 7 to 35; 3) control

Table 1. Diet composition, experiment 1 (as-fed basis)[1]

Ingredient, %	Phase 1	Phase 2	Phase 3
Corn	35.8	50.77	48.27
Soybean meal	20.87	31.57	33.06
Wheat	3.00	—	—
Bakery meal	—	—	12.50
Milk, whey powder	25.00	—	—
Dairylac 80[2]	—	9.00	—
HP 300[3]	7.50	2.50	—
Corn oil	4.00	1.50	2.50
Limestone	0.85	0.85	1.00
Monocalcium phosphate, 21%	0.73	1.50	0.85
Sodium chloride	0.50	0.60	0.50
L-Lysine HCl	0.45	0.48	0.45
DL-Methionine	0.30	0.31	0.25
L-Threonine	0.21	0.27	0.22
L-Tryptophan	0.06	0.04	0.01
L-Valine	0.12	0.16	0.09
Vitamin and trace mineral premix[4]	0.15	0.15	0.18
Zinc oxide	0.38	0.25	—
Copper sulfate	—	0.03	0.03
Choline chloride, 60%	0.04	—	—
Quantum 5000 L[5]	0.05	0.05	—
Quantum Blue 2G[6]	—	—	0.10
Product 1[7]	—	—	—
Total	100	100	100
Calculated analysis			
Standardized ileal digestible (SID) AA, %			
Lysine	1.40	1.42	1.38
Isoleucine:lysine	58	58	60
Leucine:lysine	107	109	113
Methionine:lysine	40	41	38
Methionine and cystine:lysine	58	59	57
Threonine:lysine	63	63	62
Tryptopahn:lysine	21.2	20.4	18.5
Valine:lysine	67	70	68
Total lysine, %	1.56	1.57	1.53
Net energy, kcal/kg	2,420	2,474	2,487
Crude protein, %	21.0	21.4	21.3
Calcium, %	0.74	0.77	0.67
Phosphorus, %	0.66	0.76	0.59
Available phosphorus, %	0.55	0.59	0.40

[1]Experimental diet were fed in three phases with dietary phases formulated for BW ranges of 5 to 7, 7 to 11, and 11 to 20 kg.

[2]International Ingredients, Inc., St. Louis, MO.

[3]Hamlet Protein, Findlay, OH.

[4]Provided per kilogram of premix: 26 g Mn from manganese oxide; 66 g Fe from iron sulfate; 88 g Zn from zinc sulfate; 11 g Cu from copper sulfate; 220 mg I from calcium iodate; and 198 mg Se from sodium selenite; 6,613,860 IU vitamin A; 1,468,277 IU vitamin D3; 44,092 IU vitamin E; 154 mg biotin; 1,102 mg folic acid; 2,205 mg pyridoxine; 6,614 mg riboflavin; 2,866 mg menadione; 22,046 mg pantothenic acid; 28,660 mg niacin; 6,614 mg thiamine; and 22 mg vitamin B12.

[5]Quantum 5000 (AB Vista, Plantation, FL) provided an estimated release of 0.14% available P.

[6]Quantum Blue 2G (AB Vista, Plantation, FL) provided an estimated release of 0.14% available P.

[7]Product 1 (Defusion; Provimi, Brookville, OH).

diet containing 0.50% Product 2 from days 0 to 7, 0.25% from days 7 to 28, and 0.15% from days 28 to 35; 4) control diet containing 0.50% Product 2 from days 0 to 7 and 0.25% from days 7 to 35; and 5) control diet containing 0.50% Product 2 from days 0 to 28 and 0.25% from days 28 to 35 (Table 2). On day 35, half of the pens receiving either Product 1 or Product 2 remained on those treatments and

Table 2. Diet composition, experiment 2 (as-fed basis)[1]

Ingredient, %	Phase 1	Phase 2	Phase 3
Corn	35.80	50.77	48.27
Soybean meal	20.87	31.57	33.06
Wheat	3.00	—	—
Bakery meal	—	—	12.50
Milk, whey powder	25.00	—	—
Dairylac 80[2]	—	9.00	—
HP 300[3]	7.50	2.50	—
Corn oil	4.00	1.50	2.50
Limestone	0.85	0.85	1.00
Monocalcium phosphate, 21%	0.73	1.50	0.85
Sodium chloride	0.50	0.60	0.50
L-Lysine HCl	0.45	0.48	0.45
DL-Methionine	0.30	0.31	0.25
L-Threonine	0.21	0.27	0.22
L-Tryptophan	0.06	0.04	0.01
L-Valine	0.12	0.16	0.09
Vitamin and trace mineral premix[4]	0.15	0.15	0.18
Zinc oxide	0.38	0.25	—
Copper sulfate	—	0.03	0.03
Choline chloride, 60%	0.04	—	—
Quantum 5000 L[5]	0.05	0.05	—
Quantum Blue 2G[6]	—	—	0.10
Product 1[7]	−/+	−/+	−/+
Product 2[8]	−/+	−/+	−/+
Total	100	100	100
Calculated analysis			
Standardized ileal digestible (SID) AA, %			
Lysine	1.40	1.42	1.38
Isoleucine:lysine	58	58	60
Leucine:lysine	107	109	113
Methionine:lysine	40	41	38
Methionine and cystine:lysine	58	59	57
Threonine:lysine	63	63	62
Tryptopahn:lysine	21.2	20.4	18.5
Valine:lysine	67	70	68
Total lysine, %	1.56	1.57	1.53
Net energy, kcal/kg	2,420	2,474	2,487
Crude protein, %	21.0	21.4	21.3
Calcium, %	0.74	0.77	0.67
Phosphorus, %	0.66	0.76	0.59
Available phosphorus, %	0.55	0.59	0.40

[1]Experimental diet were fed in three phases with dietary phases formulated for 5 to 7, 7 to 11, and 11 to 20 kg BW ranges.

2International Ingredients, Inc., St. Louis, MO.

[3]Hamlet Protein, Findlay, OH.

[4]Provided per kilogram of premix: 26 g Mn from manganese oxide; 66 g Fe from iron sulfate; 88 g Zn from zinc sulfate; 11 g Cu from copper sulfate; 220 mg I from calcium iodate; and 198 mg Se from sodium selenite; 6,613,860 IU vitamin A; 1,468,277 IU vitamin D3; 44,092 IU vitamin E; 154 mg biotin; 1,102 mg folic acid; 2,205 mg pyridoxine; 6,614 mg riboflavin; 2,866 mg menadione; 22,046 mg pantothenic acid; 28,660 mg niacin; 6,614 mg thiamine; and 22 mg vitamin B12.

[5]Quantum 5000 (AB Vista, Plantation, FL) provided an estimated release of 0.14% available P.

[6]Quantum Blue 2G (AB Vista, Plantation, FL) provided an estimated release of 0.14% available P.

[7]Product 1 (Defusion; Provimi, Brookville, OH) was included at the expense of corn.

[8]Product 2 (NutriQuest, Mason City, IA) was included at the expense of corn.

the other half were switched to the control diet. These combinations resulted in a total of nine treatments. There were 16 replications (feeders) for all treatments from days 0 to 35 and 8 replications per treatment from days 35 to 42 for all treatments except for the control, which continued to have 16 replications per treatment.

Experiment 3

In the third experiment, food-grade SMB (Brenntag North America, Reading, PA) was compared with Product 1. A total of 2,808 pigs (PIC 337 × 1050; initial weight 7.0 kg) were used in a 28-d growth trial. Pigs were weaned at approximately 22 d of age and were randomly sorted into 1 of 104 pens (52 pens of barrows, 52 pens of gilts) with one pen of gilts and one pen of barrows per fence line feeder. All pigs were fed a common phase 1 diet for 7 d, then 7 d after weaning, considered day 0 of the trial, a pair of pens (one adjoining feeder) were blocked by BW and randomly assigned to one of four dietary treatments with 13 feeders per treatment. Dietary treatments were fed for 28 d. The four treatments were as follows: 1) a control diet, 2) control diet with 0.50% Product 1 from days 0 to 21 followed by 0.25% Product 1 from days 21 to 28, 3) control diet with 0.25% SMB from days 0 to 28, and 4) control diet with 0.5% SMB from days 0 to 21 followed by 0.25% SMB from days 21 to 28 (Table 3).

Chemical Analysis

Feed samples for all three experiments were submitted to North Dakota Grain Inspection Service, Inc. (Bucyrus, OH) for DON analysis. Dietary DON concentrations for experiment 1 were determined by the RIDASCREEN FAST DON SC ELISA kit (R-Biopharm AG, Darmstadt, Germany). Dietary DON concentrations for experiments 2 and 3 were determined by ROSA DONQ2 Quantitative Test (Charms Sciences, Inc., Lawrence, MA). North Dakota Grain Inspection Service, Inc., follows the Federal Grain Inspection Service guidelines that consider the standard certification limits for these assays to be 0.5 to 5 mg/kg (FGIS, 2015). Thus, the minimum detection limit for both assays was 0.5 mg/kg.

Statistical Analysis

Feeder was considered the experimental unit (one pen of barrows and one pen of gilts) for all experiments. Means are reported as least square means with pooled standard error of the means. For experiments 2 and 3, individual treatment means were separated using the Tukey−Kramer multiple comparison test. Data for all experiments were analyzed as a randomized complete block design using PROC GLIMMIX in SAS, version 9.4 (SAS Institute, Inc., Cary, NC). Results were considered significant at $P \leq 0.05$ and marginally significant between $P > 0.05$ and $P \leq 0.10$.

RESULTS

Chemical Analysis

Chemical analysis of experiment 1 and 3 diets indicated that dietary DON concentrations of all diets, regardless of phase, were less than 0.5 mg/kg or below the detectable limit (Tables 4 and 6). For experiment 2 (Table 5), the control diet had DON concentrations ranging from 1.1 to 1.5 mg/kg. Both the Product 1-based diets had DON concentrations equal to or less than 1.3 mg/kg. Diets containing Product 2 had DON concentrations equal to or less than 1.1 mg/kg.

Experiment 1

From days 0 to 28, pigs fed diets containing Product 1 had greater ($P < 0.05$) ADG, ADFI, G:F, and day 28 BW than those fed the control diet (Table 7). However, from days 28 to 35, when all pigs were fed a control diet, the opposite effect was observed. Pigs previously fed the diets containing Product 1 had decreased ($P < 0.05$) ADG, ADFI, and G:F compared with pigs fed the control diet. Regardless, overall (days 0 to 35) ADG, ADFI, G:F, and day 35 BW were greater ($P < 0.05$) for those pigs fed diets containing Product 1.

Experiment 2

From days 0 to 35, pigs fed the Product 1 or Product 2 combinations control diet had increased ($P < 0.05$) ADG, ADFI, and d 35 BW compared with pigs fed the control diet (Table 8). The response to SMB products was in a dose-dependent manner with pigs fed the highest level of Product 2 having greater ($P < 0.05$) performance than the other Product 2 diets. There was no evidence for difference between pigs fed similar levels of Product 1 and Product 2. Gain to feed was greater ($P < 0.05$) for pigs fed the highest levels of Product 2 compared

Table 3. Diet composition, experiment 3 (as-fed basis)[1]

Ingredient, %	Phase 1	Phase 2
Corn	50.77	57.43
Soybean meal	31.57	33.10
Dairylac 80[2]	9.00	—
HP 300[3]	2.50	—
Corn oil	1.50	1.50
Limestone	0.85	1.05
Monocalcium phosphate, 21%	1.50	0.85
Sodium chloride	0.60	0.50
L-Lysine HCl	0.48	0.43
DL-Methionine	0.31	0.26
L-Threonine	0.27	0.22
L-Tryptophan	0.04	0.01
L-Valine	0.16	0.09
Vitamin and trace mineral premix[4]	0.15	0.18
Zinc oxide	0.25	0.25
Copper sulfate	0.03	0.03
Quantum 5000 L[5]	0.05	—
Quantum Blue 2G[6]	—	0.10
Product 1[7]	−/+	−/+
Sodium metabisulfite[8]	−/+	−/+
Total	100	96
Calculated analysis		
Standardized ileal digestible (SID) AA, %		
Lysine	1.42	1.37
Isoleucine:lysine	58	60
Leucine:lysine	109	115
Methionine:lysine	41	39
Methionine and cystine:lysine	59	58
Threonine:lysine	63	62
Tryptopahn:lysine	20.4	18.6
Valine:lysine	70	68
Total lysine, %	1.57	1.53
Net energy, kcal/kg	2,386	2,422
Crude protein, %	21.4	21.2
Calcium, %	0.77	0.68
Phosphorus, %	0.76	0.62
Available phosphorus, %	0.59	0.41

[1]Experimental diet were fed in two phases with dietary phases formulated for 7 to 11, and 11 to 20 kg BW ranges.

[2]International Ingredients, Inc., St. Louis, MO.

[3]Hamlet Protein, Findlay, OH.

[4]Provided per kilogram of premix: 26 g Mn from manganese oxide; 66 g Fe from iron sulfate; 88 g Zn from zinc sulfate; 11 g Cu from copper sulfate; 220 mg I from calcium iodate; and 198 mg Se from sodium selenite; 6,613,860 IU vitamin A; 1,468,277 IU vitamin D3; 44,092 IU vitamin E; 154 mg biotin; 1,102 mg folic acid; 2,205 mg pyridoxine; 6,614 mg riboflavin; 2,866 mg menadione; 22,046 mg pantothenic acid; 28,660 mg niacin; 6,614 mg thiamine; and 22 mg vitamin B12.

[5]Quantum 5000 (AB Vista, Plantation, FL) provided an estimated release of 0.14% available P.

[6]Quantum Blue 2G (AB Vista, Plantation, FL) provided an estimated release of 0.14% available P.

[7]Product 1 (Defusion; Provimi, Brookville, OH) was included at the expense of corn.

[8]Sodium metabisulfite was included at the expense of corn.

Table 4. DON analysis of experimental diets, experiment 1 (as-fed basis)[1]

Item	Control	Product 1[2]
DON, mg/kg		
Phase 1 diets	<0.5	<0.5
Phase 2 diets	<0.5	<0.5
Phase 3 diets	<0.5	<0.5

[1]Multiple samples were collected from each diet throughout the study, homogenized, and submitted to North Dakota Grain Inspection Service, Inc. (Bucyrus, OH) for analysis of DON as determined by the RIDASCREEN FAST DON SC ELISA test kit (R-Biopharm AG, Darmstadt, Germany).

[2]Product 1 (Defusion; Provimi, Brookville, OH).

with the lowest added Product 2 diets with pigs fed other diets intermediate.

On day 35, pigs either remained on their respective Product 1 or Product 2 diets or were switched to a diet without either of the SMB-containing additives. During this period, those pigs switched to diets without SMB had decreased ($P < 0.05$) ADG and ADFI compared with the pigs remaining on their respective Product 1 or Product 2, with those fed the control diet intermediate.

Overall, pigs fed Product 1 at the highest level had greater ($P < 0.05$) ADG and ADFI compared with pigs fed the control, with pigs fed the other diets intermediate. There was no evidence to indicate dietary treatment influenced G:F. Pigs fed the control diet had lower ($P < 0.05$) day 42 BW compared with the other dietary treatments. Pigs fed Product 1 at the highest level had greater ($P < 0.05$) day 42 BW compared with pigs fed the two lowest levels of Product 1, with pigs fed Product 2-containing diets intermediate.

Experiment 3

From days 0 to 21, pigs fed 0.25% SMB had decreased ($P < 0.05$) ADG compared with pigs fed the other diets (Table 9). Pigs fed Product 1 or 0.50% SMB had greater ($P < 0.05$) ADG compared with pigs fed the other diets. Pigs fed Product 1 or 0.50% SMB had greater ($P < 0.05$) ADFI compared with pigs fed the control diet, with pigs fed 0.25% SMB intermediate. Pigs fed 0.25% SMB had lower ($P < 0.05$) G:F than pigs fed the other dietary treatments. Pigs fed 0.50% SMB had greater ($P < 0.05$) G:F than pigs fed the control, with pigs fed Product 1 intermediate.

From days 21 to 28, pigs fed 0.25% SMB for the entire experiment had greater ($P < 0.05$) ADG compared with pigs fed the other diets. Pigs fed Product 1 had greater ($P < 0.05$) ADG compared with pigs

Table 5. DON analysis of experimental diets (as-fed basis), experiment 2[1]

	Control	Product added, %			
		Product 1[2]		Product 2[3]	
Days 0–7[4]	—	0.50	0.50	0.50	0.50
Days 7–21	—	0.25	0.25	0.25	0.50
Days 21–28	—	0.25	0.25	0.25	0.50
Days 28–35	—	0.25	0.15	0.25	0.25
Days 35–42	—	— 0.25	— 0.15	— 0.25	— 0.25
DON, mg/kg					
Days 0–7	—[4]	<0.5	<0.5	<0.5	<0.5
Days 7–21	1.4	<0.5	0.5	<0.5	<0.5
Days 21–28	1.1	0.9	1.0	0.9	1.1
Days 28–35	1.5	0.9	1.0	0.9	1.0
Days 35–42	1.3	1.3 1.3	1.3 1.0	1.3 0.8	1.3 0.9

[1]Multiple samples were collected from each diet throughout the study, homogenized, and submitted to North Dakota Grain Inspection Service, Inc. (Bucyrus, OH) for analysis of DON as determined by the ROSA DONQ2 Quantitative Test (Charms Sciences, Inc., Lawrence, MA).

[2]Product 1 (Defusion; Provimi, Brookville, OH).

[3]Product 2 (NutriQuest, Mason City, IA).

[4]Missing sample.

Table 6. DON analysis of experimental diets, experiment 3 (as-fed basis)[1]

	Control	Product added, %		
		Product 1[2]	Sodium metabisulfite	
Days 0–14	—	0.50	0.25	0.50
Days 14–21	—	0.50	0.25	0.50
Days 21–28	—	0.25	0.25	0.25
DON, mg/kg				
Days 0–14	<0.5	<0.5	<0.5	<0.5
Days 14–21	<0.5	< 0.5	<0.5	<0.5
Days 21–28	<0.5	<0.5	<0.5	<0.5

[1]Multiple samples were collected from each diet throughout the study, homogenized, and submitted to North Dakota Grain Inspection Service, Inc. (Bucyrus, OH) for analysis of DON as determined by ROSA DONQ2 Quantitative Test (Charms Sciences, Inc., Lawrence, MA).

[2]Product 1 (Defusion; Provimi, Brookville, OH).

fed the control diet, with pigs fed 0.50% SMB intermediate followed by 0.25% SMB. Pigs fed Product 1 had increased (P < 0.05) ADFI compared with pigs fed the control diet, with others intermediate. Pigs fed 0.25% SMB for the entire trial had greater (P < 0.05) G:F than pigs fed other diets.

From days 0 to 28, pigs fed Product 1 or 0.50% SMB had greater (P < 0.05) ADG compared with pigs fed 0.25% SMB or the control diet. Pigs fed Product 1 or 0.50% SMB had increased (P < 0.05) ADFI compared with pigs fed the control diet, with pigs fed the 0.25% SMB intermediate. Pigs fed 0.50% SMB had greater (P < 0.05) G:F than pigs fed the control diet, with those fed Product 1 intermediate. Pigs fed 0.25% SMB had lower (P < 0.05) G:F compared with pigs fed the other treatments. Pigs fed 0.50% SMB or Product 1 had greater (P < 0.05) day 28 BW than pigs fed the other dietary treatments.

DISCUSSION

DON analysis indicated that DON concentrations in experiments 1 and 3 were less than the detection limit of the tests used. On the basis of the Federal Grain Inspection Service guidelines, the lowest detection limit for the assays used in the analysis was 0.5 mg/kg (FGIS, 2015). Diets with SMB-based products would be expected to have slightly lower analyzed concentrations of DON relative to the control diets because of the DON binding capacity of the products (Frobose et al. 2015). This was evident in DON analysis in experiment 2, where treated feed with higher concentrations of Product 1 or Product 2 had decreased DON concentrations compared with the control diet. Pigs fed the control diet in experiment 2 were consistently exposed to DON concentrations greater than 1.1 mg/kg throughout the trial whereas pigs fed the Product 2 treatments were not exposed to DON concentration

Table 7. Effects of Product 1 on growth of nursery pigs, experiment 1[1]

Item	Control	Product 1[2]	SEM	P
Days 0−28				
ADG, g	303	365	4.7	<0.001
ADFI, g	403	443	5.0	<0.001
G:F, g/kg	751	822	6.0	<0.001
Days 28−35 (posttest)				
ADG, g	645	548	13.0	<0.001
ADFI, g	853	817	11.4	<0.002
G:F, g/kg	757	670	11.8	<0.001
Days 0−35				
ADG, g	371	401	4.9	<0.001
ADFI, g	492	517	5.5	<0.001
G:F, g/kg	753	775	5.3	<0.001
BW, kg				
Day 0	6.8	6.8	0.04	<0.921
Day 28	15.4	17.1	0.16	<0.001
Day 35	20.0	20.9	0.20	<0.001

[1]A total of 2,268 pigs (Line 337 × 1050; PIC) were used in a 35-d study. Pigs were weaned at approximately 22 d. On entry into the nursery, pigs were randomly sorted into 1 of 84 pens (42 pens of barrows, 42 pens of gilts), with one pen of gilts and one pen of barrows per fence line feeder. Pigs were blocked by BW and then randomly assigned to one of two dietary treatments in a completely randomized block design with 21 feeders per treatment. Experimental diets were fed from days 0 to 28 and a common diet was then fed from days 28 to 35.

[2]Product 1 (Defusion; Provimi, Brookville, OH).

Table 8. Effects of added Product 1 or Product 2 on growth of nursery pigs, experiment 2[1]

		Product added, %								
	Control	Product 1[2]		Product 2[3]						SEM
Days 0−7	—	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	
Days 7−21	—	0.25	0.25	0.25	0.25	0.25	0.25	0.50	0.50	
Days 21−28	—	0.25	0.25	0.25	0.25	0.25	0.25	0.50	0.50	
Days 28−35	—	0.25	0.25	0.15	0.15	0.25	0.25	0.25	0.25	
Days 35−42	—	—	0.25	—	0.15	—	0.25	—	0.25	
Days 0−35										
ADG, g	342[d]	382[ab]		365[c]		371[bc]		394[a]		7.8
ADFI, g	446[c]	490[ab]		478[b]		484[b]		502[a]		10.9
G:F., g/kg	766[ab]	780[ab]		765[b]		767[ab]		786[a]		5.7
Days 35−42										
ADG, g	728[abcd]	663[d]	780[ab]	672[cd]	770[abc]	684[bcd]	777[ab]	649[d]	794[a]	24.4
ADFI, g	1,027[bcd]	976[d]	1,089[ab]	969[d]	1,060[abc]	986[cd]	1,092[ab]	982[d]	1,127[a]	22.7
G:F., g/kg	709	679	718	694	726	697	709	660	709	20.3
Days 0−42										
ADG, g	404[d]	429[bc]	447[ab]	415[cd]	429[bc]	422[bcd]	437[abc]	436[abc]	460[a]	9.0
ADFI, g	540[d]	568[bcd]	592[ab]	558[cd]	568[bc]	567[bcd]	582[abc]	579[abc]	608[a]	12.2
G:F., g/kg	749	757	755	746	756	744	752	755	758	8.0
BW, kg										
Day 0	6.2	6.2		6.2		6.2		6.2		0.09
Day 35	18.3[d]	19.7[ab]		19.1[c]		19.3[bc]		20.1[a]		0.33
Day 42	23.5[f]	24.3[de]	25.2[ab]	24.1[e]	24.4[de]	24.1[e]	24.9[bc]	24.7[cd]	25.6[a]	0.34

[abcde]Means within a row with different superscripts differ $P < 0.05$.

[1]A total of 4,320 pigs (Line 337 × 1050; PIC) were used in a 42-d study. Pigs were weaned at approximately 22 d. On entry into the nursery, pigs were randomly sorted into 1 of 160 pens (80 pens of barrows, 80 pens of gilts), with one pen of gilts and one pen of barrows per fence line feeder. A pair of pens (feeders) were blocked by weight and then randomly assigned to one of five dietary treatments that were fed for 35 d in a completely randomized block design. Then on day 35, half of the pens receiving either Product 1 or Product 2 remained on those treatments and the other half were switched to the control diet. These combinations resulted in a total of nine treatments. There were 16 replications (feeders) for all treatments from days 0 to 35 and 8 replications per treatment from days 35 to 42 for all treatments except for the control, which continued to have 16 replications per treatment.

[2]Product 1 (Defusion; Provimi, Brookville, OH).

[3]Product 2 (NutriQuest, Mason City, IA).

Table 9. Effects of added sodium metabisulfite or Product 1 on growth of nursery pigs, experiment 3[1]

	Control	Product 1[2]	Product added, % Sodium metabisulfite		SEM
Days 0−21	—	0.50	0.25	0.50	
Days 21−28	—	0.25	0.25	0.25	
Days 0−21					
ADG, g	457[b]	482[a]	431[c]	483[a]	5.5
ADFI, g	589[b]	609[a]	592[ab]	608[a]	6.7
G:F, g/kg	776[b]	792[ab]	727[c]	796[a]	5.4
Days 21−28					
ADG, g	679[c]	700[b]	728[a]	697[bc]	6.1
ADFI, g	971[b]	1,000[a]	996[ab]	995[ab]	8.2
G:F, g/kg	700[b]	700[b]	731[a]	700[b]	4.9
Days 0−28					
ADG, g	512[b]	536[a]	505[b]	536[a]	4.6
ADFI, g	684[b]	706[a]	693[ab]	704[a]	6.2
G:F, g/kg	749[b]	759[ab]	729[c]	762[a]	3.3
BW, kg					
Day 0	7.0	7.0	7.0	7.0	0.07
Day 21	16.8[b]	17.3[a]	16.2[c]	17.3[a]	0.14
Day 28	21.6[b]	22.2[a]	21.3[b]	22.2[a]	0.16

[abc]Means within a row with different superscripts differ $P < 0.05$.

[1]A total of 2,808 pigs (Line 337 × 1050; PIC) were used in a 28-d study. Pigs were weaned at approximately 22 d. On entry into the nursery, pigs were randomly sorted into 1 of 104 pens (52 pens of barrows, 52 pens of gilts), with one pen of gilts and one pen of barrows per fence line feeder. Pigs were blocked by BW and then randomly assigned to one of four dietary treatments in a completely randomized block design with 13 feeders per treatment. Experimental diets were fed from days 0 to 28.

[2]Product 1 (Defusion; Provimi Brookville, OH).

greater than 1.1 mg/kg. Pigs fed Product 1 were not exposed to DON concentrations greater than 0.9 mg/kg until the last 7 d of the trial.

Previous research has indicated that pigs fed DON concentrations greater than 1 mg/kg will have reduced ADG and ADFI compared with pigs fed diets with lower DON concentration (Rotter et al., 1996; Forsyth et al., 1977; Eriksen and Pettersson, 2004). Frobose et al. (2015) observed that pigs fed diets with either 0.5 or 1.5 mg/kg DON had greater ADG and ADFI compared with pigs fed diets with 3 mg/kg DON. In our experiments, ADG and ADFI would have been minimally influenced by the DON concentration of the diets because all dietary DON concentrations were less than 1.5 mg/kg.

In the studies conducted by Frobose et al. (2015) and Mahan et al. (2010), ADG was improved when pigs were fed diets containing Product 1 with a dietary DON concentration of 3 or 4 mg/kg. Results of experiments 1, 2, and 3 agree with these studies because in both experiments pigs fed Product 1 had improved ADG. However, in contrast to the earlier research, diets in experiments 1 and 2 had DON concentrations that were less than 1.3 mg/kg. This is significant because it indicates that Product 1 improves growth performance of pigs fed diets with a low concentration of DON.

In experiment 2, pigs fed Product 2 for the longest duration and at the highest concentration had greater ADG compared with pigs fed Product 2 for a shorter duration and a lower concentration. This also agrees with the results of experiment 3 in which pigs fed SMB at the higher concentration had improved ADG compared with pigs fed a lower concentration of SMB. Overall this would suggest that pigs fed a higher concentration of SMB for a longer duration have improved growth performance, though further research should be conducted to determine the optimal concentration.

To the best of our knowledge, there is currently no research available that documents the effects of transitioning pigs that were fed diets containing an SMB additive to a diet without an SMB additive. In experiment 1, when pigs were transitioned to a common diet, pigs previously fed Product 1 had decreased ADG compared with pigs fed the control diet. In experiment 2, pigs previously fed Product 1 or Product 2, then switched to a control diet, had numerically lower ADG compared with pigs fed the control diet or pigs fed a diet that still contained Product 1 or Product 2. It is also interesting to note that pigs that were previously fed the highest inclusion of Product 2 numerically had the lowest ADG compared with pigs previously fed diets containing lower inclusions of Product 2. This reduction in ADG could be due to the transitioning pigs from a diet with less than 1 mg/kg DON to a diet with greater than 1 mg/kg DON. Further research should be conducted to evaluate the effects of transitioning pigs previously fed an SMB additive to a diet that does not contain an SMB additive.

In high-DON diets, the biological mechanism of SMB is suggested to be the chemical alteration of DON to a nontoxic DON-sulfonate adduct form (Frobose et al., 2015, 2017). However, in low-DON diets the biological mechanism of SMB is unclear. SMB is commonly used in the food industry as an antioxidant and antimicrobial agent; however, there is limited research available to document the effects of SMB on the microbiome of gut of the pig and feed. Previous research has indicated improvements in energy and protein utilization in broilers fed sorghum-based diets that were steam-pelleted with SMB (Selle et al., 2013, 2014; Truong et al., 2016). The biological mechanism of this improvement in protein and energy utilization is suggested to be the oxidative−reductive depolymerization of starch polysaccharides and the reduction of disulfide cross-linkages in proteins thus improving protein and starch availability (Truong et al., 2016). SMB has also shown some potential in the ability to reduce trypsin in soybean meal by the reduction of disulfide cross-linkages (Sessa and Ghantous, 1987; Wang et al., 2009). Overall, further research should be conducted to determine the biological mechanism of SMB in low-DON diets.

In conclusion, in diets relatively low in DON, pigs fed SMB-based feed additives had improved ADG compared with pigs fed a control diet. Furthermore, at the dietary concentrations of the product tested, greater inclusion and longer feeding duration resulted in the greatest benefit.

Conflict of interest statement. None declared.

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