Evaluating the effects of supplemental B vitamins in practical swine diets during the starter and grower-finisher periods A regional study

D. C. Mahan, S. D. Carter, T. R. Cline, G. M. Hill, S. W. Kim, P. S. Miller, J. L. Nelssen, H. H. Stein, T. L. Veum and The North Central Coordinating Committee On Swine Nutrition (NCCC-42)

J Anim Sci 2007.85:2190-2197.
doi: 10.2527/jas.2007-0118 originally published online Apr 27, 2007;

Evaluating the effects of supplemental B vitamins in practical swine diets during the starter and grower-finisher periods—A regional study[1,2]

D. C. Mahan,*[3] S. D. Carter,† T. R. Cline,‡ G. M. Hill,§ S. W. Kim,‖ P. S. Miller,** J. L. Nelssen,†† H. H. Stein,‡‡ T. L. Veum,§§ and the North Central Coordinating Committee on Swine Nutrition (NCCC-42)[4]

*The Ohio State University, Columbus 43210; †Oklahoma State University, Stillwater 74078; ‡Purdue University, West Lafayette, IN 47907; §Michigan State University, East Lansing 48824; ‖Texas Tech University, Lubbock 79409; **University of Nebraska, Lincoln 68583; ††Kansas State University, Manhattan 66506; ‡‡South Dakota State University, Brookings 57007; and §§University of Missouri, Columbia 65211

ABSTRACT: Two experiments were conducted to evaluate dietary fortification levels of a B vitamin premix for starter and grower-finisher pigs on subsequent performance responses. The objective was to determine whether the modern pig requires higher dietary levels of B vitamins than estimated by the NRC (1998). Both experiments added fat-soluble vitamins at the requirement levels (NRC, 1998) in all diets, whereas the B vitamins were added at 0, 100, 200, or 400% of the total NRC (1998) requirement levels for the starter and grower pig. ndigenous vitamin contributions from the feed grains were not included in the estimates. Each station used the same vitamin premixes but incorporated its own grain sources in the diets. The first experiment was conducted across 7 stations (Indiana, Ohio, Oklahoma, Michigan, Missouri, Nebraska, Texas) and involved 660 pigs in a randomized complete block design in 30 replicates. Complex nursery diets were fed in 2 phases. The first phase (0 to 14 d postweaning) and second phase (15 to 35 d postweaning) diets were formulated to Lys (total) levels of 1.50 and 1.30%, respectively. The results demonstrated no performance response to addition of B vitamins from 0 to 14 d postweaning, but performances increased quadratically ($P < 0.01$) to the 100% NRC level from 14 to 35 d postweaning and for the overall 35-d period. The second experiment was conducted across 3 stations (Ohio, Nebraska, and South Dakota) and involved 216 pigs in a randomized complete block design in 10 replicates. Corn-soybean meal mixtures were fed in 3 phases formulated to total Lys levels of 1.30% (23 to 55 kg of BW), 1.00% (55 to 85 kg of BW), and 0.78% (85 to 120 kg of BW). Pig performances increased ($P < 0.01$) to the 100% B vitamin level from 23 to 85 kg of BW, but there was no response to any level from 85 to 120 kg of BW. Carcass measurements demonstrated a greater LM area ($P < 0.01$) and a lower backfat depth ($P < 0.01$) to the 100% B vitamin level. One station evaluated an additional treatment (3 replicates) in which each replicate was fed a fifth diet containing the 100% dietary level of B vitamins from 23 to 85 kg of BW whereupon the B vitamins were removed from 85 to 120 kg of BW. This removal did not reduce pig performance responses for the final period or for the overall period. The results demonstrated that supplementation of B vitamins at the 100% total NRC levels for starter and grower pigs was sufficient to meet their needs, and there was no further improvement to or deleterious effect to greater dietary levels.

Key words: B vitamin, grow-finish, nursery, pig

J. Anim. Sci. 2007. 85:2190–2197
doi:10.2527/jas.2007-0118

INTRODUCTION

Vitamins are essential for the metabolism and maintenance of body tissue. Although functional roles differ, the B vitamins are generally involved in nutrient metabolism, increasing as feed intake increases, whereas the fat-soluble vitamins and ascorbic acid

[1]Salaries and research support were provided by state and federal funds appropriated to the various universities involved in the collaborative project.

[2]Appreciation is expressed to Akey (Lewisburg, OH) for supplying the vitamin premixes used in this project.

[3]Corresponding author: mahan.3@osu.edu

[4]Other committee members at the time of the study: G. L. Cromwell, University of Kentucky, Lexington; G. R. Hollis, University of Illinois, Urbana-Champaign; T. S. Stahly (deceased), Iowa State University, Ames; S. K. Baidoo, University of Minnesota, St. Paul; T. D. Crenshaw, University of Wisconsin, Madison. Administrative advisor: N. Merchen, University of Illinois, Urbana-Champaign.

Received February 22, 2007.
Accepted April 20, 2007.

needs are more constant, as they are involved in tissue growth processes and maintenance. Some B vitamins (e.g., niacin) are amply supplied in feed grains, but their bioavailabilities are often low, whereas other B vitamins (e.g., thiamine) have greater bioavailabilities. Folacin and biotin requirements can often be met by their indigenous levels in feed grains or they can be synthesized by the microbiota in the intestinal tract, where they are ultimately released by digestion and absorbed. Corn-soybean meal diets in the United States contain a riboflavin, pantothenic acid, niacin, and vitamin B_{12} premix for weanling and grower and finisher pigs. The NRC (1998) has established dietary B vitamin requirements, but their estimates include the contribution from indigenous feed sources. The B vitamin requirements have been established in experimental conditions with pigs of good health status and frequently with semipurified diets. Most studies were also conducted during an era when lean gains and growth rates were below those of the modern pig. Because of various factors affecting vitamin requirements, most professional nutritionists have increased their dietary B vitamin recommendations for swine above the NRC (1998) requirement levels, with minimal research to support such practices.

Because of the genetic improvement in muscling and leanness in recent decades, which may affect various nutritional requirements, we evaluated various levels of a B vitamin premix added to the diets of starter and grower-finisher pigs on their subsequent performance responses. Because feeding swine under different conditions could influence results, the study was conducted at several stations using similar protocols and vitamin premixes, but each used its own grain source.

MATERIALS AND METHODS

The experimental use of animals and the procedures followed for each experiment were approved by the Animal Care Committee of each university.

General

Two experiments were conducted: a nursery trial involving a total of 660 pigs in 30 replicates at 7 stations, and a grower-finisher trial with a total of 216 pigs in 10 replicates at 3 stations. Both experiments were conducted in a randomized complete block design. Experimental diets incorporated a fat-soluble vitamin premix (A, D, E, and K) that was added at the same level and formulated to meet the NRC (1998) requirements for the 2 experiments. The fat-soluble and B vitamin premixes were prepared at one central location (Akey Inc., Lewisburg, OH), kept in a cold room (Purdue University, West Lafayette, IN), and sent to investigators prior to initial diet preparation. Premixes were formulated to meet the requirements listed by the NRC (1998), disregarding the indigenous contributions of vitamins from the feedstuffs. Feed and water were provided ad libitum for all pigs during the experimental periods. Performance measurements (ADG, ADFI, and G:F) were collected for each pen at the various measurement periods, whereupon the data were combined for all periods to calculate overall performance measurements.

Exp. 1

The first experiment contained dietary B vitamin levels of 0, 100, 200, and 400% of NRC (1998) requirement levels for the 5-kg pig. The B vitamin premix contained (per kg of final diet mixture): biotin, 0.05 mg; folacin, 0.50 mg; niacin (available), 18.11 mg; pantothenic acid, 11.24 mg; riboflavin, 3.83 mg; thiamin, 1.00 mg; pyridoxine, 1.83 mg; and vitamin B_{12}, 19.51 μg.

Complex nursery diets were fed in 2 phases (i.e., during the 0- to 14-d and the 14- to 35-d postweaning periods). Feedstuffs that contributed indigenous vitamins to the diets during the 0- to 14-d period were corn, soybean meal, dried whey, and plasma protein, whereas the 14- to 35-d diets contained the same ingredients except that blood cells replaced plasma protein. The mixtures of ingredients were formulated to Lys (total) levels of 1.50 and 1.30% for the 2 phases, respectively. The B vitamin premix was added to treatment diets at the expense of corn. The mineral premixes and antibiotics used varied by station, but other nutrient levels met or exceeded NRC (1998) nutrient requirements, except for the experimental variable. The percentage composition of the negative control diets for both starter phases are presented in Table 1.

The study was conducted at 7 stations (Indiana, Ohio, Oklahoma, Michigan, Missouri, Nebraska, and Texas), with the number of replications ranging from 3 to 6 at each station. Weaning ranged from 14 to 22 d of age, pen space from 0.30 to 0.44 m^2/pig, and the number of pigs from 5 to 7/pen. Individual station conditions and overall pig performance responses for each station are presented in Table 2.

Exp. 2

The second experiment added the B vitamin premix to meet 0, 100, 200, or 400% of NRC (1998) requirements listed for the 20-kg pig. The pigs in this experiment had been fed nursery diets similarly formulated as in Exp. 1 from weaning to approximately 23 kg of BW, and the same B vitamin premix was incorporated at the 100% NRC level. The B vitamin premix used in the grower-finisher diets contained (per kg of final diet mixture): biotin, 0.05 mg; folacin, 0.30 mg; niacin (available), 11.22 mg; pantothenic acid, 8.50 mg; riboflavin, 2.78 mg; thiamin, 1.00 mg; pyridoxine, 1.23 mg; and vitamin B_{12}, 12.54 μg.

In addition to the 4 B vitamin treatments, one station added a fifth treatment group in each of 3 replicates, in which the pigs were fed the 100% B vitamin

Table 1. Composition of experimental basal diets (%, as-fed basis)

	Period, Exp. 1 and 2		Period, Exp. 2		
Item	0 to 14 d[1]	14 to 35 d[2]	23 to 55 kg[3]	55 to 85 kg[4]	85 to 120 kg[5]
Corn	34.89	48.11	66.77	78.45	85.45
Soybean meal, 48% CP	24.53	25.42	30.91	19.65	12.83
Plasma protein	6.00	—	—	—	—
Blood cells	—	2.00	—	—	—
Dried whey	20.00	20.00	—	—	—
L-Lys HCl	0.15	0.11	0.18	0.18	0.18
DL-Met	0.11	0.10	—	—	—
Lactose	10.00	—	—	—	—
Corn oil	1.00	1.00	—	—	—
Dicalcium phosphate	1.45	1.52	1.11	0.75	0.58
Limestone	0.89	0.76	0.73	0.67	0.66
Salt	0.35	0.35	0.25	0.25	0.25
Trace minerals[6]	+	+	+	+	+
Vitamin premix[7] (fat-soluble)	0.10	0.10	0.05	0.05	0.05
Vitamin B premix[8]	+	+	+	+	+
Antibacterial agent[9]	0.25	0.25	—	—	—
Antibiotic[10]	+	+	+	+	+
ZnO (72% Zn)	0.28	0.28	—	—	—

[1]Formulated to 1.50% Lys (total).
[2]Formulated to 1.30% Lys (total).
[3]Formulated to 1.30% Lys (total).
[4]Formulated to 1.00% Lys (total).
[5]Formulated to 0.78% Lys (total).
[6]Trace mineral premix compositions varied by station, but each met or exceeded NRC (1998) requirements and were added at the expense of corn.
[7]The fat-soluble vitamin premix was formulated to meet NRC (1998) requirements for vitamins A, D, E, and K.
[8]Added to treatment diets according to the treatment design at the expense of corn.
[9]Carbadox (Fibro, Fairfield, NJ) added at 55 mg/kg of diet.
[10]An antibiotic, when added, varied by station and was added at the expense of corn.

treatment from 23 to 85 kg of BW, but during the 85 to 120 kg of BW period the B vitamin premix was withdrawn from the diet and the pigs were fed the negative control diet.

At the end of the experiment, pigs were taken to a local abattoir and slaughtered. One station slaughtered all treatment pigs, whereas 2 stations randomly selected a similar number of pigs from each pen. Each station measured the LM area and backfat thickness at the 10th rib.

Diets provided during the grower-finisher period were formulated using corn-soybean meal mixtures and were provided in 3 phases. The first phase contained a Lys (total) level of 1.30% and was fed from

Table 2. Station conditions of starter pigs and overall station performance responses, Exp. 1

	Station No.							
Item	1	2	3	4	5	6	7	Total or average
No. of replicates	6	5	6	4	3	3	3	30
Pigs, total no.	168	100	120	80	72	60	60	660
Pigs/pen	7	5	5	5	6	5	5	5.4
Weaning age, d	21	19	21.6	20.5	14	14	21.4	
Pen space/pig, m^2	0.18	0.37	0.34	0.45	0.44	0.30	0.37	
BW, kg								
Initial	6.14	6.72	5.28	6.76	4.96	3.53	6.47	5.80
35 d	20.45	22.54	17.75	24.19	19.61	13.57	18.86	19.93
ADG, g								
0 to 14 d	279	273	214	313	107	154	211	233
14 to 35 d	496	598	451	622	245	376	446	478
ADFI, g								
0 to 14 d	381	427	282	317	186	218	305	317
14 to 35 d	897	1,019	717	1,065	406	587	674	801
G:F, g/kg								
0 to 14 d	734	664	760	1,005	577	706	700	629
14 to 35 d	557	595	629	587	603	640	665	605

Table 3. Station conditions and pig performance responses, Exp. 2

Item	Station 1	Station 2	Station 3	Total or average
No. of replicates	3	3	4	10
Pigs, total no.	60	96	48	216
Pigs/pen	6	8	3	5.6
Floor type	Partial concrete slats	Partial concrete slats	Fully slatted concrete	—
Space/pig, m^2	1.09	0.90	2.88	—
BW, kg				
Initial	23.7	22.0	24.0	23.3
Final	117.6	116.9	116.7	117.0
ADG, g	910	852	903	890
ADFI, kg	2.61	2.34	2.54	2.50
G:F, g/kg	349	364	357	357
Carcass data				
Backfat, mm	20.3	18.3	18.4	18.9
LM area, cm^2	45.0	43.2	53.3	47.8

23 to 55 kg of BW, the second phase contained 1.00% Lys (total) and was fed from 55 to 85 kg of BW, and the third phase contained 0.78% Lys (total) on an as-fed basis and was fed from 85 to 120 kg of BW or to the end of the experiment. Other nutrient needs and antibiotic sources varied by station, but all diets met or exceeded NRC (1998) nutrient requirements, except for the B vitamin variable. The B vitamin premix was added at the expense of corn. The negative control diets for each grower-finisher period are presented in Table 1.

The study was conducted with a total of 216 pigs in 10 replicates in a randomized complete block design at 3 stations (Ohio, Nebraska, South Dakota). Pigs were housed in complete confinement, and pen space ranged from 0.90 to 2.88 m^2/pig, with the number of pigs ranging from 3 to 8/pen. Experimental conditions and overall performance and carcass measurement responses for each station are presented in Table 3.

Analysis

The data were analyzed using the experimental design procedures outlined by Steele and Torrie (1980) and the GLM procedure (SAS Inst. Inc., Cary, NC). The pen was considered the experimental unit in both experiments.

RESULTS

The effects of B vitamins added to the diets of nursery pigs (Table 4) demonstrated no treatment responses during the initial 14-d postweaning on ADG, ADFI, or G:F. Pig BW were less ($P < 0.01$) at 35 d when pigs were fed the negative control compared with those fed the B vitamin-fortified diets. Consequently, during the 14- to 35-d period there was a quadratic improvement in ADG ($P < 0.05$) and G:F ($P < 0.01$) in response to B vitamin addition. For the overall 35-d nursery period, ADG ($P < 0.01$), ADFI ($P < 0.05$), and G:F ($P < 0.05$) improved in a quadratic manner in response to B vitamin addition.

The grower-finisher pigs of Exp. 2 had been fed the B vitamin level at the 100% NRC (1998) requirement level during their starter period for 35 d. Consequently, when treatments were imposed on the pigs (i.e., 23 kg of BW), the animals initially had similar body vitamin reservoirs within each treatment group. The responses reported in Table 5 demonstrate a quadratic ($P < 0.05$) increase in BW, when pigs reached 55 kg in response to B vitamin fortification levels. This resulted in improved ADG ($P < 0.05$), ADFI ($P < 0.05$), and G:F ($P < 0.05$) during the 23 to 55 kg of BW period. The plateau appeared to occur at the 100% B vitamin level, with no further improvement for any perfor-

Table 4. Effect of B vitamin addition on postweaning pig performance, Exp. 1[1]

Item	NRC, % 0	100	200	400	SEM
BW, kg[2]					
14 d	8.98	9.18	8.91	9.06	0.08
35 d	18.66	20.05	19.80	19.77	0.16[3]
ADG, g					
0 to 14 d	217	231	217	221	4
14 to 35 d	422	477	477	471	6[3]
0 to 35 d	340	379	374	372	4[3]
ADFI, g					
0 to 14 d	292	322	295	301	7
14 to 35 d	752	768	773	773	12
0 to 35 d	569	590	586	585	8[4]
G:F, g/kg					
0 to 14 d	747	723	736	735	12
14 to 35 d	572	628	629	613	8[3]
0 to 35 d	605	644	644	636	6[4]

[1]Each mean represents 30 treatment pens (an average of 5.4 pigs/pen).
[2]Average initial BW of the pigs on the experiment was 5.70 kg.
[3]Quadratic response, $P < 0.01$.
[4]Quadratic response, $P < 0.05$.

Table 5. Effect of B vitamins additions on grower-finisher pig performance, Exp. 2[1]

	NRC, %				
Item	0	100	200	400	SEM
Final BW, kg[2]					
Phase 1	51.6	55.4	53.7	53.4	1.2[3]
Phase 2	80.3	88.0	89.2	88.3	1.0[4]
Phase 3	109.2	118.8	120.0	120.0	1.2[4]
ADG, g					
23 to 55 kg of BW	775	818	827	826	15[3]
55 to 85 kg of BW	804	967	994	974	19[4]
85 to 120 kg of BW	935	952	948	963	28
Overall	826	900	914	912	12[4]
ADFI, kg					
23 to 55 kg of BW	1.62	1.70	1.71	1.75	0.03[3]
55 to 85 kg of BW	2.33	2.78	2.71	2.76	0.05[4]
85 to 120 kg of BW	3.14	3.35	3.28	3.33	0.05
Overall	2.34	2.55	2.51	2.57	0.03[4]
G:F, g/kg					
23 to 55 kg of BW	477	482	484	471	5[3]
55 to 85 kg of BW	345	348	368	353	6
85 to 120 kg of BW	298	284	289	289	8
Overall	353	353	365	355	5
Backfat thickness, mm	17.2	20.6	19.2	18.9	0.9[4]
LM area, cm^2	42.6	48.3	49.9	47.9	1.0[4]

[1]Each mean for the performance data represents 10 treatment pens (an average of 5.6 pigs/pen).
[2]Average initial BW of pigs on experiment was 23.2 kg.
[3]Quadratic response, $P < 0.05$.
[4]Quadratic response, $P < 0.01$.

mance trait when higher dietary supplemental B vitamin levels were provided.

From 55 to 85 kg of BW, B vitamin supplementation resulted in an increased BW ($P < 0.01$), and a concurrent increase in ADG ($P < 0.01$) and ADFI ($P < 0.01$). For the latter finisher period (i.e., 85 to 120 kg of BW), there was no effect from vitamin B treatment levels on pig performance responses. Although pigs fed the negative control diet had a lower BW ($P < 0.01$) and undoubtedly a lower body reservoir of B vitamins at 85 kg of BW, this had no apparent effect on performance responses from 85 to 120 kg of BW. In the one station that had withdrawn the B vitamins during the latter finisher phase, the ADG responses were similar to those of the other treatment groups (Figure 1). However, when pigs were fed the negative control diet throughout the 23- to 120-kg period, and then compared with the group in which the B vitamins were withdrawn during the 85 to 120 kg of BW period, those pigs fed the negative control diet from 23 to 120 kg of BW differed from the group in which the B vitamins were withdrawn from the diet during the 85 to 120 kg of BW period (Figure 2).

Carcass data from the treatment groups (Table 5) suggested that the addition of B vitamins resulted in improved lean tissue deposition and that it appeared to plateau at the 100% B vitamin level. This response resulted in a greater ($P < 0.01$) LM area when B vitamins were supplemented, compared with the negative control without vitamin B supplementation. When B vitamins were eliminated only during the last phase of the grower-finisher study, the LM area was greater ($P < 0.05$) than when the negative control had been fed for the entire experimental period (39.0 vs. 44.6 cm^2). Pigs not provided with supplemented B vitamin

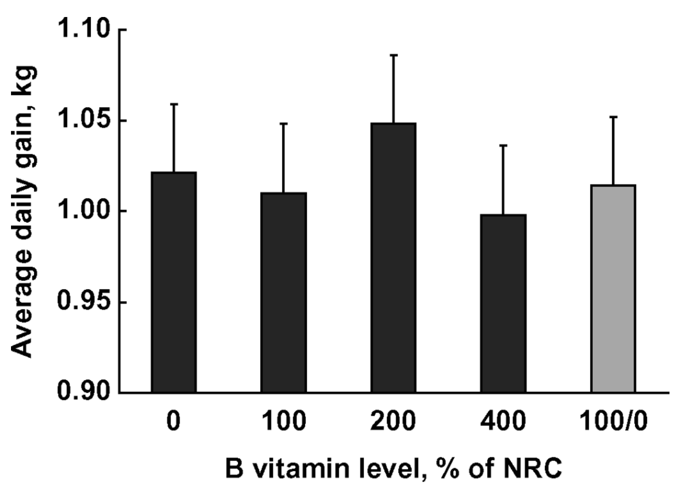

Figure 1. Treatment ADG responses to B vitamin supplementation from 85 to 120 kg of BW. Treatments: B vitamin level at 0, 100, 200, or 400% of NRC requirements and provided from 23 to 120 kg of BW; the 100/0% treatment diet contained 100% of the NRC B vitamins from 23 to 85 kg of BW, and the vitamin premix was withdrawn from 85 to 120 kg of BW. No treatment responses were noted (SEM = 0.05).

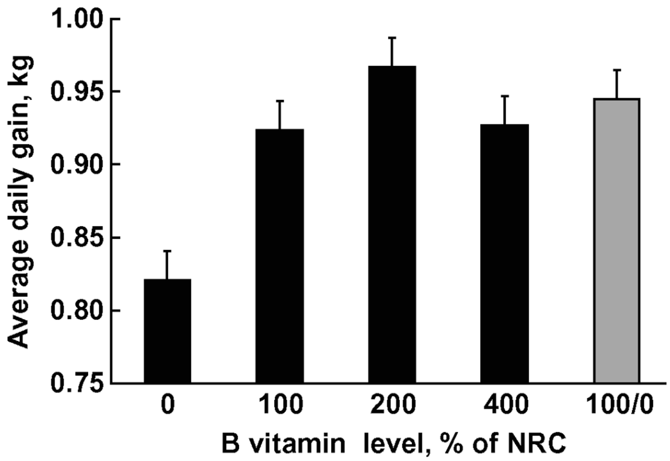

Figure 2. Treatment ADG responses to B vitamin supplementation from 25 to 120 kg of BW. Treatments: B vitamin level at 0, 100, 200, or 400% of NRC requirements and provided from 23 to 120 kg of BW; the 100/0% treatment diet contained 100% of the NRC B vitamins from 23 to 85 kg of BW, and from 85 to 120 kg of BW the vitamin premix was withdrawn. Treatment responses differed, $P < 0.01$ (SEM = 0.02).

from 23 to 120 kg of BW had lower backfat thickness measurements ($P < 0.01$).

DISCUSSION

B vitamin fortification of corn-soybean meal diets and the positive effects on pig performance have long been recognized (Krider et al., 1948; McMillen et al., 1948). Our objective was to evaluate whether the modern pig fed conventional diets at different experimental stations would respond to greater dietary B vitamin fortification levels than estimated by the current NRC (1998) publication. Our results clearly confirmed the necessity of adding B vitamins to the diets of weanling and grower-finisher pigs, but the 100% NRC level was sufficient to meet the pig's needs, and additional B vitamins do not appear necessary. Dietary levels beyond the 100% NRC level were, however, not detrimental to pig performance.

The dietary B vitamin fortification level used in our starter pig trial was set at the requirement of the 5-kg pig, whereas for the grower-finisher study they were set for the 20-kg pig. Consequently, our 100% dietary level was generally greater than the NRC (1998) requirements for pigs at heavier BW within each production phase. In addition, our 2 experiments did not consider the indigenous contribution of B vitamins from the various feed sources. The indigenous vitamins in the feed grains or those present in pig tissues at the start of an experiment may be important in determining their requirements within a production phase.

Calculation of the nursery diets with the basal feedstuffs (excluding plasma protein and blood cells) indicated that the indigenous B vitamins in the feed grains (Table 6), tissue reserves in the pigs at weaning, or the lower growth rate of pigs immediately postweaning, either independently or collectively, provided an adequate supply of B vitamins for a short time postweaning, such that no performance response resulted from B vitamin supplementation. However, for the latter 21 d and for the overall 35-d nursery period, supplemental B vitamins were clearly essential. Riboflavin and vitamin B_{12} from the basal feeds were calculated to be below the estimated requirement (Table 6). It is possible, however, that because the vitamin analyses of all feed products were not available, plasma protein and red blood cells provided some B vitamins, particularly B_{12}. The dietary necessity of vitamin B_{12} and its prevention of pernicious anemia (West, 1948), and recent research with positive growth responses to supplemental B_{12} (Blodgett et al., 2003; Albrecht et al., 2006) confirm its essentiality in modern nursery diets.

During the grower-finisher period, all pigs had been fed nursery diets fortified with the 100% NRC level of B vitamins for a 35-d period. Although there were probably some tissue reserves of B vitamins when the pigs were placed on the grower diet, either their reservoirs were inadequate, their growth rates and tissue development were greater than the amount these reservoirs could provide, or the indigenous B vitamins in the feeds or tissue reserves were collectively inadequate to meet the vitamin B needs from 23 to 55 kg of BW. Calculation of the grower-finisher diets demonstrated that they did not provide adequate amounts of pantothenic acid, riboflavin, or vitamin B_{12}, and most probably niacin. Hughes (1939) has demonstrated the necessity of adding riboflavin to pig diets. Pantothenic acid bioavailability is considered low in corn (Southern and Baker, 1981), but not in barley, wheat, and soybean meal (Dove and Cook, 2001). Although the bioavailability of many B vitamins is not known in corn-soybean meal diet mixtures, the niacin content in ground raw corn is considered to be unavailable for the young pig (Kodicek et al., 1959; Luce et al., 1967) and may limit the performance response (Blodgett et al., 2002). Other B vitamins (i.e., biotin, choline, folacin pyridoxine, and thiamine) had indigenous dietary levels substantially greater than the dietary requirement and may not have been nutritionally limiting (Table 6). The bioavailabilities of the various B vitamins are not completely known for the grower-finisher pig.

Although indigenous levels in grains could vary, the response we obtained from conducting the trial at several stations, in which each station used its own feed grain sources, implies that the indigenous vitamins in each of the feed sources were at least within a range at which none of the stations reported responses above that of the 100% vitamin B level (data not included).

We added all of the B vitamins listed in the NRC (1998) publication to our experimental premix, and therefore cannot identify whether the response could

Table 6. Average NRC (1998) dietary requirement levels for starter and grower-finisher pigs, and the endogenous B vitamin (calculated) content provided in the basal diets[1]

B vitamin, quantity/kg of diet	Nursery			Grower-finisher			
		Diet contribution[2]			Diet contribution		
	NRC	0 to 14 d	14 to 35 d	NRC	23 to 55 kg	55 to 85 kg	85 to 120 kg
Biotin, mg	0.05	0.14	0.15	0.05	0.12	0.10	0.08
Choline, g	0.45	1.25	1.36	0.35	1.26	1.02	0.88
Folacin, mg	0.30	0.56	0.59	0.30	0.52	0.39	0.30
Niacin, mg	13.75	15.8	19.1	8.5	22.8	23.2	23.3
Pantothenic acid, mg	9.5	15.2	16.1	8.0	8.6	7.7	7.1
Pyridoxine, mg	1.50	3.4	3.9	1.20	4.0	3.61	3.4
Riboflavin, mg	3.25	1.8	2.0	2.25	1.8	1.6	1.4
Thiamine, mg	1.00	7.4	7.9	1.00	3.3	3.4	3.4
Vitamin B_{12}, μg	16.25	0.8	0.8	10.00	0	0	0

[1]Composition values calculated from NRC (1998) tables.
[2]Values do not include the vitamin contribution from plasma protein or blood cells.

be attributed to specific B vitamins or their combination, or whether they differed by station. We would suspect, however, that many of the B vitamins may have been adequately provided from indigenous levels in the feeds or from microbiological synthesis in the digestive tract.

The pigs in the grower-finisher study responded to B vitamin supplementation from 23 to 85 kg of BW, but the response thereafter was minimal. During the latter part of the finisher period, the data (Table 4) from the negative control group suggested that the indigenous levels in the basal diet were adequate to meet the pig's requirement for B vitamins. Consequently, providing the 100% treatment level not only may have met the needs of pigs from 23 to 85 kg of BW, but also may have oversupplied the B vitamins that were needed to achieve maximum performance. Consequently, during the 85 to 120 kg of BW period, when muscle accretion is generally thought to decline, the need for the B vitamins appeared to be less than during the earlier growth periods. Muscle growth was, however, shown to increase with B vitamin supplementation to the 100% supplemental level, as reflected by the greater LM area (Table 4). Inadequate B vitamin supplementation also resulted in increased body fat measurements and lowered muscle deposition.

The withdrawal of the B vitamins from the 85 to 120 kg of BW period had little or no effect on performance responses (Table 4). These responses confirm the observations of others (Mavromichalis et al., 1999; McGlone, 2000; Edmonds and Arentson, 2001), but there was an effect when withdrawal occurred for the entire experiment. Our results imply that the B vitamin requirements (NRC, 1998) during the finisher period need to be more clearly established.

In conclusion, these results demonstrate that although the indigenous contribution of B vitamins may not be considered in most diet formulations, they may be important in meeting the pig's B vitamin requirements. Our results suggest that providing a B vitamin premix that meets 100% of the total estimated requirement level set by the NRC (1998) should be more than adequate to meet the modern pig's need for B vitamins to attain maximum performance and lean tissue accretion responses. Although greater dietary levels appear unnecessary, they also are not detrimental. Withdrawal of B vitamins during the latter part of the finisher period did not produce any deleterious effect on pig performance, but the pig's tissue reserves and the indigenous dietary supply of B vitamins may have provided adequate fortification to maintain growth performance. Our results suggest that the estimated (NRC, 1998) requirements for the B vitamins are adequate from weaning to 85 kg of BW, that the needs vary at different phases of the growth cycle, and that the requirements from 85 to 120 kg need to be further examined.

LITERATURE CITED

Albrecht, L., R. Fischer, and P. Miller. 2006. Effects of feeding increased concentrations of vitamin B_{12} on growth performance in weanling pigs. J. Anim. Sci. 84(Suppl. 2):124. (Abstr.)

Blodgett, S. S., P. S. Miller, A. J. Lewis, and R. L. Fischer. 2002. Response of weanling pigs to niacin and vitamin B_{12} supplementation. J. Anim. Sci. 80(Suppl. 2):69. (Abstr.)

Blodgett, S. S., P. S. Miller, and R. L. Fischer. 2003. Vitamin B_{12} requirement of weanling pigs. J. Anim. Sci. 81(Suppl. 2):77. (Abstr.)

Dove, C. R., and D. A. Cook. 2001. Water soluble vitamins in swine nutrition. Pages 317–355 in Swine Nutrition. 2nd ed. A. J. Lewis and L. L. Southern, ed. CRC Press, Boca Raton, FL.

Edmonds, M. S., and B. E. Arentson. 2001. Effects of supplemental vitamins and trace minerals on performance and carcass quality in finishing pigs. J. Anim. Sci. 79:141–147.

Hughes, E. H. 1939. The role of riboflavin and other factors of the vitamin-B complex in the nutrition of the pig. J. Nutr. 17:527–533.

Kodicek, E. T., R. Braude, S. K. Kon, and K. G. Mitchell. 1959. The availability to pigs of nicotinic acid in tortilla baked from maize treated with limewater. Br. J. Nutr. 13:363–384.

Krider, J. L., D. E. Becker, R. F. Van Poucke, and M. F. James. 1948. Crystalline or crude concentrates of B-vitamins supplement a corn-soybean meal ration for weanling pigs in drylot. J. Anim. Sci. 7:501–508.

Luce, W. G., E. R. Peo Jr., and D. B. Hudman. 1967. Availability of niacin in corn and milo for swine. J. Anim. Sci. 26:76–84.

Mavromichalis, I., J. D. Hancock, I. H. Kim, B. W. Senne, D. H. Kropf, G. A. Kennedy, R. H. Hines, and K. C. Behnke. 1999. Effects of omitting vitamin and trace mineral premixes and(or) reducing inorganic phosphorus additions on growth performance, carcass characteristics, and muscle quality in finishing pigs. J. Anim. Sci. 77:2700–2708.

McGlone, J. J. 2000. Deletion of supplemental minerals and vitamins during the late finishing period does not affect pig weight gain and feed intake. J. Anim. Sci. 78:2797–2800.

McMillen, W. N., R. W. Luecke, and F. Thorp Jr. 1948. The effect of liberal B-vitamin supplementation on growth of weanling pigs fed rations containing a variety of feedstuffs. J. Anim. Sci. 7:518–523.

NRC (National Research Council). 1998. Nutrient Requirements of Swine. 10th ed. Natl. Acad. Press, Washington, DC.

Southern, L. L., and D. H. Baker. 1981. Bioavailable pantothenic acid in cereal grains and soybean meal. J. Anim. Sci. 51:403–408.

Steel, R. G. D., and J. H. Torrie. 1980. Principles and Procedures of Statistics: A Biometrical Approach. 2nd ed. McGraw-Hill Publishing Co., New York, NY.

West, R. 1948. Activity of vitamin B_{12} in Addison's pernicious anemia. Science 107:398.