Added dietary pyridoxine, but not thiamin, improves weanling pig growth performance[1,2]

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ABSTRACT: We conducted two trials to determine the effects of added dietary pyridoxine (vitamin B_6) or thiamin (vitamin B_1) on growth performance of weanling pigs. In Exp. 1, weanling pigs (n = 180, initially 5.55 ± .84 kg, and 21 ± 2 d of age) were fed either a control diet (no added pyridoxine or thiamin) or the control diet with added thiamin (2.8 or 5.5 mg/kg) from thiamin mononitrate or pyridoxine (3.9 or 7.7 mg/kg) from pyridoxine HCl. These five diets were fed in meal form in two phases (d 0 to 14 and 14 to 35 after weaning), with identical vitamin concentrations in both phases. From d 0 to 14 after weaning, pigs fed added pyridoxine had increased (quadratic, $P < .05$) ADG and ADFI; pigs fed 3.9 mg/kg of added pyridoxine had the greatest improvement. From d 14 to 35 and 0 to 35, ADG and ADFI increased (linear $P = .06$) for pigs fed increasing pyridoxine. Growth performance was not improved by added thiamin. In Exp. 2, weanling pigs (n = 216, initially 6.08 ± 1.13 kg, and 21 ± 2 d of age) were fed a control diet or the control diet with 1.1, 2.2, 3.3, 4.4, or 5.5 mg/kg of added pyridoxine from pyridoxine HCl. From d 0 to 14 after weaning, increasing pyridoxine increased (quadratic, $P < .05$) ADG and ADFI; pigs fed 3.3 mg/kg of added pyridoxine had the greatest ADG and ADFI. Break-point analysis suggested a requirement estimate of 3.3 and 3.0 mg/kg of added pyridoxine to maximize ADG and ADFI, respectively. From d 14 to 35 or 0 to 35, increasing pyridoxine had no effect ($P > .10$) on pig growth performance. These results suggest that adding 3.3 mg/kg of pyridoxine (7.1 to 7.9 mg/kg of total pyridoxine) to diets fed from d 0 to 14 after weaning can improve pig growth performance.

Key Words: Pigs, Growth, Vitamins, Pyridoxine, Thiamin

J. Anim. Sci. 2000. 78:88–93

Introduction

Thiamin and pyridoxine have important roles in amino acid, carbohydrate, and fatty acid metabolism and also play a major role in the energy-producing citric acid cycle (McDowell, 1989). Although the need for these vitamins in swine diets is recognized, they are usually not supplemented to swine diets because of their abundance in feedstuffs. The current estimated requirements (NRC, 1998) for 5- to 20-kg pigs for pyridoxine and thiamin are 1.5 and 1.0 mg/kg, respectively. The pyridoxine and thiamin concentrations of corn, soybean meal, and dried whey, the principal ingredients in most diets of weanling pigs, range from 4 to 6.4 mg/kg and 3.2 to 4.1 mg/kg, respectively (NRC, 1998). Yen et al. (1976) determined the bioavailabilities of pyridoxine in corn and soybean meal to be 38 to 45% and 58 to 62%, respectively. Therefore, most corn-soybean meal-dried whey-based deits for weanling pigs should contain adequate pyridoxine and thiamine if the requirement is accurate. Reliability of the estimated requirements is questionable, however, because of the limited number of studies involved and because results of these early studies may not be applicable today due to advances in genetic selection and production systems that result in fast-growing, lean pigs weaned at an early age. Although some data suggest no benefit from added thiamin or pyridoxine in swine diets (Newcomb and Allee, 1986; Wilson et al., 1993), several industry professionals are recommending adding these two vitamins to weanling pig diets (BASF, 1994). Our objective was to evaluate the effects of added thiamin or pyridoxine on the growth performance of the weanling pigs fed corn-soybean meal-based diets typical of those fed today.

Materials and Methods

Animals and Facilities. Two experiments were conducted at the Kansas State University Swine Teaching

[1]Contribution no. 99-82-J of the Kansas Agric. Exp. Sta., Manhattan 66506.

[2]The authors thank Daiichi Pharmaceutical Company LTD, Tokyo, Japan, for partial financial support for these experiments, Mark Bienhoff, ADM Animal Health, Des Moines, IA, for providing the pyridoxine HCl and thiamin mononitrate, and Errol Bassoo, St. Joseph's Health Centre, London, Ontario, Canada, for the vitamin analysis.

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Received September 18, 1998.

Accepted June 21, 1999.

and Research Center. The experimental protocols used in these studies were approved by the Kansas State University Animal Care and Use Committee. Pigs (PIC line C22 × 326) were blocked by initial weight, equalized for sex (three barrows and three gilts per pen) and litter, and allotted randomly to their respective dietary treatments. Creep feed was not offered to the pigs while nursing. After weaning, pigs were housed in an environmentally controlled nursery in 1.22- × 1.52-m pens with woven wire flooring and had ad libitum access to feed and water. Initial temperature of the nursery was 34°C and the temperature was reduced approximately 1.5°C each week thereafter. Pigs were weighed and feed disappearance was determined weekly after weaning to calculate ADG, ADFI, and gain:feed ratio.

Experiment 1. Weanling pigs (n = 180, initially 5.55 ± .84 kg, and 21 ± 2 d of age) were used in a 35-d growth trial to determine the effects of added thiamin or pyridoxine on starter pig growth performance. At weaning, pigs were allotted to one of five experimental treatments with six pigs per pen and six replications (pens) per treatment.

All diets were fed in meal form. Diets fed from d 0 to 14 after weaning were formulated to contain 1.6% total lysine, .44% methionine, .90% Ca, and .80% P (Table 1). Diets fed from d 14 to 35 were formulated to contain 1.35% total lysine, .38% methionine, .85% Ca, and .75% P. All diets contained a vitamin premix formulated to contain three to four times NRC (1988) requirement estimates for most vitamins considered essential additions to swine diets (Table 1), but they did not include thiamin and pyridoxine. Experimental treatments were formulated by adding either thiamin mononitrate (providing 2.8 or 5.5 mg/kg of added thiamin) or pyridoxine HCl (providing 3.9 or 7.7 mg/kg of added pyridoxine) to the control diet. The added vitamin concentrations were selected to represent the range of thiamin and pyridoxine additions observed in commercial swine diets (BASF, 1994). Pigs were fed the same experimental vitamin concentrations throughout the 35-d study.

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

Ingredient, %	Day 0 to 14[b]	Day 14 to 35[c]
Corn	41.80	50.72
Dried whey	20.00	10.00
Soybean meal (46.5% CP)	19.62	26.94
Spray-dried animal plasma	5.00	—
Soybean oil	5.00	5.00
Select menhaden fish meal	2.55	—
Spray-dried blood meal	1.75	2.50
Monocalcium phosphate	1.20	1.66
Medication[d]	1.00	1.00
Limestone	.80	.98
Zinc oxide	.38	.25
Vitamin premix[e]	.25	.25
Salt	.20	.25
L-Lysine HCl	.15	.15
Trace mineral premix[f]	.15	.15
DL-Methionine	.15	.15

[a]In Exp. 1, diets contained added thiamin (2.8 or 5.5 mg/kg from thiamin mononitrate) or pyridoxine (3.9 or 7.7 mg/kg from pyridoxine HCl), and in Exp. 2, diets contained added pyridoxine (1.1, 2.2, 3.3, 4.4, and 5.5 mg/kg) at the expense of corn.

[b]Diets were formulated to contain 1.60% lysine, .44% methionine, .90% Ca, and .80% P and were fed from d 0 to 14 after weaning.

[c]Diets were formulated to contain 1.35% lysine, .38% methionine, .85% Ca, and .75% P and were fed from d 14 to 35. Vitamin additions were identical to those from d 0 to 14.

[d]Provided 55 mg/kg of carbadox.

[e]Provided per kg of complete feed: 11,024 IU vitamin A; 1,653 IU vitamin D_3; 44.1 IU vitamin E; 4.4 mg menadione; 9.92 mg riboflavin; 33.1 mg pantothenic acid; 55.1 mg niacin; and .04 mg vitamin B_{12}.

[f]Provided per kg of complete feed: 39.7 mg Mn; 165.4 mg Fe; 165.4 mg Zn; 16.5 mg Cu; .30 mg I; and .30 mg Se.

Table 2. Analyzed thiamin and pyridoxine concentrations, mg/kg (Exp. 1)[a]

		Added thiamin, mg/kg		Added pyridoxine, mg/kg	
Item	Control	2.8	5.5	3.9	7.7
Day 0 to 14					
Thiamin	2.4	4.7	8.0	2.7	2.5
Pyridoxine	4.3	3.8	3.1	7.1	9.4
Day 14 to 35					
Thiamin	3.5	6.8	10.2	2.7	2.5
Pyridoxine	3.1	3.9	4.3	5.6	7.9

[a]Values (as-fed basis) represent the mean of two analyses (two commercial laboratories, one analyzed in duplicate and the other in triplicate) conducted on a composite sample.

Experiment 2. Weanling pigs (n = 216; initially 6.08 ± 1.13 kg, and 21 d of age) were used in a 35-d growth trial to determine the level of pyridoxine required to maximize growth performance. Pigs were allotted to one of six treatments with six pigs per pen and six replications (pens) per treatment.

The control diet was identical in composition to that used in Exp. 1 (Table 1), but different lots (batches) of ingredients were used. Additions of pyridoxine HCl to provide 1.1, 2.2, 3.3, 4.4, or 5.5 mg/kg of added pyridoxine formed the experimental treatments. Housing, management, and data collection procedures were identical to those of Exp. 1. Feed samples from both experiments were collected and analyzed for CP and for concentrations of thiamin (Exp. 1) and pyridoxine (Exp. 1 and 2; AOAC, 1990). For each experimental diet, several samples were collected and pooled, this composite sample was subdivided and sent to two commercial laboratories for vitamin analysis (analyzed in duplicate or triplicate). Total vitamin concentrations for Exp. 1 and 2 are presented in Tables 2 and 3, respectively.

Statistical Analyses. Data were analyzed as a randomized complete block design with pen as the experimental unit. Pigs were blocked on the basis of initial weight and analysis of variance was performed using the GLM procedure of SAS (1985). Linear and quadratic polynomials were used to evaluate the effects of increasing thiamin and pyridoxine concentrations (Peterson, 1985). In Exp. 2, break-point analysis was conducted to estimate the pyridoxine requirement by fitting a one-

Table 3. Analyzed pyridoxine concentration, mg/kg (Exp. 2)[a]

	Added pyridoxine, mg/kg					
Pyridoxine	0	1.1	2.2	3.3	4.4	5.5
Day 0 to 14	3.5	5.5	7.5	7.9	8.8	12.3
Day 14 to 35	4.5	5.7	7.3	8.4	9.4	12.9

[a]Values (as-fed basis) represent the mean of two analyses (two commercial laboratories, one analyzed in duplicate and the other in triplicate) conducted on a composite sample.

slope, broken-line regression model to the data (Robbins, 1986).

Results

Crude protein analyses of diet samples were similar to calculated values. Analyzed CP values in Exp. 1 were 21.23% ± .61 and 19.66% ± .76 for diets fed from d 0 to 14 and 14 to 35, respectively. Analyzed CP values in Exp. 2 were 21.96% ± .52 and 19.81% ± 1.23 for diets fed from d 0 to 14 and 14 to 35, respectively. Analyzed concentrations of thiamin and pyridoxine increased with increasing supplementation (Tables 2 and 3).

Experiment 1. From d 0 to 14 after weaning, ADG was lowest for pigs fed 2.8 mg/kg of added thiamin, but it was similar between those fed the control diet and 5.5 mg/kg of added thiamin (quadratic, $P < .0001$; Table 4). We have no explanation for the poor growth performance exhibited by pigs fed 2.8 mg/kg of added thiamin in our study. The poor growth performance was consistent among all six observations for that treatment.

Average daily gain increased with 3.9 mg/kg of added pyridoxine but was not further improved with 7.7 mg/kg of added pyridoxine (quadratic, $P < .03$). Average daily feed intake increased with the lower supplements of thiamin and pyridoxine but decreased with the higher supplements (quadratic, $P < .10$ and .02, respectively). However, gain:feed ratio decreased then returned to control values (quadratic, $P < .0001$) with increasing thiamin. This seemed to be a result of the high feed intake and poor growth of pigs fed 2.8 mg/kg of added thiamin. Gain:feed ratio was unaffected ($P > .10$) by pyridoxine.

From d 14 to 35 after weaning, added thiamin had no effect ($P > .10$) on ADG, ADFI, or gain:feed (Table 4). Average daily gain tended to increase (linear, $P < .06$) for pigs fed diets containing added pyridoxine. This increasing ADG was a result of increasing (linear, $P < .04$) ADFI of pigs fed diets with increased pyridoxine. Pyridoxine had no effect ($P > .10$) on gain:feed ratio.

Cumulative results (d 0 to 35) showed a decrease then return to control values (quadratic, $P < .03$) in ADG and gain:feed with increasing thiamin. As for the period from d 0 to 14 after weaning, pigs fed 2.8 mg/kg of added thiamin had decreased ADG, but pigs fed 5.5 mg/kg of added thiamin had ADG similar to those of pigs fed the control diet. Pigs fed increasing pyridoxine had increased ADG (linear, $P < .05$) and ADFI (linear, $P < .02$) from d 0 to 35. Overall, ADG was numerically highest for pigs fed the diet containing 3.9 mg/kg of added pyridoxine, similar to the response from d 0 to 14. Final BW of pigs fed diets containing added thiamin

Table 4. Effects of added thiamin and pyridoxine on weanling pig performance (Exp. 1)[a]

		Vitamin, mg/kg					Probability ($P <$)			
		Thiamin		Pyridoxine			Thiamin		Pyridoxine	
Item	Control	2.8	5.5	3.9	7.7	SEM	Linear	Quadratic	Linear	Quadratic
Initial wt, kg	5.64	5.64	5.65	5.65	5.64	.005	.39	.92	.73	.23
Day 0 to 14										
ADG, g	368	300	369	413	388	11.8	.92	.0001	.24	.03
ADFI, g	434	455	434	476	452	9.9	.98	.10	.20	.02
Gain:feed	.85	.66	.85	.87	.86	.018	.99	.0001	.69	.50
Day 14 to 35										
ADG, g	607	616	633	636	644	13.0	.17	.83	.06	.51
ADFI, g	975	967	994	1,007	1,030	17.2	.46	.42	.04	.84
Gain:feed	.62	.64	.64	.63	.63	.013	.44	.64	.92	.61
Day 0 to 35										
ADG, g	511	490	528	547	541	10.1	.27	.03	.05	.12
ADFI, g	759	762	770	795	799	11.2	.49	.89	.02	.27
Gain:feed	.67	.64	.69	.69	.68	.010	.47	.02	.81	.34
Final wt, kg	23.53	22.79	24.11	24.80	24.58	.353	.26	.03	.05	.11

[a]Weanling pigs (n = 180, 21 ± 2 d of age), six pigs per pen and six pens per treatment, were used.

Table 5. Effects of added pyridoxine on weanling pig performance (Exp. 2)[a]

	Added pyridoxine, mg/kg							Probability (P <)	
Item	0	1.1	2.2	3.3	4.4	5.5	SEM	Linear	Quadratic
Initial wt, kg	6.17	6.18	6.18	6.17	6.17	6.18	.008	.64	.72
Day 0 to 14									
ADG, g	360	361	400	420	380	384	17.0	.13	.05
ADFI, g	417	427	455	459	451	424	17.4	.41	.03
Gain:feed	.86	.85	.88	.92	.84	.91	.025	.18	.99
Day 14 to 35									
ADG, g	598	574	611	602	605	603	18.1	.42	.87
ADFI, g	987	951	1,011	995	1,009	1,011	23.4	.13	.97
Gain:feed	.61	.60	.60	.61	.60	.60	.015	.68	.93
Day 0 to 35									
ADG, g	501	489	527	529	515	516	13.0	.13	.21
ADFI, g	755	741	788	781	786	776	17.3	.09	.30
Gain:feed	.66	.66	.67	.68	.66	.67	.012	.88	.69
Final wt, kg	24.14	23.29	24.62	24.67	24.20	24.24	.438	.33	.46

[a]Weanling pigs (n = 216, 21 ± 2 d of age), six pigs per pen and six pens per treatment, were used.

decreased (quadratic; P < .03), reflecting the poor growth performance of pigs fed the lower level of thiamin, then returned to control values for pigs fed 5.5 mg/kg. The final BW of pigs fed added pyridoxine increased (linear, P < .05) with increasing added pyridoxine.

Experiment 2. Based on the results of Exp. 1, Exp. 2 was conducted to determine the pyridoxine requirement of weanling pigs. From d 0 to 14 after weaning, increasing pyridoxine up to 3.3 mg/kg increased ADG (quadratic, P < .05) and ADFI (quadratic, P < .03; Table 5), with no additional improvements at higher levels. The increases in ADG seemed to be a result of the increased (quadratic, P < .03) feed intake, because increasing pyridoxine had no effect (P > .10) on gain:feed ratio. Fitting the ADG and ADFI data to a broken-line model generated estimates of 3.3 mg/kg (SE = .86) of added pyridoxine needed to maximize growth and 3.0 mg/kg (SE = .39) of added pyridoxine to maximize feed intake. From d 14 to 35 or 0 to 35, increasing pyridoxine had no effect (P > .10) on pig growth performance. Final BW was not different (P < .10) with increasing levels of pyridoxine, although pigs fed 2.2 or 3.3 mg/kg of added pyridoxine had numerically the highest final BW.

Discussion

Results of our experiments indicate that the pyridoxine requirement needed to maximize weanling pig growth performance is higher than that estimated by the NRC (1998). The NRC (1998) requirement estimates for 3- to 5- and 5- to 10-kg pigs are 2.0 and 1.5 mg/kg of pyridoxine, respectively, and are based on research conducted between 1957 (Miller et al., 1957) and 1976 (Kösters and Kirchgessner, 1976a,b). Recent research conducted by Matte et al. (1998) agrees that the pyridoxine requirement estimate for weanling pigs needs to be increased. These authors fed 14-d-old pigs a basal diet containing 2.7 ppm of pyridoxine or diets containing 10, 50, or 100 ppm of added pyridoxine for 2 wk after weaning. Pigs fed supplemental pyridoxine had improved growth compared to those fed the basal diet, even though the pyridoxine concentration in the basal diet exceeded the NRC (1998) requirement estimate. In Exp. 1, we observed an improvement in growth performance from increasing added pyridoxine throughout the 35-d study, whereas in Exp. 2 no improvements in growth performance were observed from d 14 to 35. This suggests that pyridoxine supplementation may be most critical during the period immediately after weaning.

Several recent studies have indicated that the NRC (1998) requirement estimates for vitamins may be too low. Lindemann et al. (1995) fed weanling pigs a control diet (corn-soybean meal and 15% dried whey with no experimental vitamins) or diets containing .5, 1, 2.5, and 5 times the NRC (1988) requirement estimates for vitamins A, D, E, and K, niacin, pantothenic acid, riboflavin, and vitamin B_{12}. Pigs fed the control diet or the diet with .5 times the NRC (1988) requirements had reduced growth performance and feed intake, whereas pigs fed five times the requirements had the highest ADG and ADFI. However, because the amount of the entire vitamin premix was increased, it is impossible to determine whether the response was due to a single vitamin or to a combination. Wilson et al. (1991b) observed that pigs fed corn-soybean meal-based diets and given injections of vitamin B_{12} (100 × NRC [1988]) or several B-vitamins 10 × NRC [1988]) (Wilson, 1991a) at weaning had increased daily gain and feed intake compared to pigs given injections of distilled water as a placebo. Subsequent studies also suggested that dietary addition of various B-vitamins at 2 to 10 times NRC (1988) estimates was beneficial to weanling pig growth performance (Wilson, 1992a,b). However, when control diets (containing corn, soybean meal, dried whey, and spray-dried animal plasma) contained B-vitamin concentrations similar to industry averages (three to four times NRC [1988] requirement estimates), Wilson et al. (1993) observed no benefits from additional B-vitamins. Earlier, in a similar study, Newcomb and Allee (1986) conducted two experiments to determine the effects of adding three to four times NRC (1979) estimates of folic acid, thiamin, biotin, pyridoxine, or ascorbic acid to a corn-soybean meal-20% dried whey starter diet. The control diet contained a standard vitamin premix without any of the experimental vitamins. No benefits of additional B-vitamins were observed. Recently, Stahly and Cook (1996) observed increased growth performance of high-health weanling pigs fed up to 400% of the NRC (1988) requirement estimates of riboflavin, niacin, pantothenic acid, cobalamin, and folacin. However, these pigs were fed a vitamin-deficient diet from 21 d of age to 9.8 kg BW, so these results may overestimate the response to added vitamins.

Many trials have illustrated the important role pyridoxine plays in amino acid metabolism. Pyridoxine's role in tryptophan metabolism was reviewed by the ARC (1981). A pyridoxine deficiency results in the excretion of xanthurenic acid, a tryptophan metabolite, that accumulates when nicotinic acid synthesis from tryptophan is limited. As tryptophan and other amino acid requirements of weanling pigs increase as a result of improvements in environment, health status, and genetics, increases in vitamin requirements such as pyridoxine would be expected to increase as well.

Protein level, source, and quality all have been shown to affect the pyridoxine requirement. Miller and Baumann (1945) observed that mice fed diets containing 60% casein required approximately three times as much supplemental pyridoxine as mice fed diets containing only 20% casein. Daghir and Shah (1973) fed chicks diets containing 15, 20, or 25% protein and found that the amount of pyridoxine required to increase body weight and feed efficiency increased with increasing dietary protein. Kazemi and Kratzer (1980) fed chicks diets containing soybean meal, cottonseed meal, or safflower meal as the primary protein source. The chicks fed diets containing soybean meal required more pyridoxine to maximize growth, even though the chemical analysis showed that soybean meal contained the highest pyridoxine concentration. The authors believed that soybean processing might cause binding of the pyridoxal phosphate, an active form of pyridoxine, to proteins and could decrease its bioavailability. Another possibility is that the high serine concentration of the soybean meal caused an increase in the amount of pyridoxine needed to support growth, because serine has been shown to increase the pyridoxine requirement (Kratzer and Aboaysha, 1978). An increase in methionine supplementation in chick diets also has been shown to increase the pyridoxine requirement needed to improve growth (Kazemi and Daghir, 1971).

The lack of a positive growth response to thiamin in our trial agrees with findings by Stahly and Cook (1997) for pigs fed thiamin concentrations equivalent to 200, 330, 460, 590, and 720% of the NRC (1988) requirement estimates. In that study, increasing thiamin concentrations had no effect on ADG, ADFI, or gain:feed ratio.

Implications

Adding thiamin to diets does not seem to improve the growth performance of weanling pigs. However, adding pyridoxine can improve average daily gain and average daily feed intake of pigs from d 0 to 14 after weaning. The supplemental pyridoxine requirement seems to be approximately 3.3 mg of pyridoxine/kg of diet fed from d 0 to 14 after weaning. This corresponds to an analyzed total pyrodoxine concentration of approximately 7.1 to 7.9 mg/kg of diet on an as-fed basis.

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