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Research Article

Effects of Low-Protein Diet Supplemented with Tryptophan, Pyridoxine and Niacin on Feed Intake and Growth Performance of Weaning Piglets

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Abstract: This study aimed to investigate the effects of dietary tryptophan (Trp), pyridoxine and niacin supplementation on feed intake and growth performance of weaning pigs fed low-protein diet. A total of 42 day-old crossbred (Landrace×Yorkshire×Duroc) of weaned female pigs were reared under seven dietary treatments. Treatments were 1) corn-soybean meal diet, 2) pyridoxine + niacin, 3) pyridoxine, 4) niacin, 5) 0.30% synthetic Trp + pyridoxine + niacin, 6) 0.30% synthetic Trp + pyridoxine and 7) 0.30% synthetic Trp + niacin. The experimental results indicated no significant difference ($p>0.05$) in feed intake for pigs fed the experimental diets. However, pigs fed the synthetic Trp + pyridoxine diet tended to have better feed intake among dietary treatments, followed by synthetic Trp + niacin diet. Overall (wk 1 to 8), pigs consuming supplemental Trp diets had better weight gain and feed efficiency than without Trp supplemental pigs ($p<0.01$). In conclusion, supplementation of Trp in combination with pyridoxine or niacin in weaning pigs diets greatly improve growth performance than only supplementing Trp alone in low crude protein diet.

Keywords: Feed intake, low-protein diet, niacin, pyridoxine, tryptophan, weaning piglets

INTRODUCTION

Protein represents the most expensive component of pig diets. The use of low-protein diets supplemented with essential amino acids may reduce feed costs and decreased nitrogen excretion from livestock. A low-protein diet usually has low soybean meal and high corn in the diet. In corn cereal based diets tryptophan (Trp) is the first limiting amino acid for pigs (Baker *et al*., 1969; Sharda *et al*., 1976). The low level of the amino acids Trp in corn protein has been one of the important factors limiting the amount of this cereal grain in swine diets (Wahlstrom *et al*., 1977).

Tryptophan is known to play important biological roles, most of them being associated to metabolic pathways. Trp is the precursor for the synthesis of serotonin, an important neuromediator associated to mood, stress response, sleep and appetite regulation (Henry *et al*., 1992; Voet and Voet, 1995; Le Floc'h and Sève, 2007). Dietary tryptophan can be converted to niacin has been shown in many reports (Krehl *et al*., 1945; Firth and Johnson, 1956; Blodgett *et al*., 2002). Niacin is an essential vitamin in pig diets. Young piglets require a dietary source of niacin when fed diets deficient in Trp (Luecke *et al*., 1947; Ivers *et al*., 1993; Real *et al*., 2004).Vitamin B6 is a collective term for pyridoxal, pyridoxine and pyridoxamine and their phosphorylated forms (Rall and Meydani, 1993). Pyridoxine plays a role in the conversion of Trp to niacin derivatives in rats, mice and swine (Okada *et al*., 1997). However, there is very little published information on supplemental Trp in combination with pyridoxine and niacin in low-protein diet of weaned pigs. Therefore, the objective of this study was to investigate the effects of dietary Trp, pyridoxine and niacin supplementation on feed intake and growth performance of weaning piglets.

MATERIALS AND METHODS

Animals, experimental diets and management: The experiment was conducted in the nursery house of the farm in National Pingtung University of Science and Technology, Taiwan, Republic of China. Three-way crossbred (Landrace×Yorkshire×Duroc) females were used as experimental animals. A total of 42 pigs, which were weaned at approximately 28 days of age, were distributed into 7 treatments randomly. Each treatment had 3 pens. Each pen had 2 piglets. There were 6 replicates for weight gain and 3 replicates for feed intake and feed efficiency. Pigs were fed a low-protein diet, 12% Crude Protein (CP) corn-soybean meal diet for 8 weeks.

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Table 1: Composition of dietary treatments (% on as fed basis)

	Treatments						
Ingredients	1	2	3	4	5	6	7
Corn	83.60	83.60	83.60	83.60	84.20	84.20	84.20
Dehulled soybean meal	12.10	12.10	12.10	12.10	11.20	11.20	11.20
Dicalcium phosphate	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Limestone	1.00	1.00	1.00	1.00	1.00	1.00	1.00
L-Lysine HCL	0.50	0.50	0.50	0.50	0.50	0.50	0.50
DL-Methionine	0.40	0.40	0.40	0.40	0.40	0.40	0.40
L-Threonine	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Acidofacs[1]	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Mineral premix[2]	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Vitamin premix	0.10	0.10	0.10	0.10	0.10	0.10	0.10
L-Tryptophan	-	-	-	-	0.30	0.30	0.30
Calculated nutrient content, on as fed basis							
ME, kcal/kg[3]	3500	3500	3500	3500	3500	3500	3500
Crude Protein,%	12.4	12.4	12.4	12.4	12.4	12.4	12.4
Calcium,%	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Phosphorus,%	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Lysine,%	1.19	1.19	1.19	1.19	1.19	1.19	1.19
Methionine + Cystein,%	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Threonine,%	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Tryptophan,%	0.22	0.22	0.22	0.22	0.44	0.44	0.44

[1]: Supplied individually per kilogram of diet: phosohate 10%; fumarate 20%; citric acid 10%; malic 10% and protect hydrogenated plant lipids; [2]: Supplied individually per kilogram of diet: Fe, 150 g; Cu, 30 g; Mn 60 g; Zn, 120 g; Co, 0.7 g, I, 1.5 g; Se, 0.3g; [3]: ME is calculated, whereas all other values are analyzed

Table 2: Composition of vitamin premix in experimental diets[1] (gram, as-fed basis)

	Treatments						
Item	1	2	3	4	5	6	7
Vitamin B6 (pyridoxine)	0.153	0.306	0.306	0.153	0.306	0.306	0.153
Vitamin B3 (niacin)	1.256	2.513	1.256	2.513	2.513	1.256	2.513
Vitamin K3	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Vitamin B12	0.150	0.150	0.150	0.150	0.150	0.150	0.150
Calpan	0.918	0.918	0.918	0.918	0.918	0.918	0.918
Vitamin B1	0.102	0.102	0.102	0.102	0.102	0.102	0.102
Vitamin B2	0.375	0.375	0.375	0.375	0.375	0.375	0.375
Folic acid	0.031	0.031	0.031	0.031	0.031	0.031	0.031
Biotin	0.250	0.250	0.250	0.250	0.250	0.250	0.250
Choline	66.667	66.667	66.667	66.667	66.667	66.667	66.667
Vitamin E	20.000	20.000	20.000	20.000	20.000	20.000	20.000
Vitamin A/D3	0.175	0.175	0.175	0.175	0.175	0.175	0.175

[1]: Vitamin premix was supplied on a corn-based carrier

Calculated composition of the experimental diets is presented in Table 1 and 2. Seven experimental diets, which contained 0.22% total Trp, were formulated to meet National Research Council (1998) recommendations, except for Trp supplementation in dietary treatment 5, 6 and 7, which used synthetic Trp formulated to contain 2 times the National Research Council (1998) requirements of piglets.

Treatment 1: Control diet (12% CP), Trp content 0.22%.

Treatment 2: 12% CP with pyridoxine and niacin, Trp content 0.22%.

Treatment 3: 12% CP with pyridoxine, Trp content 0.22%.

Treatment 4: 12% CP with niacin, Trp content 0.22%.

Treatment 5: 12% CP with 0.30% synthetic Trp+ pyridoxine and niacin, Trp content 0.44%.

Treatment 6: 12% CP with 0.30% synthetic Trp+ pyridoxine, Trp content 0.44%.

Treatment 7: 12% CP with 0.30% synthetic Trp+ niacin, Trp content 0.44%.

Pigs were housed in partially slotted and solid concrete floor pens, with an automatic watering cup and heating lamp. Feed and water were provided *ad libitum* during the entire experimental period of 8 weeks growth performance. Feed was provided in a mash form in the feeder. The feeders were checked twice daily at 0600 and 1800 h to remove and weigh the residue in the feeder and also make sure the feeders were not empty. Feed refuse and feed supplied were carefully weighed prior to feeding times. The amount of feed was about 0.5 to 1 kg more than the pigs could eat. Every evening, the residue in the feeders was collected into a plastic container and weighed. The daily feed consumption and weekly body weight were recorded for Average Daily Feed Intake (ADFI), Average Daily Weight Gain (ADWG) and Feed Efficiency (FE) calculations.

Table 3: Effect of diet on feed intake of the experimental piglets (g/day)

	Treatments[1]								
	T1	T2	T3	T4	T5	T6	T7	SEM[2]	Sig.[3]
Trp	-	-	-	-	+	+	+		
B6	-	+	+	-	+	+	-		
Niacin	-	+	-	+	+	-	+		
wk 1	322.40	254.37	265.80	205.07	221.77	248.80	286.67	25.66	ns
wk 2	299.80	216.30	201.60	260.33	144.10	358.37	263.60	55.66	ns
wk 3	352.93	276.17	207.90	336.37	252.23	475.67	302.73	60.77	ns
wk 4	343.97	312.07	231.50	361.63	233.60	460.03	309.60	56.72	ns
wk 5	351.80	325.10	284.60	354.40	226.30	506.70	438.20	76.29	ns
wk 6	310.20	328.30	305.10	424.00	273.00	633.60	479.20	98.03	ns
wk 7	450.10	390.60	362.20	407.70	320.20	724.70	655.30	101.48	ns
wk 8	400.10	407.30	389.90	438.10	333.20	763.70	712.80	110.52	ns
wk 1-4	329.78	264.73	226.70	290.85	212.93	385.72	290.65	44.99	ns
wk 5-8	378.10	362.80	335.40	406.10	288.20	657.20	571.40	93.29	ns
wk 1-8	353.92	313.77	281.07	348.45	250.55	521.45	431.01	66.80	ns

[1]: Treatment 1: Control diet (12% CP), Treatment 2: 12% CP with pyridoxine and niacin, Treatment 3: 12% CP with pyridoxine, Treatment 4: 12% CP with niacin, Treatment 5: 12% CP with 0.30% synthetic Trp + pyridoxine and niacin, Treatment 6: 12% CP with 0.30% synthetic Trp + pyridoxine, Treatment 7: 12% CP with 0.30% synthetic Trp + niacin, Trp content 0.44%; [2]: SEM: Standard error of the mean; [3]: Probability of significance: ns, not significant, p>0.05

Statistical analysis: For each animal, ADFI, ADWG and FE ratios were calculated based on a weekly basis using the formulas: ADFI = Total weekly feed intake/7; ADWG = Total weekly WG/7; FE = ADWG/ADFI. The experimental data were analyzed as a randomized complete block design with one pen as the experimental unit. Pigs were blocked on the basis of initial weight and analysis of variance was performed using the general linear model procedure of SAS software (2004). Differences among treatment means were determined using Duncan's New Multiple Range Test (DNMRT) at p<0.05 significant level.

RESULTS AND DISCUSSION

The effects of dietary treatment on feed intake of pigs are shown in Table 3. There were no significant differences (p>0.05) of feed intake observed in any treatment. However, throughout the entire 8-wk study, pigs fed a diet containing synthetic Trp + pyridoxine (Treatment 6) showed better feed intake than other dietary treatments, followed by pigs fed the diet with synthetic Trp + niacin (Treatment 7). The results of the present study indicated that there was a tendency for supplementation of Trp, pyridoxine and niacin in the low-protein diet to improve feed intake. These findings are in concordance with Hsia (2005) who reported that feed intake of pigs improved when the total level of Trp is increased from 0.177 to 0.237% in a corn-soybean meal diets. Another study conducted by Ettle and Roth (2004) also reported that piglets showed a clear preference for a higher Trp diet when given a choice of feeding between the higher Trp diet and a Trp-deficient diet. The feed intake was lower for the pigs fed treatment 5 (synthetic Trp + pyridoxine + niacin) when compared with the two Trp treatments (Treatment 6 and 7). The result may be due to two possibilities; Firstly, we did not have as much as excess Trp and secondly, the niacin level is in excess (niacin equivalent from excess Trp). The excess or insufficiency of essential nutrients to some extent generally makes pigs eat less. This imbalanced diet normally leads to lower feed intake of pigs (Harper and Roger, 1965; Li *et al*., 1998; Dong and Pluske, 2007).

Weight gains of pigs fed the experimental diets are presented in Table 4. The results showed that during the entire wk 1-4, wk 5-8 and wk 1-8 experimental period, weight gain of pigs effected by dietary treatments was significant (p<0.05; p<0.01 respectively). Pigs fed treatment 6 (synthetic Trp + pyridoxine) had the highest weight gain among dietary treatments, followed by treatment 7 (synthetic Trp + niacin) and treatment 5 (synthetic Trp + pyridoxine + niacin). Pigs fed a diet containing pyridoxine (Treatment 3) had the lowest weight gain. In addition, pigs consuming supplemental Trp diets (Treatments 5, 6 and 7) had better weight gain than without Trp supplemental groups (Treatments 2, 3 and 4) and control group (Treatment 1). Table 5 indicated dietary treatments affected feed efficiency significantly (p<0.01) during the entire experimental period (wk1-8). The feed efficiency also showed the same trend as the trend in weight gain.

The finding in this study are contrary to those of Kerr *et al*. (1995), who reported that pigs fed the low crude protein diets without amino acid supplementation grew more slowly and had less efficient in feed conversion. In contrast, one study found that no significant differences in the feed efficiency, weight gain and intake of weaned pigs fed niacin diet. However, increasing dietary niacin tended to improve feed efficiency (Real *et al*., 2004). Woodworth *et al*. (2000) also reported that added dietary pyridoxine (vitamin B6) or thiamin (vitamin B1) in diet of weaning pigs improve weight gain. These results showed greater weight gain for pigs fed 3.9 mg/kg of added pyridoxine.

Table 4: Effect of diet on weight gain of the experimental piglets (g/day)

	Treatments[1]								
	1	2	3	4	5	6	7	SEM[2]	Sig.[3]
Trp	-	-	-	-	+	+	+		
B6	-	+	+	-	+	+	-		
Niacin	-	+	-	+	+	-	+		
wk 1	77.23	89.67	30.30	48.23	114.83	79.97	77.53	25.70	ns
wk 2	46.10[b]	33.53[b]	30.53[b]	32.40[b]	48.63[b]	94.37[a]	112.73[a]	14.36	**
wk 3	136.53	58.47	36.47	84.53	130.37	272.17	135.70	47.69	ns
wk 4	73.70	125.00	45.33	130.70	139.77	214.73	139.70	41.05	ns
wk 5	101.20	131.67	88.80	138.33	110.33	253.10	157.67	42.46	ns
wk 6	154.30	101.20	78.33	160.70	127.13	304.30	204.30	51.69	ns
wk 7	105.70[c]	124.53[c]	104.03[c]	101.20[c]	148.80[bc]	397.13[a]	253.07[b]	37.99	***
wk 8	94.50[c]	119.97[c]	79.77[c]	80.00[c]	157.13[bc]	465.20[a]	327.63[ab]	57.41	**
wk 1-4	83.39[bc]	76.67[bc]	35.66[c]	73.97[bc]	108.40[abc]	165.31[a]	116.42[ab]	22.65	*
wk 5-8	113.93[bc]	119.34[bc]	87.73[c]	120.06[bc]	135.85[bc]	354.93[a]	235.67[b]	36.39	**
wk 1-8	98.66[bc]	98.00[bc]	61.70[c]	97.01[bc]	122.13[bc]	260.12[a]	176.04[b]	25.66	**

[1]: Treatment 1: Control diet (12% CP), Treatment 2: 12% CP with pyridoxine and niacin, Treatment 3: 12% CP with pyridoxine, Treatment 4: 12% CP with niacin, Treatment 5: 12% CP with 0.30% synthetic Trp + pyridoxine and niacin, Treatment 6: 12% CP with 0.30% synthetic Trp + pyridoxine, Treatment 7: 12% CP with 0.30% synthetic Trp + niacin, Trp content 0.44%; [2]: SEM: Standard error of the mean; [3]: Probability of significance: ns, not significant, p>0.05; *: p <0.05; **: p<0.01; ***: p<0.001

Table 5: Effect of diet on feed efficiency of the experimental piglets (g feed/g)

	Treatments[1]								
	1	2	3	4	5	6	7	SEM[2]	Sig.[3]
Trp	-	-	-	-	+	+	+		
B6	-	+	+	-	+	+	-		
Niacin	-	+	-	+	+	-	+		
wk 1	6.10[ab]	2.97[b]	10.03[a]	4.87[b]	2.50[b]	3.57[b]	4.77[b]	1.39	*
wk 2	8.50	7.33	8.20	9.07	3.40	3.80	2.83	1.87	ns
wk 3	4.50	6.20	7.83	4.27	2.27	2.10	2.30	1.45	ns
wk 4	10.77	2.57	6.87	3.37	1.90	2.23	2.80	2.64	ns
wk 5	4.07	2.83	3.67	2.60	2.07	1.97	4.27	0.84	ns
wk 6	3.23	3.43	6.10	3.17	2.33	2.07	3.37	1.27	ns
wk 7	4.23	3.83	4.67	4.87	2.17	1.80	2.57	0.88	ns
wk 8	8.93	3.47	8.73	8.03	2.20	1.73	2.23	2.48	ns
wk 1-4	7.47	4.77	8.23	5.39	2.52	2.93	3.18	1.45	ns
wk 5-8	5.12	3.39	5.79	4.67	2.19	1.89	3.11	1.04	ns
wk 1-8	6.29[ab]	4.08[bc]	7.01[a]	5.03[abc]	2.35[c]	2.41[c]	3.14[c]	0.84	**

[1]: Treatment 1: Control diet (12% CP), Treatment 2: 12% CP with pyridoxine and niacin, Treatment 3: 12% CP with pyridoxine, Treatment 4: 12% CP with niacin, Treatment 5: 12% CP with 0.30% synthetic Trp + pyridoxine and niacin, Treatment 6: 12% CP with 0.30% synthetic Trp + pyridoxine, Treatment 7: 12% CP with 0.30% synthetic Trp + niacin, Trp content 0.44%; [2]: SEM: Standard error of the mean; [3]: Probability of significance: ns, not significant, p>0.05; *: p<0.05; **: p<0.01

CONCLUSION

From the results obtained in this study, we conclude that supplemental synthetic Trp with pyridoxine diet showed the best feed intake and growth performance. Dietary Trp-supplemented pigs had better growth performance than non-supplemental Trp pigs. Furthermore, providing pigs with the supplemental Trp in combination with pyridoxine or niacin for weaning pigs greatly improve growth performance than only supplementing pyridoxine or niacin alone in low CP diets for newly weaned piglets.

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