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NICOTINIC ACID—TRYPTOPHAN RELATIONSHIP IN THE NUTRITION OF THE WEANLING PIG

B. G. HARMON, D. E. BECKER, A. H. JENSEN AND D. H. BAKER
Illinois Agricultural Experiment Station, Urbana

SINCE the discovery of the essentiality of nicotinic acid in the diet of the pig, a number of reports relative to the quantitative need have appeared in the literature. Hughes (1943) first reported that the requirement was between .11 and .22 mg. per kg. of body weight daily for weanling pigs fed a purified diet containing 15% casein. Subsequent studies conducted by Powick *et al.* (1947) showed that 0.6 to 1.0 mg. of nicotinic acid per kilogram of liveweight per day was needed for optimal growth in 3- to 9-week-old pigs fed diets containing 25% casein. Firth and Johnson (1956) reported that the baby pig required no more than 20 ppm of nicotinic acid in a diet containing 0.3% DL-tryptophan.

The growth promotant effect of tryptophan in nicotinic acid-deficient rats was reported first by Krehl *et al.* (1945) and later in pigs by Luecke *et al.* (1947, 1948), Powick *et al.* (1948) and Firth and Johnson (1956). Becker *et al.* (1955) found that the L-tryptophan need of the weanling pig is 0.115% of a diet containing 15.3% protein and an excess of nicotinic acid. Hence, it seemed desirable to evaluate the nicotinic acid need of the weanling pig fed the required tryptophan level, particularly with diets containing different levels of yellow corn.

Experimental Procedure

Four experiments were conducted. The ingredients and protein, tryptophan and nicotinic acid contents of the diets are presented in table 1.

In experiment 1, 36 crossbred pigs approximately 40 days of age were used. Six outcome groups were formed on the basis of ancestry, weight and general condition, and allotment was made at random to the nicotinic acid levels. In addition, pairs of outcome groups were made on the basis of weight and allotted at random to the two levels of corn. The data was analyzed statistically as a split plot design. The feeding period was 44 days.

Forty crossbred pigs approximately 40 days of age formed into eight outcome groups equalized on the basis of ancestry, weight and general condition were used in Experiment 2. The pigs within outcome groups were allotted at random to the nicotinic acid levels, and the groups within nicotinic acid levels were allotted at random to the corn levels. The data was analyzed statistically as a split plot design. The pigs were fed for 40 days.

In Experiment 3, 30 crossbred or Yorkshire pigs approximately 50 days of age were allotted at random to the treatments from outcome groups of five pigs formed on the basis of breed, ancestry, weight and condition. The feeding period was 35 days.

In Experiment 4, 12 crossbred pigs 40 days of age were allotted at random to the two treatments from pairs formed on the basis of litter, weight and condition. The pigs were fed for 42 days.

In all studies, pigs were individually self-fed in metal, wire-bottom cages.

Nicotinic acid analyses were completed by the U.S.P. (1950) procedure involving sulfuric acid hydrolysis of the sample. Total nicotinic acid is measured by this procedure.

Results

The results of Experiment 1 in which 0 and 40% yellow corn were fed are presented in table 2.

There was a marked difference in the response of pigs fed the two diets in the absence of supplementary nicotinic acid. On the 0% corn diet the pigs gained 0.33 kg. daily and the gain-feed ratio was 0.30; whereas, with 40% corn in the diet the rate of gain was 0.07 kg. daily and the gain/feed was 0.11. Hence, the severity of the nicotinic acid deficiency was greater in the presence than in the absence of corn, in spite of a somewhat greater level of tryptophan and more total nicotinic acid in the corn diet. Daily gain and gain/feed were significantly ($P<0.01$) influenced by level of nicotinic acid, increasing curvilinearly and plateauing at 8.8 ppm of added nicotinic acid (11.3 ppm total nicotinic acid) with the corn-free diet. With 40% corn in the diet daily gain plateaued at 13.2 ppm added nicotinic acid (24.0 ppm total nicotinic acid). Maximum

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TABLE 1. PERCENTAGE COMPOSITION OF DIETS

Diet description	Minimum tryptophan level			Excess tryptophan	Corn-soybean meal
Ingredients					
Casein, vitamin-extracted	14.0	12.0	8.0	10.0	....
Yellow corn	....	40.0	80.0	80.0	75.0
Soybean meal	....	....	....	....	20.5
Corn starch	63.4	25.4	....	....	....
Dextrose	10.0	10.0	7.4	5.4	....
Cellulose	3.0	3.0	....	....	....
Corn oil	3.0	3.0	....	....	....
Mineral mixture[a]	4.0	4.0	4.0	4.0	4.0
Vitamin A and D oil (3000A–600D)	0.5	0.5	0.5	0.5	0.5
DL-methionine	0.1	0.1	0.1	0.1	....
Vitamin mixture[b]	+	+	+	+	+
Composition					
Protein (N x 6.25), %	11.44	13.94	14.4	16.12	16.19
Tryptophan, %[c]	0.102	0.12	0.12	0.19	0.23
Nicotinic acid, ppm[d]	2.51	10.78	18.33	18.30	22.48

[a] Becker and Terrill, 1954.
[b] Becker *et al.*, 1954. Nicotinic acid was omitted from the vitamin mixture.
[c] Assayed by the method of Henderson and Snell, 1948.
[d] Assayed by the method of U.S.P. (1950). The procedure involves sulfuric acid hydrolysis which releases all bound nicotinic acid.

gain/feed was obtained with 8.8 ppm added nicotinic acid for pigs receiving the 40% corn diet, just as was the case with the 0% corn diet. In addition to the gain and feed data, the deficiency symptoms observed suggested a more intense pellagragenic effect with the corn diet. Pigs fed the unsupplemented 40% corn diet became weak and emaciated and exhibited a rough hair coat, a brownish exudate on the body and a profuse diarrhea. Frequently, the fecal matter of deficient pigs exhibited extensive amounts of blood.

The results of Experiment 2 in which 40 and 80% yellow corn were fed are presented in table 3.

In contrast to Experiment 1, increasing corn in the unsupplemented diet to 80% did not reduce daily gain or gain/feed from that observed with 40% of corn in the diet. Nicotinic acid levels in both diets significantly ($P<0.01$) influenced weight gain and gain/feed. With the diets containing 40 and 80% corn, weight gain was maximized with the addition of 13.2 ppm of nicotinic acid. As much supplemental nicotinic acid was needed to maximize gain and gain/feed when the 80% corn diet containing 18.33 ppm of nicotinic acid was fed as when the 40% corn diet was fed containing 10.78 ppm of nicotinic acid. With each diet, feed efficiency was maximized at a lower level of supplemental nicotinic acid than was weight gain. Feed efficiency was maximized at 4.4 ppm of nicotinic acid with the 80% corn diet and 8.8 ppm with the 40% corn diet.

The results of Experiment 3, in which corn

TABLE 2. RESPONSE OF THE GROWING PIG TO LEVELS OF NICOTINIC ACID IN DIETS DEVOID OF OR CONTAINING 40% OF YELLOW CORN (EXPERIMENT 1)

Level of nicotinic acid added, ppm	0	4.4	8.8	13.2	17.6	22.0	Av.
Av. daily gain, gm.[a]							
0% corn	327±112[b]	490±86	663±31	658±33	690±36	645±36	577
40% corn	73±26	527±53	531±35	704±23	672±38	690±12	536
Av.	200	508	599	681	681	667	554
Gain/feed							
0% corn	0.30±.08	0.41±.04	0.44±.03	0.47±.03	0.42±.01	0.44±.03	0.42
40% corn	0.11±.02	0.40±.01	0.43±.01	0.42±.01	0.43±.01	0.42±.01	0.40
Av.	0.23	0.41	0.43	0.44	0.42	0.43	0.41

[a] Av. initial weight 13.3 kg.
[b] Standard error of the mean.

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TABLE 3. RESPONSE OF THE GROWING PIG TO LEVELS OF NICOTINIC ACID IN DIETS CONTAINING 40 OR 80% OF YELLOW CORN (EXPERIMENT 2)

Level of nicotinic acid added, ppm	0	4.4	8.8	13.2	17.6	Av.
Av. daily gain, gm.[a]						
40% corn	168±36[b]	499±73	681±84	735±37	726±23	562
80% corn	272±100	663±63	690±40	758±34	726±27	621
Av.	218	581	686	745	726	591
Gain/feed						
40% corn	0.24±.03	0.38±.04	0.42±.01	0.43±.01	0.42±.01	0.38
80% corn	0.27±.06	0.41±.01	0.41±.02	0.40±.02	0.38±.01	0.37
Av.	0.26	0.40	0.41	0.41	0.40	0.38

[a] Av. initial weight 14.3 kg.
[b] Standard error of the mean.

and casein were combined to give a 16% protein diet and supplemented with specific levels of nicotinic acid, are presented in table 4. Weight gain was maximized with the addition of 4.4 ppm of nicotinic acid to this diet which contained 0.19% tryptophan. Gain/feed was not significantly influenced by treatment. However, pigs fed the unsupplemented diet ate significantly ($P<0.01$) less feed than pigs receiving the supplemented diets.

The results of Experiment 4, in which a corn-soybean meal diet containing .23% tryptophan and 16% protein was fed, are presented in table 4. The addition of 13.2 ppm of nicotinic acid to the basal diet containing 22.48 ppm resulted in no significant increase in gain or gain/feed.

In none of the four experiments did the addition of excess nicotinic acid result in depressed gain or gain/feed.

Table 5 contains a summary of the effective levels of added nicotinic acid for the various diets fed in the four experiments. In the diets containing corn, the level of nicotinic acid needed to maximize gain and gain/feed was reduced as dietary tryptophan was increased. In the corn-free diets, gain and gain/feed were maximized with 8.8 ppm of added nicotinic acid.

Discussion

The effect of corn in increasing the nicotinic acid requirement is clearly shown in the first experiment in which a diet of 40% corn was compared to a corn-free diet. Increasing the corn from 40 to 80% of the diet (Experiment 2) did not increase the need for supplemental nicotinic acid. It should be noted that the nicotinic acid level increased as corn was substituted into the diet and corn starch was removed. Luce *et al.* (1965) observed similar

TABLE 4. RESPONSE OF THE PIG TO NICOTINIC ACID ADDED TO A CORN-CASEIN OR TO A CORN-SOYBEAN MEAL DIET

Description	Av. daily gain, kg.	Gain/feed
Experiment 3 (corn-casein)[a]		
Lot 1—control	0.59±.04[c]	0.34±.02
2— +4.4 ppm nicotinic acid	0.75±.01	0.36±.01
3— +8.8 ppm nicotinic acid	0.70±.02	0.36±.01
4— +13.2 ppm nicotinic acid	0.70±.04	0.35±.01
5— +17.6 ppm nicotinic acid	0.70±.02	0.35±.01
	0.70±.02	0.35±.01
Experiment 4 (corn-soybean meal)[b]		
Lot 1—Control	0.53	0.43
2— +13.2 ppm nicotinic acid	0.51	0.44

[a] Av. initial weight 18.6 kg.
[b] Av. initial weight 13.7 kg.
[c] Standard error of the mean.

TABLE 5. SUMMARY OF THE RESPONSE OF THE PIG TO NICOTINIC ACID ADDITIONS TO VARIOUS DIETS

Diet description	Minimum tryptophan level			Excess tryptophan	Corn-soybean meal
Corn, %	0	40	80	80	75
Protein, %	11.44	13.94	14.40	16.12	16.19
Tryptophan, %	0.10	0.12	0.12	0.19	0.23
Supplemental nicotinic acid needed, ppm.	8.8	13.2	13.2	4.4	0.00
Total nicotinic acid needed, ppm.	11.31	23.98	31.53	20.30	<22.48
Total minus corn nicotinic acid, ppm.	11.31	15.18	13.93	5.10	<5.98

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gain for pigs receiving diets containing 40, 60 or 80% of corn with no supplemental nicotinic acid. Kodicek *et al.* (1956), Kodicek (1960) and Chaudheri and Kodicek (1960) have clearly demonstrated that all or almost all nicotinic acid in corn is in a bound form.

The level of supplemental as well as total nicotinic acid necessary in diets containing corn to support maximal gain and gain/feed in this study is greater than the 5 to 10 mg. daily suggested by Braude *et al.* (1946) with diets containing corn, pea meal and purified casein. Hughes *et al.* (1943) had earlier suggested an even smaller requirement for growing pigs receiving a diet containing beet sugar and casein. However, Wintrobe *et al.* (1945) and Luecke *et al.* (1948) were unable to produce a nicotinic acid deficiency in swine fed diets containing 25 to 26% of casein.

Pigs receiving 0.19% tryptophan in the corn-casein diet in Experiment 3 required 4.4 ppm of supplemental nicotinic acid, while pigs receiving 0.23% tryptophan in the corn-soybean meal diet required no supplemental nicotinic acid. In the study by Luecke *et al.* (1948), pigs were consuming a diet containing approximately 0.41% tryptophan in the 25% casein diet devoid of nicotinic acid. Firth and Johnson (1956) suggested a requirement of 0.45% DL-tryptophan in the absence of nicotinic acid. Recent studies with humans (Brown *et al.*, 1958; Vivian *et al.*, 1966) indicate that a fraction of tryptophan is normally catabolized to nicotinic acid. Vivian (1964) and Goldsmith *et al.* (1961) suggested that 3 to 3.3% of dietary tryptophan is converted to nicotinic acid irrespective of dietary status.

The high level of leucine in corn-containing diets also may have influenced gain and gain/feed in the current studies. Raghuramulu *et al.* (1965) reported that excess leucine caused increased urinary excretion of the tryptophan and nicotinic acid metabolites, quinolinic acid and N′-methylnicotinamide.

The results indicate that the nicotinic acid in corn is largely unavailable. Pigs fed similar diets containing corn, but with tryptophan levels greater than suggested by Becker *et al.* (1955), required considerably less nicotinic acid. Pigs fed the corn-soybean meal diet, typical of diets currently in use (Becker *et al.*, 1966) required no additional nicotinic acid.

Summary

The nicotinic acid requirement of the weanling pig weighing approximately 14 kg. was determined using diets in which the level of yellow corn and the level and source of supplementary protein were varied.

Diets containing 0, 40 and 80% yellow corn, 14, 12 and 8% vitamin-extracted casein and 0.10, 0.12 and 0.12% of tryptophan required 11.3, 24.0 and 31.5 ppm of total nicotinic acid, respectively, to support a satisfactory rate and efficiency of gain. A diet containing 80, 10 and 0.19% of yellow corn, vitamin-extracted casein and tryptophan, respectively, required a level of 22.7 ppm of total nicotinic acid to support satisfactory performance. On the other hand, a corn-soybean meal diet containing 16.2% protein, 0.23% tryptophan and 22.5 ppm of total nicotinic acid was not improved by an addition of nicotinic acid.

Assuming that the nicotinic acid of yellow corn is largely unavailable to the pig, the minimum requirement is similar at the various levels of corn. However, the need varied indirectly with the level of dietary tryptophan fed in excess of that needed for growth.

When tryptophan is fed to meet the requirement, the weanling pig needs approximately 13.2 mg. of available nicotinic acid per kg. of diet.

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