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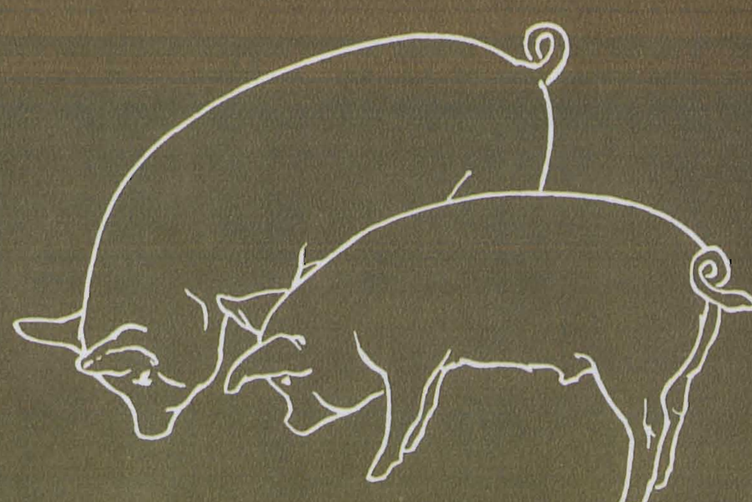

B-Vitamin Supplementation of Conventional Diets for Growing Swine

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Contents

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INTRODUCTION

During the three decades since Chick (5 and 6), Hughes (12 and 13) and Wintrobe (47) demonstrated that nicotinic acid (niacin), panthothenic acid, and riboflavin were dietary essentials for the growing pig, many experiments have been conducted in an attempt to describe accurately the deficiency symptoms, relate diet to deficiency states, and delineate more precisely the requirements of the growing pig.

Original investigators (6 and 13) described locomotor incoordination in growing pigs fed diets that would have been lacking in pantothenic acid. They also associated sensory neuron degeneration with the vitamin deficiency (51). Several investigators (9, 15, 25, 26, 27, 29, and 50) demonstrated that calcium pantothenate protected against locomotor incoordination caused by sensory neuron degeneration. Diet was also related to this deficiency symptom (8, 25, 26, 27, 29, and 49) and other deficiency symptoms were described (7 and 52). Hughes and Ittner (17) originally proposed that the pig required 5 to 8 mg. of pantothenic acid per kg. of diet (179 to 268 mcg. per kg. liveweight). Other workers (9) subsequently reported that 515 mcg. of pantothenic acid per kg. liveweight was necessary to protect against nerve degeneration.

Luecke and coworkers (25, 26, 27, and 29) reported symptoms of pantothenic acid deficiency in growing pigs fed diets based on natural feedstuffs and containing 3.82 to 4.21 mg. of pantothenic acid per pound. They were able to prevent the deficiency symptoms, including loss of appetite, poor growth, and diarrhea, by supplementing the basal diets with calcium pantothenate. In one experiment, they reported that pigs fed a diet containing 6.15 mg. of pantothenic acid per pound of diet did not exhibit deficiency symptoms and they suggested that the requirement of the growing pig was no greater than that level. These workers had previously reported on B-vitamin deficiencies in growing pigs on Michigan farms (30). In another study (32) they reported that liberal additions of calcium pantothenate, nicotinic acid, and riboflavin significantly increased daily gains of young pigs, prevented deficiency symptoms, and reduced feed required per unit of gain by 22 to 25 percent. Pigs fed 14.5 percent protein corn-meat scraps diets without supplemental calcium pantothenate were reported to develop pantothenic acid deficiency (11). In another study (33), growing pigs fed 16 percent protein corn-meat and bone scraps diets without supplemental calcium pantothenate did not develop deficiency symptoms (locomotor incoordination) and adding the vitamin did not effect more rapid and efficient gains.

Subsequent to the discovery of vitamin B_{12} and of the role of antibiotics in diets for growing swine, corn-soybean meal diets containing as little as 3.7 mg. pantothenic acid per pound were reported adequate for growing pigs (4). However, supplemental pantothenic acid did increase daily gains. The authors suggested that vitamin B_{12} and pantothenic acid exerted a "sparing" action on each other in the absence of chlortetracycline (aureomycin) and that chlortetracycline appeared to "spare" both vitamins. They suggested, "With healthy, undepleted pigs weighing 35 to 45 pounds, a 14 percent protein corn-soybean oil meal ration balanced in other respects and containing adequate amounts of vitamin B_{12} and aureomycin need not be supplemented with pantothenic acid for optimum growth."

In one instance (1), pigs fed low protein diets containing very low levels of pantothenic acid did not exhibit classical symptoms of deficiency. And, rate and efficiency of gain were not significantly affected by supplementing the basal diet with 2 to 7 mg. pantothenic acid per pound of diet, with or without supplemental chlortetracycline.

On the other hand, young pigs started on experiments at 16 to 20 pounds showed pantothenic acid deficiency symptoms when fed low protein (14.4 and 14.66 percent protein) corn-soybean meal diets containing 3.08 and 3.04 mg. of the vitamin per pound, respectively. When the basal diet was supplemented with 10 mg. of chlortetracycline per pound, deficiency symptoms did not occur (31).

In two other studies (38 and 39), pigs fed diets based on natural feedstuffs and containing less than 3 mg. pantothenic acid per pound of diet did not show symptoms of deficiency, and rate and efficiency of gain were not improved by adding calcium pantothenate. The basal diet fed in one study (38) contained 100 mg. chlortetracycline per pound while that fed in the other experiment (39) contained 18 mg. of the antibiotic per pound.

The National Research Council (36) reported that growing pigs required 4.5 mg. pantothenic acid per pound of diet. Since various investigators (1, 4, 31, and 39) did not demonstrate improved rate and efficiency of gain by feeding diets that contained more than 3 to 4 mg. pantothenic acid per pound, it is interesting to note that the National Research Council in 1964 (37) reported the growing pig to require 5.0 mg. pantothenic acid per pound of diet. The investigators cited above had not demonstrated classical deficiency symptoms in pigs fed diets that contained as little as 3 to 4 mg. pantothenic acid per pound.

Early investigators (12, 13, 47, and 51) determined that riboflavin was essential to the young pig. Retarded growth, diarrhea, and a limb abnormality (13) could be prevented or at least temporarily relieved by including riboflavin in the diet. Lens opacity was shown to be a specific symptom of riboflavin deficiency in the growing pig (48).

Hughes (14) reported that the growing pig required between 1 and 3 mg. riboflavin per 100 pounds bodyweight daily, equivalent to 0.25 to 0.75 mg. of the vitamin per pound of diet when pigs are eating at a rate equivalent to 4 percent of their bodyweight daily. In 1949 (21) it was reported that the growing pig required 1.4 mg. riboflavin per pound of diet. Subsequently, another group of investigators (34) reported that a diet containing 0.83 mg. riboflavin per pound was adequate for growing swine being fed in drylot, but that 0.55 mg. of the vitamin per pound was inadequate for growth and riboflavin deficiency symptoms developed. The National Research Council (36 and 37) recommends 1.0 to 1.2 mg. riboflavin per pound of diet for growing pigs weighing more than 50 pounds.

The possible effects of environmental temperature on the riboflavin requirements of growing swine may be of interest, particularly in evaluating results of experiments conducted during different seasons. In 1950, Mitchell et al (35) reported requirements of 0.54 mg. riboflavin per pound of diet at an environmental temperature of 85° F. and 1.04 mg. per pound of diet when the temperature was 42° F.

Results of a recent extensive study by Seymour and associates (46) indicate that over a temperature range of —4° C. to 32° C., environmental temperature did not consistently influence the riboflavin requirement of pigs weaned at an early age. The pigs were weaned at 2 weeks and fed a semi-purified basal diet containing 0.5 mg. riboflavin per pound for 2 to 3 weeks before being assigned to treatment. Experimental diets were fed over a 5-week period. Diets supplying 0.5 to 0.6 mg. riboflavin per pound were inadequate to support rate and efficiency of gain equal to that resulting when the diet contained greater quantities of riboflavin. The investigators suggested that the young pig required 1.4 to 1.8 mg. riboflavin per pound of diet. In some of their separate experiments, however, they were unable to demonstrate significantly increased rate and efficiency of gain once the diet contained at least 1.0 mg. riboflavin per pound.

Severe diarrhea, lack of appetite, and retarded growth are associated with multiple B-vitamin deficiencies (12, 13, and 30); but, severe diarrhea appears to be nearly specific for a lack of nicotinic acid in the diet (2, 3, 5, and 42).

Although the niacin requirement of the growing pig is indicated to be 5 mg. per pound of diet (37), the minimum requirement remains somewhat ill defined. Hughes (16) indicated a minimum requirement of 220 mcg. nicotinic acid per kg. liveweight daily. Powick and coworkers (42) reported that between 0.6 and 1.0 mg. of niacin was needed per kg. liveweight daily for optimum growth of very young pigs. In another study (2), as little as 5 to 10 mg. niacin per pig daily cured or prevented symptoms of deficiency in pigs fed a diet known to be deficient in the vitamin.

In addition to the wide variation between individual pigs (2 and 42) and possible biosynthesis of the vitamin, the pellagragenic effect of high corn diets (40), lack of availability of niacin from corn (22 and 24), and the conversion of tryptophan to niacin (28 and 41) make it difficult to establish a precise nicotinic acid requirement for the growing pig. Modern diets based on corn and soybean meal contain tryptophan in excess of the pigs' needs and this may be converted to niacin to meet at least a portion of the pigs' requirement for this B-vitamin. The report by Wintrobe and associates (53) that only pigs fed a low protein diet needed supplemental nicotinic acid may in fact have been related to the capacity of high protein diets to provide more tryptophan than needed by growing pigs with resultant conversion to niacin.

The objectives of this study were to determine the effects of season, year, location, source of basic ingredients, and source of supplemental protein on the response of growing swine to supplemental calcium pantothenate and riboflavin. The effects of adding nicotinic acid to a corn-soybean meal diet were also investigated. Another objective of these experiments was to re-evaluate the requirements of the growing pig for niacin, pantothenic acid, and riboflavin when basal diets were composed of conventional feedstuffs.

MATERIALS AND METHODS

In this study, 1,523 growing pigs were used in 14 experiments to determine the effects of supplemental calcium pantothenate, niacin, and riboflavin on rate and efficiency of gain. The pigs were fed diets of several formulations at different locations (environments) during different seasons and years. Observations were also made of the occurrence of deficiency symptoms that might indicate separate diets to be inadequate in specific vitamins to prevent the onset of specific and obvious deficiency symptoms.

All pigs used in these experiments were reared in concrete drylot prior to 8 or 10 weeks of age when they were placed on experiment. Most of the pigs had been weaned when 3 to 5 weeks old, but in some of the early experiments they nursed their dams until they were 6 to 8 weeks old. Pigs weaned at 3 to 5 weeks were fed nutritionally adequate pig starters, including supplemental B-vitamins, during the subsequent developmental period. Pigs nursing their dams to 6 or 8 weeks had access to the sows' feed, either a 16 percent protein corn-soybean meal or corn-soybean meal-tankage diet, during the nursing period; a nutritionally adequate pig starter was also offered. Both the lactating sows' diet and the pig starter were supplemented with B-vitamins.

The pigs were maintained in concrete drylot in all experiments. Pens were bedded with wood shavings during fall and winter months at St. Paul, and straw was used at other locations. Pens were not bedded during the summer months at St. Paul. During the summer, pigs had access to outside concrete runways and diets were not supplemented with vitamin D because pigs were exposed to sunshine.

All diets were self-fed and fresh water was supplied from self-waterers or automatic fountains during all experiments. Pigs were weighed individually when placed on experiment and at 14- to 21-day intervals during separate experiments.

All vitamin-antibiotic premixes were prepared centrally using either soybean meal, solvent, 44 percent protein, or finely ground yellow corn as a diluent. Premixes were then given to responsible personnel at the experiment sites. Generally, premixes were formulated to be deficient in the test vitamin, or to carry graded increments of the vitamin and to supply adequate amounts of other vitamins thought to be needed in supplemental amounts in typical diets for growing swine. The premixes also contained recommended levels of one of the known effective antibiotic preparations.

In all experiments, an effort was made to stratify pigs by sex within breeding group and then to make random assignment of pigs to the experimental treatments or to groups of pigs that were randomly assigned to treatments. Data were evaluated statistically using analysis of variance (45). When replicate pens of pigs were used within separate experiments, the pen was treated as the experimental unit and pen means were used in testing for significance of differences between means for daily gain and feed conversion efficiency. The individual pig was treated as the experimental unit in experiments involving 17 to 24 pigs per treatment in large groups and with no replication of treatments. Means for feed conversion efficiency could not be tested for statistical significance in those experiments.

Experiment 1

This experiment was conducted at the West Central Experiment Station, Morris, during the fall and winter of 1960-61. One hundred twenty crossbred pigs from the Minnesota lines were used. The pigs averaged 54 pounds initially, were approximately 10 weeks old, and were randomly assigned to the 10 experimental treatments for which vitamin additions are shown in table 2. The basal diet was estimated to contain 2.78 mg. pantothenic acid and 0.83 mg. riboflavin per pound, initially. It would have supplied 56 and 69 percent, respectively, of the amounts of pantothenic acid and riboflavin reported by the National Research Council (37) to be required by pigs of this weight and age. This study was designed to demonstrate the extent to which the basal corn-soybean meal diet (table 1) was deficient in each of the vitamins. If supplemental quantities of the two vitamins were required to maximize rate and efficiency of gain, the results might indicate the extent of interaction between the two vitamins in influencing these response criteria.

Experiment 2

One hundred forty-four Yorkshire pigs averaging 8½ weeks old and 44 pounds were randomly allotted to 6 pens of 24 pigs each. The basal corn-soybean meal-tankage diet was estimated to contain 2.39 mg. pantothenic acid per pound, 48 percent of the growing pigs' requirement (37), and was supplemented with the amounts of calcium pantothenate shown in table 3. The final diets would have contained 2.39, 2.85, 3.31, 3.77, 4.23, and 4.69 mg. pantothenic acid per pound if the calculated amount of the vitamin in the basal diet was a reasonably accurate indication of the amount present. These levels of supplemental pantothenic acid did not effectively bracket the reported requirement of 5 mg. of the vitamin per pound of diet and did not supply excesses. This experiment was conducted at the St. Paul Campus during the summer of 1961, and pigs had access to outside concrete runways during the investigation.

Experiment 3

Four lots of 17 pigs were formed by random assignment from the original group of 68 Yorkshire pigs averaging 47.4 pounds and approximately 9 weeks of age. The pigs were fed corn-soybean meal diets (15 percent protein to 100 pounds, and 12 percent protein after 100 pounds) as described in table 1. The diets fed over the 85-day feeding period were supplemented with calcium pantothenate as shown in table 4 so that the final diets contained 2.78, 3.70, 4.62, and 6.46 mg. total pantothenic acid per pound, assuming the estimated concentration of 2.78 mg. of the vitamin per pound of basal diet closely approximated the quantity supplied. The experiment was conducted at the St. Paul Campus during the summer of 1962 and pigs had access to outside concrete runways as well as to sunshine.

Experiment 4

This experiment was conducted at the St. Paul Campus during the fall and winter of 1962-63. The barn had supplemental heat so that the environmental temperature seldom was less than 55-60° F. Ninety-six Yorkshire pigs averaging 41.2 pounds and approximately 8 weeks of age were randomly assigned to 16 groups of six pigs. The pens of pigs were randomly assigned to treatment and location within the barn. The corn-soybean meal diets provided 15 percent protein to 100 pounds and 12 percent protein from the time the pigs averaged 100 pounds until the termination of the 95-day feeding period; none of the diets was supplemented with riboflavin. The amounts of calcium pantothenate added to the basal diet (table 1) are shown in table 5.

Experiment 5

Ninety-six crossbred pigs (Hampshire x Minn. No. 2) averaging 50 pounds and approximately 10 weeks of age were randomly assigned to 16 groups of six pigs. Four groups of pigs were assigned to each of the experimental diets which were formed by supplementing the basal diet with 0, 2, 4, or 6 mg. calcium pantothenate per pound (table 5). This experiment differed from the previous one in that levels of 16 and 13 percent protein replaced those of 15 and 12 percent, respectively. Part of the total goal of this series of experiments was to determine the effects of level of dietary protein as well as source of supplemental protein on the response of growing swine to supplemental calcium pantothenate. This experiment was conducted at the West Central Experiment Station, Morris, during the fall and winter of 1962-63. The barn was not provided with supplemental heat and the environmental temperature may have sometimes declined to less than 40° F. for short periods. Pigs were fed the experimental diets over a 92-day feeding period.

Experiment 6

In this experiment, a factorial arrangement of treatments was used so that the basal diet would be supplemented with 0, 1, 2, or 3 mg. calcium pantothenate, or 0, 0.2, 0.4, or 0.6 mg. riboflavin, per pound with each source of vitamin supplementation being used alone and in all possible combinations (table 6). Thus, four groups of six pigs were fed diets containing calculated levels of 2.78, 3.70, 4.62, and 5.55 mg. calcium pantothenate per pound and four groups of six pigs were fed diets containing an estimated 0.83, 1.03, 1.23, or 1.43 mg. riboflavin per pound. The corn-soybean meal diets provided 15 percent protein from initiation of the experiment until pigs averaged 100 pounds and 12 percent protein from 100 pounds until pigs were removed for slaughter at 200 pounds, or more, or were removed after 111 days.

Ninety-six crossbred pigs (48 Minn. No. 2 x Yorkshire, 32 Hampshire x [Duroc x Poland] and 16 Minn. No. 2 x [Minn. No. 1 x Minn. No. 3]) were used to form the 16 lots of six test animals. The pigs averaged 40.5 pounds at the initiation of the study.

In addition to obtaining data on rate and efficiency of gain, carcass data were collected from all pigs weighing 200 pounds, or more, before 111 days. These data were obtained to determine whether either of the vitamins alone, or any combinations, would significantly influence any of the measures of carcass leanness as shown in table 7.

This experiment was conducted at the Southern School and Experiment Station, Waseca, during the fall and winter of 1962-63. The barn was fully insulated, but in some instances there was not adequate exhaust capacity to remove excessive moisture from the environmnt in the unheated building. In some instances, the temperature within the building declined to less than 45-50° F.

Experiments 7, 8, and 9

These experiments were conducted at four locations during the fall and winter of 1964-65. All barns were fully insulated. The barn at the St. Paul Campus had supplemental heat so that the environmental temperature seldom dropped below 50-60° F. Other barns had no supplemental heat; but air was exchanged by thermostatically-controlled electrically-powered exhaust fans which could not eliminate all excessive moisture when outside temperature dropped to about 0° F., or below. Generally, the inside temperature exceeded 45-50° F. except when the outside temperature was at 0° F., or less.

Diets fed at all locations contained 15 percent protein until pigs averaged 100 pounds and 12 percent protein from 100 pounds until the separate experiments were terminated. The pantothenic acid content of the basal diets was determined by microbiological assay by the double enzyme method of Kaplan and Lipmann (19) as described by Kavanagh (20). The resulting values are shown in table 1. Diets were supplemented with either 0, 1, 2, or 4 mg. calcium pantothenate per pound as shown in table 8.

Experiment 7. This experiment was conducted at St. Paul. Eighty Yorkshire pigs averaging 40.8 pounds and 8½ weeks were randomly assigned to 16 pens of five pigs. Pens of pigs were randomly assigned to treatments and locations in the barn. In this experiment, soybean meal, solvent process, dehulled, 48.5 to 50 percent protein, replaced the meal containing 44 percent protein that was used in most other experiments. As shown in table 1, the pantothenic acid contents of the basal diets did not differ greatly from the amounts predicted to be present and the diet fed initially would have provided only 53 percent of the pigs' requirement (N.R.C., 1964) for the vitamin.

Experiment 8. Part of this experiment was conducted at the Northeast Experiment Station, Duluth, and part at the Southern School and Experiment Station, Waseca. Forty-eight crossbred pigs averaging 49.2 pounds were randomly assigned to eight pens of six pigs, and two pens were assigned to each experimental diet at the Northeast Station. Twenty-four crossbred pigs averaging 40.8 pounds were randomly allotted to provide six pigs per dietary treatment at the Southern School and Experiment Station. Data from the two stations were treated as representing three replicates to facilitate statistical analysis. Although there was a difference in average initial weights between stations (table 8), significant differences were not demonstrated between replicates for either rate or efficiency of gain. The data presented in table 1 show the pantothenic acid contents of the basal diets and suggest differences between the basal diets used at the two locations. The diet fed at the Southern Station contained 2.73 mg. of the vitamin per pound (55 percent of the requirement) while the diet used at the Northeast Station contained 3.89 mg. pantothenic acid per pound (74 percent of the requirement).

Experiment 9. Two groups of 32 crossbred pigs averaging 46.6 pounds were randomly allotted to four lots of eight pigs to form two replicates (table 8). Within replicates, pens of pigs were randomly assigned to treatments. The basal diets contained 3.78 and 3.28 mg. pantothenic acid per pound (table 1). Thus, the diet fed initially would have provided 73 percent of the reported requirement for the vitamin.

Experiment 10

Seventy-five 9-week old pigs (53 crossbred and 22 Yorkshire) averaging 49.7 pounds were randomly allotted to 15 pens of five pigs with the restriction that not more than two Yorkshire pigs could be assigned to a pen. Pens of five pigs were then randomly assigned to treatments and to locations in the barn. In this experiment, approximately 40 percent of the protein from soybean meal was replaced by protein from tankage, a protein supplemental feed containing very little (about 1.1 mg. per pound) pantothenic acid. As shown in table 1, the 15 percent protein diet fed initially and until pigs within lots averaged 100 pounds contained 3.42 mg. pantothenic acid per pound (68 percent of the requirement) and experimental diets fed initially would therefore have contained 3.42, 4.22, 5.23, 6.13, and 7.04 mg. pantothenic acid per pound. The 12 percent protein diets fed from 100 pounds until termination of the 77-day experiment would have contained 0.22 mg. less pantothenic acid per pound. This experiment was conducted at St. Paul during the summer of 1966.

Experiments 11, 12, and 13

Experiments 11, 12, and 13 were conducted concurrently at three locations during the fall and winter of 1966-67. Basal diets were formulated to contain approximately 15 percent protein from initiation of experiments until pigs within lots averaged 100 pounds and 12 percent protein diets were fed from 100 pounds until the separate experiments were terminated. Diets were classified as corn-soybean meal, corn-soybean meal-tankage (2:1 ratio), and corn-soybean meal-fish meal (2:1 ratio). These different diets were fed to determine if the pigs' response to pantothenic acid supplementation would differ with source of supplemental protein. Protein contents of diets, predicted pantothenic acid contents, and composition of the several diets are shown in table 1.

Experiment 11. This experiment was conducted at the North Central Station, Grand Rapids. Two sets of 120 crossbred pigs averaging 52.2 pounds were randomly assigned to experimental diets. Diets were supplemented with 0, 0.98, 1.97, 2.96, and 3.95 mg. calcium pantothenate per pound, and diets based on all sources of protein were fed.

Experiment 12. Two sets of 60 crossbred pigs averaging 51.8 pounds and approximately 9½ weeks of age were randomly assigned to 10 pens of six pigs to form two replicates. Within replicate, individual pens of pigs were randomly assigned to dietary treatments. Diets of the corn-soybean meal and corn-soybean meal-fish meal types were fed and pantothenic acid supplementation was as indicated in table 11. This experiment was conducted at the Southern School and Experiment Station, Waseca.

Experiment 13. At the West Central Station, Morris, two sets of 60 crossbred pigs averaging 37 pounds and 8½ weeks were randomly assigned to 10 groups of six pigs to form two replicates. Within replicates, pens of six pigs were assigned to treatments using a table of random numbers. Diets of the corn-soybean meal and corn-soybean meal-tankage types were fed and levels of pantothenic acid supplementation were as indicated in table 11.

Experiment 14

This experiment was conducted at St. Paul during the summer of 1960. One hundred twenty-six growing pigs (78 Yorkshire and 48 Hampshire) were randomly assigned to provide 21 pigs per treatment. Corn-soybean meal diets containing about 15 percent protein were fed from initiation of the experiment until pigs within lots averaged 100 pounds and 12 percent protein diets were fed from 100 pounds until termination of the 91-day experiment. As shown in table 1, the contribution of niacin by soybean meal was very small; the possible contribution of corn was ignored because of the likelihood that it was unavailable, or at least poorly available. As shown in table 10, the basal diets were supplemented with 0, 1, 2, 4, 8, and 12 mg. niacin per pound. Since the experiment was conducted during the summer the pigs had access to outside concrete runways and the diets were not supplemented with vitamin D.

RESULTS

Experiment 1. As shown in table 2, adding 0.4 or 0.8 gm. riboflavin, or 1.0, 2.0, or 4.0 gm. calcium pantothenate per ton of diet, alone and in combination, did not significantly affect rate of gain. Also, means for feed conversion efficiency do not reflect improved efficiency of utilization due to vitamin additions. The basal corn-soybean meal diet contained 16.6 percent protein to 100 pounds and 13.0 percent protein during the growing period subsequent to 100 pounds. Locomotor incoordination, an indication of pantothenic acid deficiency, was not observed.

Experiment 2. The basal corn-soybean meal-tankage diet was formulated to contain 15 percent protein from the start of the experiment until pigs averaged 100 pounds and 12 percent protein during the final growing period. Additions of calcium pantothenate to provide final levels of 2.39, 2.85, 3.31, 3.77, 4.23, and 4.69 mg. pantothenic acid per pound of diet did not significantly affect rate of gain (table 3). Pigs fed diets supplemented with at least 0.50 mg. calcium pantothenate (0.46 mg. pantothenic acid) per pound appeared to gain faster than those fed the basal diet. Means for feed conversion efficiency could not be tested for statistical significance, but they did not appear to be affected by additions of calcium pantothenate to the basal diet. Locomotor incoordination was not encountered in this experiment.

Experiment 3. Supplementation of corn-soybean meal diets (15 percent protein to 100 pounds and 12 percent protein after 100 pounds) with calcium pantothenate to provide 2.78, 3.70, 4.62, and 6.46 mg. pantothenic acid per pound of diet did not result in significant differences in daily gains of pigs weighing about 48 pounds at the initiation of the experiment (table 4). There was no evidence of pantothenic acid deficiency, and feed conversion efficiency was not consistently improved as a result of additions of calcium pantothenate.

Experiments 4 and 5. These experiments were conducted at different locations and the corn-soybean meal diets provided 15 percent protein initially at one location and 16 percent protein at the other. Rate and efficiency of gain were not significantly improved at either location by adding 1.84, 3.68, or 5.52 mg. pantothenic acid as calcium pantothenate to basal diets containing approximately 3.1 mg. pantothenic acid per pound (table 5). There was no evidence of pantothenic acid deficiency in any of the pigs used in these experiments.

Experiment 6. As shown in table 6, supplementation of corn-soybean meal diets containing about 15 percent protein initially with 0, 0.2, 0.4, or 0.6 mg. riboflavin or 0, 1.0, 2.0, or 3.0 mg. calcium pantothenate per pound of diet, alone and in combination, did not significantly improve rate of gain of pigs averaging about 41 pounds at the initiation of the experiment. Means for feed conversion efficiency were variable and efficiency of feed utilization was not consistently improved by additions of vitamins alone or in combination.

Data in table 7 show that carcass leanness was not consistently affected by supplemental amounts of either vitamin or combinations of the two vitamins.

Experiments 7, 8, and 9. The summary in table 8 reflects apparent differences in average daily gain and feed conversion efficiency between stations. However, the patterns for these response criteria are consistent within stations and show the lack of significant effect of supplemental calcium pantothenate (0, 1, 2, and 4 mg. per pound of diet) on pig performance. As in other experiments reported here, there was no evidence of locomotor incoordination in pigs assigned to the unsupplemented basal corn-soybean meal diet. The basal diets contained from as little as 2.7 to as much as 3.9 mg. pantothenic acid per pound.

Experiment 10. As in other experiments in which corn-soybean meal basal diets initially containing 15 percent protein were supplemented with graded increments of calcium pantothenate, there was no evidence from this experiment that adding from nearly 2 to 8 gm. calcium pantothenate per ton of diet significantly improved either rate or efficiency of gain (table 9). The basal diet contained 3.42 mg. pantothenic acid per pound.

Experiments 11, 12, and 13. The basal diets used in this experiment were formulated to contain 15 percent protein from initiation of experiment until pigs within lots averaged 100 pounds and 12 percent protein during the growing period subsequent to 100 pounds. As shown in table 1, diets containing tankage or fish meal were formulated to maintain a ratio of approximately 1.5:1 between protein from soybean meal and that from the animal or marine protein. Basal diets containing tankage or fish meal by calculation contained 2.5 mg., or less, of pantothenic acid per pound.

As in experiments 7, 8, and 9 (table 8) the means for average daily gain and feed conversion efficiency reflect differences between stations. The summary presented in table 11 shows consistent patterns for daily gain and feed conversion efficiency within source of protein and station, and there were no significant improvements in either response criterion due to additions of calcium pantothenate.

In experiment 11, pigs fed the corn-soybean meal-tankage diet gained slightly, but significantly ($P<.05$), less rapidly than those fed either corn-soybean meal or corn-soybean meal-fish meal diets indicating a slight influence of source of supplemental protein but not of supplemental calcium pantothenate. Pigs fed the corn-soybean meal-fish meal diets in experiment 12 gained significantly ($P<.05$) faster than those fed the corn-soybean meal diets, but the difference was small.

Experiment 14. Only one experiment was conducted in which a corn-soybean meal diet containing 15 percent protein initially was supplemented with graded levels of nicotinic acid. Niacin additions did not cause significant increases in average daily gains. Means for a feed conversion efficiency could not be tested for a statistical significance because of the experimental design, but there was an average improvement of 4 percent in this response criterion due to niacin additions.

DISCUSSION

Thirteen experiments were conducted in which growing pigs were fed diets containing 15 to 16 percent protein at initiation of the separate studies and 12 to 13 percent protein after pigs within lots averaged 100 pounds. Supplemental protein was provided by soybean meal (solvent, 44 or 50 percent protein) alone or in combination with tankage or fish meal. By calculation, basal diets fed initially contained as little as 2.33 mg. pantothenic acid per pound in one experiment and as much as 2.85 mg. per pound in another study. Microbiological assays of some diets (19 and 20) showed diets to contain as little as 2.67 mg. pantothenic acid per pound and as much as 3.89 mg. per pound in another experiment. Thus, the basal diets fed in these experiments provided from about 50 to nearly 80 percent as much pantothenic acid as reported by the National Research Council (37) to be required by growing swine.

As noted in footnotes c, d, e, f, and g, table 1, all basal diets used in these experiments contained 20 gm. antibiotic per ton. The antibotics were chlortetracycline (aureomycin), oxytetracycline (terramycin), and a combination of streptomycin and penicillin (3:1 ratio). Also, all diets were supplemented with vitamin B_{12}. Thus, the antibiotics may have exerted a sparing action on the pantothenic acid requirement of growing swine. Catron and coworkers (4) reported that 14 percent protein corn-soybean meal diets containing adequate chlortetracycline did not require supplemental pantothenic acid and at least one other group has reported a "sparing" action of chlortetracycline on the pantothenic acid requirement of very young pigs (31). Barnhart and coworkers (1) were unable to demonstrate a beneficial effect on rate and efficiency of gain of young pigs fed semi-purified diets supplemented with calcium pantothenate with or without supplemental chlortetracycline. Palm (38) fed diets containing 31 percent of the reported requirement of very young pigs for pantothenic acid and was unable to demonstrate a benefit from supplementing the diets with calcium pantothenate. His diets contained 100 gm. chlortetracycline per ton. None of these workers reported classical symptoms of pantothenic acid deficiency due to feeding diets containing 31 to about 80 percent of the amount of pantothenic acid reported to be required by growing pigs (37).

In experiments 1 and 6, corn-soybean meal diets containing approximately 0.83 mg. riboflavin per pound were supplemented with graded increments of riboflavin without significantly improving rate or efficiency of gain. These diets would have contained as much riboflavin as reported by Miller and coworkers (34) to be adequate for growing swine but only 65 to 75 percent as much as reported by other groups (21 and 37) to be required by growing swine. At least two possibilities exist. One of these is that the growing pig does not require more than 0.83 mg. riboflavin per pound of diet during the growing period subsequent to 45 to 50 pounds. The second possibility is that antibiotics included in basal diets exert a "sparing" action on the riboflavin requirement of the growing pigs. It may be appropriate to indicate that riboflavin supplementation was inadvertently omitted from basal diets fed in experiments 4 and 5; the means for average daily gain and feed conversion efficiency do not suggest serious impairment of performance due to dietary deficiency.

Several groups of investigators have studied the role of antibiotics in sparing B-vitamins for the growing rat (10, 18, 23, 43, and 44). Generally, chlortetracycline, penicillin, and streptomycin have been reported to be effective in "sparing" pantothenic acid but reports are not consistent with respect to sparing of riboflavin. One group (23) reported that antibiotics were most effective when the basal diet contained enough riboflavin or pantothenic acid for one-half maximum growth. Another worker (43) found chlortetracycline and penicillin to improve gains of rats fed pantothenic acid deficient diets but to cause no great improvement in gains of rats fed riboflavin deficient diets. Increased urinary excretion of riboflavin and pantothenic acid were reported to result from chlortetracycline or penicillin supplementation of diets deficient in these vitamins for growing rats (10). Chlortetracycline increased fecal excretion of pantothenic acid and penicillin increased the fecal output of riboflavin. Such modes of action as modification of the intestinal microflora, reduced competition of microflora with the host for the vitamins and increased synthesis of particular B vitamins were suggested as means of effecting the apparent "sparing" action for certain B vitamins.

In this study, there appeared to be differences between stations in general performance level of pigs when similar experiments were conducted during the same season. However, the lack of response to calcium pantothenate and riboflavin supplementation of the conventional diets used was consistent between stations and between seasons or years. Source of supplemental protein did not appear to influence the lack of response of growing pigs to supplementation of diets with calcium pantothenate although diets containing tankage or fish meal generally contained slightly less pantothenic acid than those based on corn and soybean meal.

Only one study was conducted to study the effect of niacin supplementation of a typical corn-soybean meal diet on rate and efficiency of gain of growing pigs. Assuming the niacin to be unavailable from the corn in the basal diet fed initially (22 and 24), the basal diet should have contained about 2.2 mg. "available" nicotinic acid per pound. Failure of added increments of niacin to improve rate and efficiency of gain may reflect a lower requirement than that reported by the N.R.C. (37) or it may mean that surplus tryptophan in corn-soybean meal diets can be converted to niacin by the growing pig, or both.

SUMMARY

Fourteen experiments involving 1,523 growing pigs were conducted at five locations during 10 seasons over a 7-year period to determine the effects of nicotinic acid, pantothenic acid, and riboflavin supplementation of conventional diets on rate and efficiency of gain of pigs during the growing period subsequent to 45-50 pounds. Diets were based on corn and soybean meal except that protein from tankage or fish meal replaced one-third to one-half of the soybean protein in four experiments.

Basal diets were formulated to contain 15 or 16 percent protein from initiation of experiments until pigs within lots averaged 100 pounds and 12 or 13 percent protein during the growing period subsequent to 100 pounds. By calculation, basal diets contained from 2.3 to about 2.9 mg. pantothenic acid and 0.83 mg. riboflavin per pound. Microbiological assay indicated some test diets to contain 2.67 to 3.89 mg. pantothenic acid per pound, 53 to 80 percent of the growing pigs' requirement.

In the 13 experiments in which basal diets were supplemented with 0.5 to 6 mg. calcium pantothenate (equivalent to 0.46 to 5.52 mg. pantothenic acid) per pound, neither rate nor efficiency of gain was significantly improved or affected by the vitamin additions. The possible role of antibiotics in exerting a "sparing" action on the pigs' requirement for pantothenic acid in modern diets was pointed out as well as the possibility that the pig does not require 5 mg. pantothenic acid per pound of diet.

Supplementation of corn-soybean meal diets that by calculation contained 0.83 mg. riboflavin per pound with graded increments of the vitamin did not significantly improve either rate or efficiency of gain. The likelihood that the growing pig may not require more than 0.83 mg. riboflavin per pound of diet was recognized as well as the possible role of antibiotics commonly included in all diets in sparing riboflavin.

Niacin supplementation of a corn-soybean meal diet did not result in significantly increased gains of growing pigs weighing about 50 pounds at the initiation of the 91-day feeding period.

Table 1. Composition of basal diets

Period when fed												
Start to 100 lb.	+		+		+		+		+		+	
100 lb. to finish		+		+		+		+		+		+
Percent protein, calculated	15.0	12.0	16.0	13.0	15.0	12.0	15.0	12.0	15.0	12.0	12.0	12.0
Ingredient, lb.[a]												
No. 2 yellow corn	78.5-80.0	87.2-88.0	77.5	85.5	82.5	90.5	83.5-84.0	89.2-89.7	84.7	91.2	83.6	89.6
Soybean meal, solvent, 44%	17.5-19.0	10.0-10.5	20.0	12.5	—	—	10.0	6.0	—	—	10.0	6.0
Soybean meal, solvent, 50%	—	—	—	—	15.0	7.5	—	—	9.0	4.5	—	—
Tankage, digester	—	—	—	—	—	—	5.0	3.0	5.0	3.0	—	—
Fish meal	—	—	—	—	—	—	—	—	—	—	5.0	3.0
Dicalcium phosphate	1.0	1.0	1.0	0.5	1.0	0.8	0-0.5	0-0.5	—	—	0.2	0.2
Ground limestone	1.0	0.8	1.0	1.0	1.0	0.7	0.4-0.8	0.4-0.8	0.8	0.8	0.7	0.7
Salt, trace mineralized[b]	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Vitamin-antibiotic premix	+[cdefg]	+[cdefg]	+[e]	+[e]	+[f]	+[f]	+[cg]	+[cg]	+[f]	+[f]	+[g]	+[g]
Experiment in which used	1, 3, 4, 6, 8, 9, 11 and 14	1, 3, 4, 6, 8, 9, 11 and 14	5	5			2, 11 and 13	2, 11 and 13	10	10	11 and 13	11 and 13
Percent protein, by analysis												
Experiment 1	16.63	13.00										
Experiment 4	15.37	12.56										
Experiment 5	14.62	12.18										
Experiment 8	15.14	12.75										
Experiment 9	14.91	12.42										
Experiment 10									15.28	12.49		
Experiment 11	15.87	12.68					15.20	13.70			15.41	12.92
Experiment 12	15.11	12.20									15.73	12.60
Experiment 13	15.84	13.04					14.82	12.61				
Experiment 7					14.50	11.86						
Pantothenic acid, mg./lb., by analysis												
Experiment 7					2.67	2.25						
Experiment 8	3.89											
Experiment 8	2.73											
Experiment 9	3.78	3.28										
Experiment 10									3.42	3.20		
Pantothenic acid, mg./lb., calculated	2.78	2.41	2.85	2.61	2.64	2.31	2.39	2.22	2.33	2.14	2.53	2.31
Riboflavin, mg./lb., calculated	0.83	0.76	0.84	0.79	0.79	0.74	0.79	0.75	0.77	0.73	0.85	0.78
Niacin, mg./lb., calculated	2.20	1.28	2.44	1.53	1.47	0.74	2.11	1.27	1.77	0.98	2.49	1.49

[a] All portions of ingredients expressed as pounds, air-dry feed.
[b] Provided the following amounts of elements indicated, ppm, complete diet: Zn, 40; Mn, 26.2; Fe, 13.5; Cu, 2.7; Co, 0.55; and I, 0.50.
[c] Provided the following per ton of diet, experiment 1: vitamin A, 1,000,000 I.U.; vitamin D_2, 400,000 I.U., niacin, 10 gm.; vitamin B_{12}, 10 mg.; chlortetracycline, 20 gm.; provided the following per ton of diet in experiment 2: vitamin A, 600,000 I.U.; riboflavin, 0.8 gm.; niacin, 6 gm.; vitamin B_{12}, 10 mg.; chlortetracycline, 20 gm.; provided the following per ton of diet in experiment 14: vitamin A, 2,000,000 I.U.; riboflavin, 2 gm.; calcium pantothenate, 4 gm.; vitamin B_{12}, 10 mg.; oxytetracycline, 20 gm.
[d] Provided the following per ton of diet in experiment 3: vitamin A, 2,000,000 I.U.; riboflavin, 1.2 gm.; niacin, 10 gm.; vitamin B_{12}, 10 mg.; antibiotic, 20 gm. (3:1 mixture of streptomycin and procaine penicillin).
[e] Provided the following per ton of diet in experiments 4, 5, and 6: vitamin A, 2,000,000 I.U.; vitamin D_2, 400,000 I.U.; niacin, 6 gm.; vitamin B_{12}, 10 mg.; and antibiotic, 20 gm. (3:1 mixture of streptomycin and procaine penicillin).
[f] Provided the following per ton of complete diet in experiments 7, 8, 9, and 10: vitamin A, 2,000,000 I.U.; vitamin D_2, 400,000 I.U.; riboflavin, 1.6 gm.; niacin, 6 gm.; vitamin B_{12}, 10 mg.; antibiotic, 20 gm. (3:1 mixture of streptomycin and procaine penicillin).
[g] Provided the following per ton of diet in experiments 11, 12, and 13: vitamin A, 2,000,000 I.U.; vitamin D_2, 200,000 I.U.; riboflavin, 1.7 gm.; niacin, 6 gm.; vitamin B_{12}, 10 mg.; antibiotic, 20 gm. (3:1 mixture of streptomycin and procaine penicillin).

Table 2. Influence of calcium pantothenate and riboflavin supplementation of corn-soybean meal diets on rate and efficiency of gain of growing swine, experiment 1[a,b]

Riboflavin added, gm./ton	0	0	0	0	0.4	0.4	0.4	0.8	0.8	0.8
Calcium pantothenate added, gm./ton	0	1.0	2.0	4.0	1.0	2.0	4.0	1.0	2.0	4.0
Items										
No. pigs										
Started	12	12	12	12	12	12	12	12	12	12
Finished	12	12	11[c]	11[d]	11[c]	12	12	12	12	10[e]
Av. initial wt., lb.	54.2	54.1	54.3	54.4	54.2	54.0	54.5	54.7	54.7	54.0
Av. final wt., lb.	210.2	207.0	197.4	207.9	209.2	211.3	200.3	201.9	205.6	204.2
Av. daily gain, lb.	1.86	1.82	1.70	1.81	1.82	1.87	1.73	1.75	1.79	1.77
Feed/gain	3.37	3.49	3.47	3.58	3.37	3.24	3.66	3.63	3.37	3.46

[a] Pigs were fed 15% protein corn-soybean meal diets from initiation of study until average weight of 100 lb. was attained; a 12% protein diet was fed from 100 lb. to completion of study; duration of study, 84 days.
[b] Calcium pantothenate contains 92.01% pantothenic acid.
[c] One pig removed from each lot, death following rectal prolapse, gain data omitted.
[d] Gain data for one pig omitted, growth failure.
[e] Gain data for two pigs omitted, growth failure.

Table 3. Effect of supplemental calcium pantothenate on rate and efficiency of gain of growing pigs fed corn-soybean meal-tankage diets, experiment 2[a]

Calcium pantothenate added, gm./ton[b]	0	1.0	2.0	3.0	4.0	5.0
Items						
No. pigs						
Started	24	24	24	24	24	24
Finished	24	24	24	23[c]	22[d]	24
Av. initial wt., lb.	43.6	43.4	43.6	43.8	43.8	43.5
Av. final wt., lb.[e]	175.5	180.9	188.3	186.5	184.4	183.0
Av. daily gain, lb.[e]	1.48	1.54	1.63	1.59	1.58	1.57
Feed/gain	3.44	3.43	3.43	3.51	3.44	3.47

[a]Pigs were fed a 15% protein corn-soybean meal-tankage diet from initiation of experiment until average weight of 100 lb.; a 12% protein diet was fed from 100 lb. to completion of experiment; duration of experiment, 89 days.
[b]Calcium pantothenate contains 92.01% pantothenic acid.
[c]Gain data for one pig omitted; growth failure.
[d]One pig died after 13 days on experiment; one pig died after 41 days; deaths not due to treatment; gain data omitted.
[e]For pigs completing experiment.

Table 4. Effect of additions of calcium pantothenate to corn-soybean meal diets on rate and efficiency of gain of growing swine, experiment 3[a]

Calcium pantothenate added, gm./ton[b]	0	2	4	8
Items				
No. pigs	17	17	17	17
Av. initial wt., lb.	47.5	47.1	47.5	47.3
Av. final wt., lb.	176.5	167.4	172.4	176.8
Av. daily gain, lb.	1.51	1.41	1.47	1.52
Feed/gain	3.33	3.02	3.35	3.24

[a]Pigs were self-fed corn-soybean meal diets containing 15% protein from start of experiment until they attained within lot average weights of 100 lb.; 12% protein diets fed from 100 lb. to termination of experiment; duration of experiment, 85 days.
[b]Calcium pantothenate contains 92.01% pantothenic acid.

Table 5. Influence of calcium pantothenate supplementation of corn-soybean meal diets on rate and efficiency of gain of growing swine, experiments 4 and 5

Calcium pantothenate added, gm./ton[a]	0	4	8	12
Items				
Experiment 4, St. Paul[b]				
No. lots of pigs	4	4	4	4
No. pigs per lot	6	6	6	6
Av. initial wt., lb.	41.0	41.2	41.3	41.6
Av. final wt., lb.	206.9	207.3	205.6	197.2
Av. daily gain, lb.	1.78	1.79	1.77	1.67
Feed/gain	3.42	3.34	3.39	3.41
Experiment 5, W. Central Station[c]				
No. lots of pigs	4	4	4	4
No. pigs per lot	6	6	6	6[d]
Av. initial wt., lb.	49.8	50.2	49.3	49.7
Av. final wt., lb.	205.8	214.4	211.8	213.9
Av. daily gain, lb.	1.73	1.82	1.80	1.84
Feed/gain	3.41	3.37	3.44	3.42

[a]Calcium pantothenate contains 92.01% pantothenic acid.
[b]Pigs were fed 15% protein diets from start until they averaged 100 lb.; 12% protein diets were fed from 100 lb. to completion of experiment.
[c]Pigs were fed 16% protein diets from start until they averaged 100 lb.; 13% protein diets were fed from 100 lb. to completion of experiment.
[d]One pig died after 78 days on experiment, death not due to treatment; gain data omitted.

Table 6. Effects of riboflavin and calcium pantothenate supplementation of corn-soybean meal diets on rate and efficiency of gain of growing swine, experiment 6[a]

Calcium pantothenate added, gm./ton[b]	0	2	4	6	By level of riboflavin
Items					
No supplemental riboflavin					
No. pigs	6	6	6	6[c]	24[c]
Av. initial wt., lb.	40.7	40.0	41.0	40.7	40.6
Av. final wt., lb.	207.3	206.0	203.2	202.8	204.9
Av. daily gain, lb.	1.63	1.70	1.68	1.53	1.64
Feed/gain	3.34	3.30	3.54	3.28	3.36
0.4 gm. riboflavin added/ton					
No. pigs	6	6	6	6	24
Av. initial wt., lb.	40.7	40.0	41.3	39.7	40.4
Av. final wt., lb.	212.0	212.0	210.0	200.7	207.2
Av. daily gain, lb.	1.77	1.71	1.75	1.63	1.72
Feed/gain	3.51	3.21	3.04	3.40	3.32
0.8 gm. riboflavin added/ton					
No. pigs	6	6	6	6	24
Av. initial wt., lb.	40.3	41.3	30.4	41.3	40.8
Av. final wt., lb.	200.8	198.3	210.0	212.0	205.3
Av. daily gain, lb.	1.67	1.58	1.72	1.81	1.70
Feed/gain	3.65	3.26	3.11	3.02	3.26
1.2 gm. riboflavin added/ton					
No. pigs	6	6	6	6	24
Av. initial wt., lb.	41.0	40.7	41.3	40.3	40.8
Av. final wt., lb.	211.7	206.0	212.3	203.3	209.1
Av. daily gain, lb.	1.77	1.67	1.72	1.60	1.69
Feed/gain	3.21	3.22	3.13	3.13	3.17
By level of calcium pantothenate					
No. pigs	24	24	24	24[c]	
Av. initial wt., lb.	40.7	40.5	41.0	40.5	
Av. final wt., lb.	208.0	204.1	209.1	205.4	
Av. daily gain, lb.	1.71	1.66	1.72	1.64	
Feed/gain	3.42	3.25	3.20	3.20	

[a]Pigs were fed 15% protein corn-soybean meal diets from start of experiment until they averaged 100 lb.; 12% protein diets were fed from 100 lb. to completion of experiment.
[b]Calcium pantothenate contains 92.01% pantothenic acid.
[c]One pig died after 91 days on experiment; death not due to treatment; gain data omitted.

Table 7. Influence of riboflavin and calcium pantothenate supplementation of corn-soybean meal diets for growing swine on carcass characteristics, experiment 6[a]

Calcium pantothenate added, gm./ton[b]	0	2	4	6	By level of riboflavin
Items					
No supplemental riboflavin					
No. pigs slaughtered	6	5[f]	4[f]	6	21[f]
Av. slaughter wt., lb.	207.3	211.2	207.0	202.8	206.9
Av. carcass length, in.	30.6	30.7	30.2	30.0	30.4
Av. backfat thickness, in.[c]	1.49	1.61	1.63	1.45	1.54
Av. loin eye area, sq. in.[d]	3.85	3.65	3.74	3.91	3.80
Percent trimmed ham and loin[e]	25.9	25.0	25.4	25.7	25.5
0.4 gm. riboflavin added/ton					
No. pigs slaughtered	6	6	6	5[f]	23[f]
Av. slaughter wt., lb.	212.0	206.0	210.0	206.8	208.7
Av. carcass length, in.	30.2	30.1	30.7	29.6	30.2
Av. backfat thickness, in.[c]	1.63	1.47	1.51	1.62	1.56
Av. loin eye area, sq. in.[d]	4.24	3.91	3.90	3.90	3.99
Percent trimmed ham and loin[e]	26.0	26.4	26.6	25.1	26.1
0.8 gm. riboflavin added/ton					
No. pigs slaughtered	4[f]	5[f]	6	6	21[f]
Av. slaughter wt., lb.	211.2	206.8	210.0	212.0	209.4
Av. carcass length, in.	30.2	30.1	30.5	30.8	30.4
Av. backfat thickness, in.[c]	1.73	1.50	1.52	1.48	1.54
Av. loin eye area, sq. in.[d]	3.58	4.08	3.62	3.71	3.75
Percent trimmed ham and loin[e]	24.9	26.2	27.0	25.6	26.0
1.2 gm. riboflavin added/ton					
No. pigs slaughtered	5[f]	6	6	5[f]	22[f]
Av. slaughter wt., lb.	212.4	206.0	212.3	209.6	210.0
Av. carcass length, in.	30.7	29.9	30.7	30.6	30.4
Av. backfat thickness, in.[c]	1.56	1.54	1.51	1.52	1.53
Av. loin eye area, sq. in.[d]	3.79	3.78	4.04	3.92	3.89
Percent trimmed ham and loin[e]	25.4	26.0	26.2	26.1	25.9
By level of calcium pantothenate					
No. pigs slaughtered	21[f]	22[f]	22[f]	22[f]	
Av. slaughter wt., lb.	210.6	206.7	210.1	207.8	
Av. carcass length, in.	30.7	30.2	30.8	30.3	
Av. backfat thickness, in.[c]	1.59	1.53	1.54	1.52	
Av. loin eye area, sq. in.[d]	3.90	3.86	3.83	3.85	
Percent trimmed ham and loin[e]	25.6	25.9	26.4	25.6	

[a] Pigs were fed 15% protein corn-soybean meal diets from start of experiment until they averaged 100 lb.; 12% protein diets were fed from 100 lb. to completion of the experiment.
[b] Calcium pantothenate contains 92.01% pantothenic acid.
[c] The average of three measurements taken at the levels of the first thoracic and last lumbar vertebra and the last rib.
[d] Determined by measurement with a planimeter of a tracing of the cross-sectional area of the longissimus dorsi at the level of the 10th rib.
[e] Percent combined weight of trimmed hams and loins of off-test weight of pigs.
[f] When less than 6 pigs slaughtered per individual treatment, carcass data were not obtained on missing pigs because they did not weigh 200 lb. at 111 days of the experiment.

Table 8. Effects of calcium pantothenate supplementation of corn-soybean meal diets on rate and efficiency of gain of growing swine, experiments 7, 8, and 9[a]

Calcium pantothenate added, gm./ton[b]	0	2	4	8
Items				
Av. initial wt., lb.				
Experiment 7[c]	40.8	41.1[f]	40.6	41.0
Experiment 8[d]	46.9[g]	46.9	45.9	46.4[h]
Experiment 9[e]	46.8	46.6	46.5	46.5
Av. final wt., lb.				
Experiment 7[c]	192.7	188.2	190.0	193.4
Experiment 8[d]	201.1	202.8	200.3	202.3
Experiment 9[e]	203.0	200.6	201.0	200.3
Av. daily gain, lb.				
Experiment 7[c]	1.60	1.54	1.58	1.60
Experiment 8[d]	1.89	1.88	1.85	1.93
Experiment 9[e]	1.82	1.76	1.79	1.73
Feed/gain				
Experiment 7	3.33	3.36	3.29	3.36
Experiment 8	3.14	3.37	3.21	3.06
Experiment 9	3.34	3.40	3.35	3.37

[a]Pigs were self-fed 15% protein corn-soybean meal diets from start of experiments to 100 lb.; 12% protein diets fed from 100 lb. to completion of experiments.
[b]Calcium pantothenate contains 92.01% pantothenic acid.
[c]Experiment conducted at St. Paul; four lots of 5 pigs per treatment; duration of experiment, 97 days for replicates 1, 2, and 3, 90 days for replicate 4.
[d]Data from two lots of pigs per treatment, Northeast Station, combined with data from one lot of pigs per treatment, Southern Experiment Station, making three lots of six pigs per treatment; av. initial wt. of pigs from Southern Experiment Station, 40.8 lb.; av. initial wt. of pigs from Northeast Station, 49.2 lb.; av. daily gain of all pigs, Southern Station, 1.84; average daily gain of all pigs, Northeast Station, 1.92.
[e]Experiment conducted at North Central Station; two lots of 8 pigs per treatment; duration of experiment, 84 to 89 days, av. 87.1 days.
[f]One pig removed from replicate 1 after 84 days, injury, gain data omitted.
[g]One pig died after 46 days on experiment, Southern Station; had gained 1.34 lb. daily prior to death; death not considered due to treatment.
[h]One pig died after 46 days on test, Southern Station; had gained 1.61 lb. daily prior to death; death not considered due to treatment.

Table 9. Influence of supplemental calcium pantothenate on rate and efficiency of gain of growing swine, experiment 10[a]

Calcium pantothenate added, gm./ton[b]	0	1.97	3.95	5.92	7.89
Items					
No. lots of pigs	3	3	3	3	3
No. pigs per lot	5	5	5	5	5
Av. initial wt., lb.	49.5	49.7	49.7	49.7	49.7
Av. final wt., lb.	174.1	174.4	175.8	169.1	167.5
Av. daily gain, lb.	1.62	1.58	1.63	1.55	1.52
Feed/gain	3.33	3.38	3.38	3.39	3.46

[a]Pigs were fed 15% protein corn-soybean meal-tankage diets to 100 lb.; 12% protein diets were fed after 100 lb.; duration of experiment 77 days.
[b]Calcium pantothenate contains 92.01% pantothenic acid.

Table 10. Influence of supplemental niacin on rate and efficiency of gain of pigs fed corn-soybean meal diets, experiment 14[a]

Niacin added, gm./ton	0	2	4	8	16	24
Items						
No. pigs	21	21	21	21	21	21
Av. initial wt., lb.	51.4	49.6	50.6	50.2	50.5	49.9
Av. final wt., lb.	185.8	182.3	182.2	182.7	181.9	183.1
Av. daily gain, lb.	1.48	1.46	1.45	1.46	1.44	1.46
Feed/gain	3.58	3.41	3.43	3.42	3.42	3.46

[a]Pigs were fed 15% protein corn-soybean meal diets until they averaged 100 lb.; 12% protein diets were fed from 100 lb. until completion of experiment; duration of experiment, 91 days.

Table 11. Effects of calcium pantothenate supplementation of diets for growing pigs on rate and efficiency of gain, experiments 11, 12, and 13

Calcium pantothenate added, gm./ton[a]	0	1.97	3.95	5.92	7.89
Items					
Av. initial wt., lb.					
Experiment 11[b]					
Corn-soybean meal (CS) diets	52.5[g]	51.7	52.4	52.3	52.5[g]
Corn-soybean meal-tankage (CST) diets	52.1	51.6	53.1[g]	52.1[g]	52.4
Corn-soybean meal-fish meal (CSF) diets	51.8	51.5	52.0	52.0	52.4
Experiment 12[c]					
CS diets	52.6[g,h]	52.0	51.4	52.2	51.6
CSF diets	51.8	52.0	52.2	51.2	50.2
Experiment 13[d]					
CS diets	36.6	37.1	36.6	36.7	37.2
CST diets	37.1[g]	37.0	36.8	36.9	37.2[g]
Av. final wt., lb.					
Experiment 11					
CS diets	204.2	202.0	204.0	204.2	203.2
CST diets	205.8	204.0	203.3	203.4	206.2
CSF diets	204.4	204.5	204.2	206.0	202.7
Experiment 12					
CS diets	201.0	206.5	202.8	204.8	202.0
CSF diets	201.8	205.2	205.8	206.8	208.1
Experiment 13					
CS diets	205.6	205.6	208.2	208.0	207.4
CST diets	204.1	205.2	205.6	204.8	207.1
Av. daily gain, lb.					
Experiment 11					
CS diets	1.90	1.92	1.88	1.91	1.86
CST diets[e]	1.83	1.82	1.82	1.80	1.85
CSF diets	1.86	1.90	1.93	1.94	1.88
Experiment 12					
CS diets	1.83	1.86	1.88	1.90	1.79
CSF diets[f]	1.90	1.96	1.84	1.89	1.90
Experiment 13					
CS diets	1.70	1.61	1.68	1.75	1.62
CST diets	1.61	1.68	1.65	1.57	1.63
Feed/gain					
Experiment 11					
CS diets	3.25	3.21	3.24	3.22	3.31
CST diets	3.26	3.23	3.48	3.34	3.32
CSF diets	3.26	3.17	3.24	3.22	3.16
Experiment 12					
CS diets	3.36	3.07	3.10	3.18	3.14
CSF diets	3.04	3.02	3.11	3.08	3.12
Experiment 13					
CS diets	3.35	3.30	3.32	3.27	3.46
CST diets	3.30	3.33	3.34	3.45	3.54

[a] Calcium pantothenate contains 92.01% pantothenic acid.
[b] Experiment conducted at North Central Station; two lots of eight pigs fed each experimental diet; diets contained approximately 15% protein until pigs averaged 100 lb. and 12% protein from 100 lb. until completion of experiment.
[c] Experiment conducted at Southern Experiment Station; two lots of six pigs fed each experimental diet.
[d] Experiment conducted at West Central Experiment Station; two lots of six pigs fed each experimental diet.
[e] Average daily gain of pigs fed CST diets significantly ($P < .05$) less than gains of pigs fed CS and CSF diets.
[f] Average daily gain of pigs fed CSF diets significantly ($P < .05$) greater than that of pigs fed CS diets.
[g] Gain data omitted for one pig from each treatment group indicated; pigs eliminated from experiment due to growth failure, not considered to be due to experimental treatments.
[h] One pig died after 15 days on experiment; gain data omitted.

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