PANTOTHENIC ACID REQUIREMENT OF WEANLING PIGS ON A PURIFIED RATION

by

Charles E. Barnhart

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Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

Head of Major Department

Signature was redacted for privacy.

Dean of Graduate College

Iowa State College

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INTRODUCTION

Repeated reports of "goose-stepping" pigs being fed rations supposedly adequate in pantothenic acid and even when grazing a good legume pasture have caused considerable concern. A deficiency of pantothenic acid results in slow and inefficient gains and is of considerable economic importance.

Considerable research has been conducted in an attempt to determine the pantothenic acid requirement of growing-fattening pigs. However, there has been disagreement as to the recommended level of this vitamin necessary to insure satisfactory growth of pigs and to prevent deficiency symptoms. In view of new information regarding interrelationships of nutrients and antibiotics, and due to the fact that most of the pantothenic acid requirement work with pigs has been done using natural feed ingredients, which contain a large percentage of pantothenic acid in a bound form, it seemed advisable to study the requirement of pigs for pantothenic acid under carefully controlled conditions.

REVIEW OF LITERATURE

Norris and Ringrose (1930) described a syndrome in chickens involving the eyelids, corners of the mouth and adjoining skin areas and the skin on the bottom of the feet. Feathering was also retarded. When 5 to 10 per cent autoclaved yeast was added to the ration which contained casein the symptoms described were entirely prevented. Williams et al. (1933) reported that extracts from various tissues contained material capable of stimulating the growth of Gebrüde Mayer yeast. These workers concluded that the ability of these materials to stimulate growth was due to a single substance, which they called pantothenic acid.

Jukes and Lepkovsky (1936) reported that the "filtrate factor," belonging to the vitamin B group, when fed to chicks gave growth responses proportional to the amount fed. Williams et al. (1936) working with yeast observed that the addition of pantothenic acid to the sugar solution in which the yeast was suspended increased fermentation, respiration of the yeast and increased the carbohydrate content of the yeast.

Woolley et al. (1939) reported that the chick antidermatitis factor appeared to be similar to pantothenic acid. Jukes (1939) also reported that the chick antidermatitis factor was identical to pantothenic acid and established the pantothenic acid requirement of the chick at approximately 1.4 mg. per 100 grams of diet.

Dimick and Lepp (1940) compared the relationship between the "filtrate factor" and pantothenic acid. It was found that pantothenic acid cured or prevented nutritional dermatitis produced by feeding a diet of heated natural feedstuffs. Bauernfeind and Norris (1939) found that the antidermatitis factor was also necessary for reproduction in domestic fowl. Williams (1939) stated that pantothenic acid was a vitamin of importance in animal nutrition, and one year later Williams and Major (1940) reported the complete synthesis of pantothenic acid.

Chick et al. (1938), Hughes (1939) and Ellis and Madsen (1939) all observed that in addition to thiamin, riboflavin and niacin there were at least two other factors or vitamins necessary for the pig.

Oleson et al. (1939) and Subbarow and Hitchings (1939) found that pantothenic acid stimulated the growth of rats. György et al. (1940) reported that pantothenic acid appeared to contain one factor necessary for the cure of nutritional achromotrichia in rats. McKibbin *et al.* (1939) published evidence indicating that pantothenic acid was required by the dog. Fouts and co-workers (1940) demonstrated that adult dogs required the chick antidermatitis factor. Morgan and Simms (1940a) found that the "filtrate factor" prevented the fur of foxes from greying.

Deficiency Symptoms

Wintrobe and associates (1938) reported that pigs fed an artificial diet plus thiamin and riboflavin developed marked ataxia, degeneration of the posterior columns of the spinal cord, dorsal root ganglion and the peripheral nerves. Wintrobe *et al.* (1939) feeding the same ration described above plus niacin to pigs reported anemia characterized by the presence of macrocytes and nucleated red cells. Wintrobe *et al.* (1940) reported that pigs fed a purified ration with the only B vitamins added being thiamin, riboflavin, and niacin developed an abnormal gait and degenerative changes in the nervous system. Wintrobe *et al.* (1942) reported that weanling pigs fed a purified diet complete with all the known B vitamins grew and developed normally. When calcium pantothenate was not included in the ration the pigs developed an abnormal gait, degenerative changes in the peripheral nerves, posterior root ganglia, the posterior roots and the posterior funiculi of the spinal cord. Additional symptoms observed were alopecia, reddening of the skin, thinning of hair over rump and along spinal column, diarrhea, and inflammation of the colon. Wintrobe et al. (1943) reported the following additional pantothenic acid symptoms in pigs: edema and bleeding of the bowel, moderate normocytic anemia, a fall in serum chlorides, an increase in carbon dioxide combining power of the blood, a terminal rise in non-protein nitrogen and sometimes hypoglycemia. Follis and Wintrobe (1945) have described similar pantothenic acid deficiency symptoms in pigs. Sharma and co-workers (1952) reported degenerative changes in the intestinal tract of pantothenic acid deficient pigs.

Phillips and Engel (1939) found that pantothenic acid was necessary for maintenance of the normal structures of the spinal cord in chicks. Shaw and Phillips (1945) reported that a pantothenic acid deficiency caused a widespread myelin and axon degeneration in the spinal cord of chicks.

Unna (1940) described pantothenic acid deficiency symptoms in the rat as being characterized by scant, coarse fur showing rusty spots, inflammation of the nose and blood caked whiskers. Autopsy of the deficient rats revealed hemorrhages under the skin and into the adrenal cortex. He found that for optimum growth the rat required approximately 80 micrograms of pantothenic acid per rat per day. Morgan and Sims (1940b) reported that rats fed an adequate ration plus thiamin, riboflavin, and pyridoxine developed grey fur usually in bilateral patterns. When filtrates of rice bran, yeast, liver, molasses and alfalfa were fed this symptom was cured.

McElroy *et al*. (1941) also reported the red deposit around the nose and on the whiskers of pantothenic acid deficient rats and stated this was coproporphyrin derived from the Harderian gland.

Voris and Moore (1943) reported that a pantothenic acid deficiency in rats lowered the fat, protein and water composition of the body.

Bowles and co-workers (1949) reported that rats fed a pantothenic acid deficient diet developed corneal vascularization. Deficient rats fed 1 milligram of calcium pantothenate per day showed signs of recovery. In addition to the deficiency symptoms in rats already described, Berg *et al.* (1949) reported that pantothenic acid deficient rats also develop penetrating ulcers in their intestinal tract. Nelson *et al.* (1950) reported that pantothenic acid deficient rats displayed decreased growth of the tibia, and marked impairment in chrondrogenesis, osteogenesis and hematopoiesis.

Jones and associates (1945) described pantothenic acid deficiencies in mice as being characterized by a loss of hair, spasticity of the extremities, acute arching of the spine, an awkward gait, dryness of the skin, hyperemia, and edema of the eyelids.

Fouts *et al.* (1940) reported that pantothenic acid deficient dogs displayed a loss of appetite, loss of weight, intermittent diarrhea, anemia and death. Scudi and Hamlin (1942) found that a deficiency of pantothenic acid in dogs produces a lowering of the blood cholesterol, cholesterol esters, lipoid phosphorus and total lipoids. Deficient dogs also showed fatty livers.

McCall and co-workers (1946) reported that the pantothenic acid deficiency syndrome in monkeys was characterized by lack of growth, ataxia, greying and thinning of the fur, anemia and diarrhea.

Melampy *et al.* (1951) found that adult male mice fed a pantothenic acid deficient diet developed lymphopenia followed by lymphocytosis. Hypertrophy of the adrenal cortex was also reported.

Lewis and Page (1953) described the first symptoms of a pantothenic acid deficiency in dogs as being characterized by a loss of hair, scaly skin, diarrhea, decreased food intake, and ultimately becoming weak, irresponsive and prostrate.

Mills et al. (1940) reported that young rats maintained on a purified ration deficient in pantothenic acid developed hemorrhagic cortical necrosis of the adrenals. Salmon and Engel (1940) reported that pantothenic acid prevented adrenal hemorrhage and necrosis frequently observed in filtrate factor deficient rats. These observations have also been confirmed by Cowgill et al. (1952) and Perry and associates (1953). Erskoff et al. (1953) found that a pantothenic acid deficiency did not significantly impair pituitary adrenal function in rats.

Gillis and co-workers (1942) presented evidence showing that pantothenic acid is necessary for reproduction in hens. Gillis et al. (1948) further reported on the role of pantothenic acid in reproduction in hens. They reported that embryonic mortality due to pantothenic acid deficiency was confined almost entirely to the last two to three days of the incubation period. They also reported that the pantothenic acid content of the diet is quickly reflected in the amount of pantothenic acid in blood and eggs.

Taylor *et al.* (1943) found that pantothenic acid fortified rations fed to pregnant rats and mice increased the number of offspring per litter.

Requirements

Following the establishment of the need for and isolation of pantothenic acid many reports have been published concerning the requirement of various species of animals for this vitamin.

Elvehjem and co-workers (1941) feeding a purified diet to rats found that 5 micrograms of calcium pantothenate per day prevented adrenal necrosis but gave little growth response. When the daily allowance of calcium pantothenate was increased to 10 to 50 micrograms, gains were increased. Increased gains were noted although not as great when the calcium pantothenate was increased to 50 - 100 micrograms per day. Pantothenic acid content in the urine varied with the intake. The pantothenic acid content in the feces was independent of intake. Henderson and associates (1942) reported that urinary excretion studies with rats indicated that the daily requirement for calcium pantothenate was approximately 100 micrograms per day. Good agreement between growth and excretion was reported.

Hughes and Ittner (1942) reported that the pantothenic acid requirement of pigs fed a purified ration was between 7.8 and 11.8 milligrams per 100 pounds of live weight per day. Stothers et al. (1952) found that the pantothenic acid requirement of the baby pig was between 1.0 and 2.0 milligrams per 100 grams of solids. Luecke and associates (1953) reported that 25 pound pigs fed a 15.4% protein natural feedstuffs ration containing 4.15 milligrams of pantothenic acid developed symptoms of pantothenic acid deficiencies. With the addition of 2 milligrams of calcium pantothenate per pound of feed there were no manifestations of a pantothenic acid deficiency.

Schaefer and associates (1942) described symptoms of a pantothenic acid deficiency in dogs and set the requirement at 100 micrograms of calcium pantothenate per kilogram of body weight per day. Silber (1944) in reporting on pantothenic acid studies with dogs pointed out that urinary excretion of pantothenic acid decreased as intake of the vitamin decreased. He reported that the requirement for the vitamin decreased as the dogs grew older.

Bauernfeind and co-workers (1942) found that Single Comb White Leghorn chicks required 500 to 550 micrograms of pantothenic acid per 100 grams of feed to prevent dermatitis. However, 600 micrograms per 100 grams of diet were required for maximum growth. Rhode Island Red chicks required 75 micrograms less pantothenic acid per 100 grams of diet than did the Leghorns. These workers used a semi-purified ration and pointed out that their requirement figures were somewhat less than that reported by other workers using natural feedstuffs. Jukes and McElroy (1943) using a heated natural feedstuffs ration found the pantothenic acid requirement of the chick variable. They found the requirement to be approximately 1 milligram per 100 grams of diet. Hegsted and Riggs (1949) reported that chicks fed a purified diet required 955 micrograms of calcium pantothenate per 100 grams of diet. These authors stated that they felt that requirements established by feeding a purified ration are near minimum and that the requirement is higher when practical rations are fed. Hegsted and Lipman (1948) pointed out this observation by reporting that pantothenic acid in coenzyme A is only 66 per cent available to the chick. Since Lipman and co-workers (1947) have reported that much of the pantothenic acid in feeds is combined in the complex compound coenzyme A, possibly this accounts for the difference in requirements established with purified rations and rations composed of natural feedstuffs. Lih et al. (1950) found that rats grew as well on the diphosphate and the "Y" monophosphate of pantothenic acid as they did on the free acid. Panthenol showed no activity with *L. arabinosus* but was as active for rats as pantothenic acid. King and Strong (1952) prepared several pantothenic acid phosphates that could not be utilized by microorganisms but were fully active for animals. These investigators believed the phosphatase in the intestine of animals liberates these forms of pantothenic acid. McRorie et al. (1950) reported that the *Lactobacillus bulgaricus* factor may be a bound form of pantothenic acid and is 50-100 times more active than free pantothenic acid. They report that this factor will replace pantothenic acid in the nutrition of the rat.

Kratzer and Williams (1948) reported the pantothenic acid requirement for optimum growth of turkey poults was 10.5 milligrams of pantothenic acid per kilogram of diet.

Pearson and Schmidt (1948) working with Shetland ponies reported the requirement to be 38 micrograms of pantothenic acid per kilogram of body weight per day. They also reported that the amount of pantothenic acid excreted by the renal pathway is influenced by the levels ingested.

Fenton and associates (1950) found the pantothenic acid requirement for mice varied with the strain of mice under study. Six micrograms of pantothenic acid per gram of diet were adequate for one strain of mice while 8 micrograms per gram of diet were inadequate for another strain.

Swine

That swine require pantothenic acid for normal growth has been demonstrated many times. The amount required by swine has met with considerable disagreement among investigators.

Ellis and Madsen (1941) demonstrated pantothenic acid deficiency symptoms in pigs by feeding a natural feed ingredient ration that had been heated to 115° - 120°C for 30-40 hours. Ellis _et al_. (1943) found that the addition of calcium pantothenate to either a heated ration or a purified ration greatly reduced locomotor incoordination in pigs. He stated that the occurrence of locomotor incoordination in growing pigs fed natural feedstuffs rations appeared to be due to the borderline level of pantothenic acid present in relation to the requirement.

Hanson (1943) observed that when 0.2 pound of Brewer's yeast or 0.3 pound of non-irradiated dry yeast per day was added to a corn soybean meal ration, abnormal skin conditions and incoordination were improved in growing-fattening pigs. Increasing alfalfa meal from 5 to 10 per cent of the ration also improved these conditions.

McMillen and co-workers (1948) reported that pasture raised pigs, when fed a corn, soybean meal ration with vitamin A, D, thiamin, riboflavin, niacin and pyridoxine, goose stepped seven weeks after being placed on a concrete floor. When 25 milligrams of pantothenic acid per pound of feed were added to this ration no goose stepping was observed. McMillen _et_ _al_. (1949a) demonstrated the necessity of adding B vitamins to a corn, soybean meal, meat scraps, alfalfa meal ration for growing fattening pigs being fed in dry lot. McMillen and associates (1949b) reported that niacin, pantothenic acid and riboflavin are stored for only 2 to 4 weeks in weanling pigs. These workers further reported that they observed goose stepping, slow gains and diarrhea in weanling pigs fed a ration containing pantothenic acid in excess of 5 milligrams per pound.

Luecke _et_ _al_. (1949a) reported that deficiencies of niacin and pantothenic acid are involved in producing symptoms of nutritional enteritis in pigs. Luecke and co-workers (1949b) reported that pigs fed rations of corn, casein, soybean meal and minerals and supplemented with thiamin, riboflavin, niacin, and pyridoxine and containing 3.82 and 3.42 milligrams of pantothenic acid per pound of ration developed locomotor incoordination and myelin degeneration. When these rations were supplemented with 15 milligrams of calcium pantothenate per pound, good growth was obtained and no pantothenic acid deficiency symptoms were observed. Luecke and associates (1950) reported that pigs confined to dry lot and fed a ration of corn, soybean meal and minerals that assayed 4.21 milligrams of pantothenic acid per pound developed pantothenic acid symptoms. When 10 milligrams of calcium pantothenate were added per pound of ration no deficiency symptoms were observed.

Hodgskiss et al. (1950) found that gilts fed a purified ration complete in all nutrients except pantothenic acid conceived but did not farrow any pigs.

Wiese and co-workers (1951) reported that 48 hour old pigs fed a complete synthetic diet containing 1.30 milligrams of calcium pantothenate per kilogram of diet developed a loss of appetite, scours, dermatitis, goose stepping, alopecia and low urinary excretion of pantothenic acid. A daily supplementation of 10 to 20 milligrams of calcium pantothenate resulted in recovery from these symptoms.

Briggs and Beeson (1951), and Hanson and Ferrin (1952) have reported the need for pantothenic acid in practical rations fed pigs confined to concrete feeding floors.

Bowland and Owen (1952) studied the effects of feeding calcium pantothenate levels of 3 to 12 milligrams per pound of ration as a supplement to a ration containing 2.7 milligrams of pantothenic acid per pound of feed. Higher levels fed to females tended to have a detrimental effect on birth weight of offspring and on the growth of suckling pigs. The pantothenic acid content of the blood and milk of the sows, and the blood of the nursing pigs was related to the content of pantothenic acid in the sows' ration.

Interrelationships

The interrelationships and sparing effects of nutrients are numerous; therefore, quantitative requirements for specific nutrients are difficult to establish. Woolley (1940) emphasized the need for caution in studying the "filtrate factor" and pointed out that its activity might possibly be contributed to more than one compound. Richardson and Hogan (1940) demonstrated that rats recover from dermatitis more completely when both pantothenic acid and pyridoxine were fed than when either one alone was fed. Terroine and Adrian (1951) have noted that a pyridoxine deficiency in rats incites a secondary pantothenic acid deficiency.

Wright and Welch (1943) (1944) reported that folic acid and biotin play an essential role in the utilization of pantothenic acid. Emerson and Wurtz (1944) found that a biotin deficiency in rats could be aggravated by superimposing a pantothenic acid deficiency. The feeding of biotin appeared to lessen the severity of the pantothenic acid syndrome. Colby _et al_. (1948) have also observed such an interrelationship in pigs. The inclusion of biotin in the ration of pantothenic acid deficient pigs prolonged their life. Robbles and Clandinin (1953) described a disorder in turkey poults fed a practical starter ration characterized by poor growth, high mortality, broken feathers, dermatitis, and diarrhea. Supplementation of calcium pantothenate partially prevented the disorder, but supplementation of both calcium pantothenate and biotin proved best.

Milligan and Briggs (1940) have reported that Wilsons Liver Fraction "L" spares pantothenic acid in chick rations.

Richardson (1940) reported that pantothenic acid, pyridoxine and unsaturated fatty acids are associated with the cure of dermatitis in rats. Salmon (1941) found that there were three factors necessary for the cure of rat acrodynia--pyridoxine, linoleic acid and pantothenic acid.

Singer and Davis (1950) have found that greying hair of rats fed a copper deficient ration responds to the administration of either copper or calcium pantothenate. They suggest a metabolic relationship between copper and pantothenic acid and further suggest that the pantothenic acid requirement may be higher when a suboptimum level of copper is present in the ration.

Antibiotics appear to have a sparing effect on certain B vitamins. Alston (1953) reported that chlortetracycline, or aureomycin as it is commonly called, had an apparent sparing effect on riboflavin, niacin and pantothenic acid when pigs were fed a ration containing suboptimum levels of these vitamins. Catron et al. (1953) reported that vitamin B_{12} and pantothenic acid spared each other in the absence of aureomycin and that aureomycin appeared to spare both vitamin B_{12} and pantothenic acid when included in a corn soybean meal ration and fed to healthy growing-fattening pigs.

Streptomycin, terramycin, and aureomycin were found to stimulate growth of rats fed a low pantothenic acid diet, Guggenheim et al. (1953). The increase in growth was not noted when pantothenic acid was supplied in the diet at required levels. Lih and Bauman (1951) compared aureomycin, penicillin, terramycin and chloromycetin for their sparing effect upon B vitamins. They found that aureomycin and streptomycin were best in sparing pantothenic acid. This trial was conducted using weanling male rats. On the other hand Coates and associates (1951) reported that penicillin fed at the rate of 2.5 milligrams per 100 grams of diet had no sparing effect on thiamin, riboflavin, pyridoxine, or pantothenic acid when fed to chicks.

Yacowitz *et al.* (1950) reported that vitamin B_{12} spared pantothenic acid in a purified chick ration. However, Luecke and co-workers (1951) failed to find any relationship between vitamin B_{12} and pantothenic acid when feeding a natural feed ingredient ration to pigs.

Evans and associates (1951) reported that chicks receiving adequate vitamin B_{12} in their ration had a lower pantothenic acid content in their liver than when chicks were fed a vitamin B_{12} deficient diet. They suggested that vitamin B_{12} aids in the transfer of pantothenic acid from the liver to other parts of the body.

Sure and Ford (1942) noted an increase in total non-protein nitrogen and urea in the blood during the terminal stages of a pantothenic acid deficiency in rats. Wright and Skeggs (1946) reported that the fecal elimination of pantothenic acid in rats fed ad libitum increased as the protein content of the diet was increased. In equalized feeding of rats, the fecal elimination of pantothenic acid was also increased as the protein level of the diet was increased. Nelson and Evans (1945) reported that rats maintained on a pantothenic acid deficient diet grew more and survived longer on a 64% casein diet than they did when fed a 24% casein diet. Nelson et al. (1947) found that urinary excretion of pantothenic acid in rats was significantly higher when fed a 64% casein diet than when fed a diet containing only 24% casein, pantothenic acid levels in the diet being the same. Growth rate and survival was higher for those rats fed the ration containing the higher level of casein. When the pantothenic acid level of the 24% casein diet was doubled the results were equivalent to those observed with a 44% casein diet but were not equal to the 64% casein diet. Luecke and associates (1952) reported data indicating that higher levels of protein in the ration spared the pantothenic acid required by the pig.

Unlike some of the other B vitamins, Mills (1942) found that temperature did not affect the pantothenic acid requirement of young rats. Collins et al. (1953) reported that relative humidity had no effect on rats on a pantothenic acid deficient diet. Humidity did have an effect on rats deficient in pyridoxine or riboflavin.

Wright (1942) reported that consistent decreases of 20-30 per cent in the level of blood pantothenic acid have been obtained in rabbits following the administration of 5 to 10 grams of glucose. He suggests that pantothenic acid apparently participates in glucose utilization.

Figge and Atkinson (1941) found a relationship between water metabolism and pantothenic acid. By partially dehydrating normal rats they produced porphyrin incrustations on the nose and fur of rats. This is a most conspicuous symptom of pantothenic acid deficiency in albino rats.

Axelrod et al. (1947) reported that when either pyridoxine, riboflavin or pantothenic acid is withdrawn from the ration of rats, the animals' antibody response to human red cells was decreased. Ludovici and Axelrod (1951) found that panthenol, an alcohol analogue of pantothenic acid, was as effective as pantothenic acid in promoting both growth and a high serum antibody response in rats. Ludovici and co-workers (1951) reported that the supplementation of DL-methionine in the diet of pantothenic acid deficient rats increased the antibody titers. DL-methionine did not increase the antibody titers of non-deficient rats. These workers reported that improved growth was observed in pantothenic acid deficient rats when supplemented with DL-methionine.

Lotspeich (1950) reported an interesting observation that adult female rats could be made to develop symptoms of a pantothenic acid deficiency when stimulated to grow rapidly by the continued injection of anterior pituitary hormone.

Russell and Nasset (1941) reported that calcium pantothenate, when added to the ration of dogs, increased the rate of digestion and absorption of carbohydrates 51 per cent and 37 per cent, respectively.

Miscellaneous Relationships

Barnhart (1948) found that the addition of 10 per cent alfalfa meal to the gestation and lactation ration fed brood sows increased the pantothenic acid content of the milk produced by these sows.

Bruce and Bowland (1952) reported that the pantothenic acid content of the blood and milk of sows and the blood of suckling pigs was related to the content of the vitamin in the sows' ration.

Snell *et al*. (1940) found that tissue from chicks grown on pantothenic acid deficient diets contained only 30 to 70 per cent as much pantothenic acid per gram as tissue from chicks fed a diet adequate in pantothenic acid. After studying the pantothenic acid content of eggs, Snell and associates (1941) concluded that within limits the pantothenic acid content was directly proportional to that of the diet. Pearson et al. (1946) also reported that the pantothenic acid content of blood and tissue from chickens was affected by the level of the vitamin in the ration fed the birds.

Evans and co-workers (1952) reported that twelve months of cold storage resulted in an 8 per cent loss of pantothenic acid in eggs and that there was also a shift of pantothenic acid from the yolk to the albumen.

Melampy and Northrop (1951) reported that a pantothenic acid deficiency in mice decreased the content of the vitamin in the heart, kidney and thigh muscle significantly. The average daily urinary and fecal excretion of pantothenic acid decreased 96 and 80 per cent, respectively, after mice had been made deficient for 6 weeks.

EXPERIMENTAL PROCEDURE

To determine the pantothenic acid requirements of weanling pigs from weaning to approximately 100 pounds, 48 Duroc x Poland China x Landrace cross-bred pigs were allotted according to outcome groups to 12 different ration treatments. A randomized block design was used with 4 pigs, 2 males and 2 females, being fed the 6 levels of pantothenic acid with and without chlortetracycline (aureomycin HCl). The pigs were 43 to 47 days of age ranging in weight from 17 to 33 pounds when they were placed on the experimental rations. The pigs pictured in Figure 1 are representative of all pigs started on this experiment. These pigs were selected from approximately 100 pigs that had been produced specifically for this study. The sows producing these pigs were fed the ration presented in Table 1 during lactation. Approximately 1 week prior to allotment the pigs were weaned, treated with lime sulfur to control external parasites, and fed 0.5 per cent sodium fluoride in the feed for 2 days to control internal parasites. From weaning until 12 days following allotment, a 12 per cent protein holding ration low in B-vitamins was fed. Composition of this ration is given in Table 2. Each pig was

Fig. 1. Pigs representative of those started on the experiment.

Table 1. Composition of the brood sow lactation ration.

Ingredients	Per cent
Ground yellow corn	65.00
17% dehydrated alfalfa meal	10.00
Ground oats	10.00
50% meat and bone scraps	5.00
Dried whey	2.50
Solvent soybean oil meal (3 sources blended)	6.40
Calcium carbonate	0.10
Salt (I)	0.50
Trace minerals	0.10
Bi con 3 + 3	0.30
9-F irradiated yeast	0.01
Nopcay '20' Type III (Vit. A)	0.01
25% choline chloride	0.10
Fortafeed 2-49C	0.04
Total	100.06

Table 2. Composition of the holding ration.

Ingredients	Per cent
Ground yellow corn	86.50
Solvent soybean oilmeal (3 sources blended)	6.00
Vitamin A premix (200,000 I.U. per lb.)	3.00
Vitamin D_2 premix (20,000 I.U. per lb.)	2.00
Di-Calcium phosphate	1.00
Ground calcium carbonate	1.00
Iodized salt	0.50
Total	100.00

individually fed and confined to crates with wire floors. Because of the difference in construction of the two different types of crates used, all females were kept in one type of crate housed in building F and all males were kept in the other type of crate housed in building E on the Swine Nutrition Experimental Farm. The crates in building F were more adapted to complete and accurate collection of urine from females than those crates in building E, thus explaining this separation in sex. Photographs of the two types of crates are presented in Figure 2. The crates in building F were equipped with self-feeders and automatic waterers, while each crate in building E was equipped with a sizeable feed trough and water pan. Therefore, feed and water was available to the pigs at all times. The pens were washed 3 times daily to prevent coprophagy. Periodically throughout the course of the experiment the pigs were sprayed with benzene hexachloride for external parasite control.

For the first 12 days following allotment the pigs were fed the 12% protein ration to give them sufficient time to adjust to their new environment before being placed on the experimental rations. Immediately prior to being placed on the experimental rations a 48 hour urine collection was made from each pig. The urine was collected by using a metal tray that fit tightly under

Fig. 2. Metal crates used for females pictured above and wooden crates used for males pictured below.

the crate. A copper screen over the top of the collection tray separated the fecal material and waste feed from the urine, with the urine running through the screen into the bottom of the tray and on into a glass jar. This equipment is pictured in Figure 3. The urine was collected frequently and stored in a walk-in refrigerator until the end of the collection period at which time the total volume of urine was thoroughly mixed, the total volume measured, and a 15 milliliter aliquot taken. This was stored in a deep freeze for future pantothenic acid assay. From the time the urine was collected until the aliquot was placed in the freezer the urine was preserved with toluene.

Upon completion of the initial urine collections the pigs were weighed and placed on the experimental rations. This weight was taken as the initial weight for the experimental period. A purified ration, the composition of which is presented in Table 3, was fed. Six levels of pantothenic acid, 2, 3, 4, 5, 6 and 7 milligrams per pound of ration were fed with and without 5 milligrams of chlortetracycline. A pilot trial was conducted prior to this experiment to develop a satisfactory purified ration. Starch and sucrose was compared with starch and 10% cerelose and starch and 30% cerelose as energy sources. Although the equipment used in this preliminary trial was unsatisfactory for determining accurate feed consumption

Fig. 3. Metal crate with urine collection tray and jar in place.

Table 3. Composition and calculated analysis of basal ration.[a]

Ingredients	Per cent
Pearl starch	37.50
Cerelose	30.00
Drackett protein	19.50
Woodflock	2.00
Corn oil	4.00
Trace mineral mix no. 594[b]	3.00
Di Calcium phosphate	1.80
Vitamin premix no. 594[c]	2.00
98% DL-Methionine	0.20
Total	100.00

[a]Calcium pantothenate was premixed with pearl starch. Two pounds of this premix per 100 pounds of ration provided 1 mg. of pantothenic acid per pound of ration. This premix was added to this basal ration to compose the 3, 4, 5, 6, and 7 mg. pantothenic acid rations. Chlortetracycline was premixed with pearl starch and 2 pounds of the premix per 100 pound of ration provided 5 mg. of chlortetracycline per pound of ration. Six of the ration treatments contained no antibiotic and the other six rations contained the antibiotic.

[b]Contributed the following per cent of ration: Mn .01; Fe .036; Cu .00076; Co .0003; Zn .003; Mg .05; K .40; NaCl .51; KI .0003.

[c]Contributed the following per pound of ration: Alpha tocopherol acetate, 3 mg.; biotin, 0.2 mg.; ascorbic acid, 50 mg.; choline chloride, 450 mg.; pantothenic acid, 1.63 mg.; folic acid, 0.5 mg.; niacin, 14.5 mg.; riboflavin, 1.5 mg; thiamin HCl, 3 mg.; pyridoxin, 1 mg.; vitamin K, 1 mg.; para-amino-benzoic acid, 0.5 mg.; inositol, 200 mg.; vitamin B_{12}, 5 mcg.; vitamin A, 2525 I.U.; vitamin D, 400 I.U.

Table 3 (Continued)

Calculated Analysis	Per cent
Protein, %	16.06
Fat, %	4.00
Fiber, %	2.00
Calcium, %	.75
Phosphorus, %	.49
Vitamin A, I.U. per lb.	2525.00
Vitamin D, I.U. per lb.	400.00
Riboflavin, mg. per lb.	1.60
Pantothenic acid, mg. per lb.	2.00
Niacin, mg. per lb.	15.03
Choline, mg. per lb.	450.00
Vitamin B_{12}, mcg. per lb.	5.00
Thiamin, mg. per lb.	3.02
Pyridoxine, mg. per lb.	1.49
Folic acid, mg. per lb.	.72
Inositol, mg. per lb.	226.69

data, the ration which included starch and 30% cerelose produced faster gains and appeared more palatable than either the other two rations. The Drackett Industrial protein, a purified soybean protein very low in water soluble vitamins, when properly supplemented with vitamins and minerals proved to be as satisfactory a source of protein as soybean meal.

Pigs were weighed and feed was weighed back each week throughout the entire experiment.

When each pig reached 75 pounds a final urine collection was made in the same manner as the initial collection was made, except the urine was measured and a proportionate aliquot was taken at the end of each 24 hours and frozen. The two aliquots were combined and stored in a deep freeze for a pantothenic acid assay. This change in handling of the final urine collection was necessary because of the extremely hot weather.

When the pigs weighed between 75 and 100 pounds, fecal collections were made twice, one day apart, from those pigs fed the 2, 4 and 7 milligram levels of pantothenic acid both with and without chlortetracycline. The collection schedule is given in Table 4. The fecal collections were made at approximately 7:30 A.M. in sterile "Dixie cups" and taken immediately to the laboratory for bacteriological counts. Two 1 gram aliquots

Table 4. Feces collection schedule.

Level of Pantothenic Acid (Mg. per lb. ration)	2		4		7	
	Pig No.	Dates Feces Collected	Pig No.	Dates Feces Collected	Pig No.	Dates Feces Collected
Without Chlortetracycline	5292	7/14 & 16	5138	7/14 & 16	5345	7/14 & 16
	5231	7/21 & 23	5210	7/21 & 23	5148	7/21 & 23
	5204	7/28 & 30	5290	7/28 & 30	5142	7/28 & 30
	5141	8/4 & 6	5205	8/4 & 6	5291	8/4 & 6
With Chlortetracycline	5257	7/14 & 16	5226	7/14 & 16	5316	7/14 & 16
	5240	7/21 & 23	5137	7/21 & 23	5135	7/21 & 23
	5149	7/28 & 30	5144	7/28 & 30	5150	7/28 & 30
	5250	8/4 & 6	5200	8/4 & 6	5228	8/4 & 6

from each sample were taken, diluted in water and blended in a Waring blender. Each of the two aliquots were further divided into 2 additional aliquots and plated out at dilutions of 10^4, 10^5, 10^6 and 10^7 on Lactobacilli, Linden Thioglycolate medium, Mitis Salivarius Agar, Tryptone Glucose Extract Agar, and Violet Red Bile Agar and dilutions of 10^3, 10^4, and 10^5 on Littman Oxgall Agar. Composition of media, volume of media used per plate, and length of incubation time was that recommended in Difco Manual (1953). Colonies growing on the six different differential media were counted following incubation. Only plates with counts falling between 30 and 300 were used in the final summary. Dry matter determinations were made on all fecal samples.

Hemoglobin, red blood cell counts, white blood cell counts, hematocrit, clotting time, and differential white cell counts were all determined when the pigs weighed between 75 and 100 pounds. Hemoglobin determinations were made with a Fisher Electro Hemometer. Clotting time was determined by drawing blood into a capillary tube and breaking the tube every 15 seconds to check blood coagulation.

Pantothenic acid assays were made according to the method described in the Difco Manual (1953). Three dilution levels of each urine sample were assayed. One, 2 and 4 milliliters of urine were added to 5 milliliters of pantothenic acid assay media and distilled water added to bring the total volume up to 10 milliliters. Lactobacillus arabinosus 17-5 ATCC 8014 was used for the assay organism. Inoculated tubes were incubated in a 37°C water bath for 24 hours and growth determined turbidimetrically; after 72 hours of incubation growth of the organism was measured acidimetrically. The urine samples collected at the beginning of the experiment were all diluted 1:30 for assaying. The final urine samples were diluted according to the level of pantothenic acid in the ration the pigs were fed; 2 and 3 milligrams 1:50, 4 milligrams 1:75, 5 and 6 milligrams 1:125, 6 milligrams 1:175 and 7 milligrams 1:200.

The assay procedure for the determination of the pantothenic acid concentration of the urine samples was conducted as a randomized blocks design experiment.

The juxtaposition of the culture tubes during the incubation in the water bath and sterilization in the oven was determined by random allottment. The order of addition to the tubes of the water, media, and urine, and the order of reading the tubes in the colorimeter was determined by randomization.

On the basis that the variation in pantothenic acid concentration of urine is much greater between samples from different pigs than between samples from the same pigs, only one tube was cultured at each of three urine concentrations for each pig. The elimination of duplicate tubes permitted the handling of the urine samples from all 48 pigs and the standard samples in a single simultaneous assay procedure.

Following the suggestion given by Finney (1952 p 110) the responses obtained from the 3 urine concentrations were "matched" to 3 approximately equal responses from the standard solutions, to avoid, as far as possible, errors due to curvature in the response--log-concentration relationship.

An example follows below for pig number 5158.

S_1	S_2	S_3	TOTALS S_T	
8	15	32	55	
9	17	35	61	$U_T - S_T = 6$
U1	U2	U3	UT	

$b = (S_3 - S_1) + (U_3 - U_1) = 12.50$

$M = \frac{U-S}{3\,b} = \frac{6}{37.50} =$ 0.1600

$(\text{Log}_{10}\ 2) \times M =$ 0.0482

$\text{Antilog}\ (\text{Log}_{10}\ 2) \times M =$ 1.118

P.A. concentration per 2 ml. urine

$= 1.118 \times 0.08 = 0.0894$ mg.

S = Standard

U = Unknown or Urine

b = Regression of colorimeter reading on P.A. log-concentration of test substance.

M = The horizontal distance between the response curves (linear regressions) for standard and urine.

It is to be noted that in the above example (as in most parallel line assay experiments) both urine and standard concentrations were at ratios of 1, 2, 4 resulting in equidistant log concentration scales. In instances where it was necessary to use unequal interval values for the standard response, adjustment was made using factors worked out by Dr. H. O. Hartley of the Experimental Statistics Department at Iowa State College. The factors in their reduced form are presented in appendix Table G.

RESULTS AND DISCUSSION

Summary of the average daily gain per pig, average daily feed consumed per pig, average amount of feed required per pound of gain, and the analyses of variance for these three items are presented in Tables 5 and 6, respectively. There were no significant differences in rate of gain, daily feed consumed and feed required per pound of gain between pigs fed the six different levels of pantothenic acid either with or without chlortetracycline. Average daily gains and feed required per pound of gain is illustrated graphically in Figure 4.

Two pigs were removed from the experiment before they reached 100 pounds. One suffered a prolapsed rectum. The other one was unthrifty in appearance and was gaining slowly when it was removed from the experiment and sent to the veterinary diagnostic laboratory. The autopsy report was as follows:

> Re: Case No. 2286. Examination of pig 5149 from project 959, experiment 594, revealed a congenital hypoplasia of the small colon and anterior portion of the rectum. The constriction caused an accumulation of fecal material in the large colon.
>
> Signed: William S. Monlux, D.V.M.
> Iowa Vet. Diag. Lab.

This pig which had been fed a ration containing 2 milligrams

Table 5. Summary of average daily gain, average daily feed consumed, and average amount of feed required per pound of gain.

Ration Treatments Mg. Pantothenic Acid	Av. Daily Gain, lb.	Av. Daily Feed Consumed, lb.	Av. Feed Consumed Per lb. Gain, lb.
Without Chlortetracycline			
2	1.18	2.88	2.44
3	1.31	3.35	2.54
4	1.18	3.01	2.54
5	1.22	3.03	2.48
6	1.34	3.26	2.41
7	1.28	3.05	2.38
With Chlortetracycline			
2	1.32	2.92	2.21
3	1.30	3.07	2.37
4	1.30	3.10	2.38
5	1.37	3.24	2.35
6	1.31	3.02	2.30
7	1.29	2.95	2.29
Average all levels no antibiotic	1.25	3.10	2.46
Average all levels with antibiotic	1.31	3.05	2.32
Average of Pantothenic Acid levels			
2	1.25	2.90	2.32
3	1.30	3.21	2.46
4	1.24	3.05	2.46
5	1.29	3.13	2.41
6	1.33	3.14	2.35
7	1.29	3.00	2.33

Table 6. Analyses of variance of average daily gain, feed consumption, and feed per pound gain.

Source of Variation	Degrees of Freedom	Mean Squares		
		Av. Daily Gain	Av. Daily Feed	Feed per lb. Gain
Replications	3	0.0733	2.0566	4619
Antibiotic	1	0.0475	0.0252	2567
P. A. Levels	5	0.0096	0.1007	309
Antibiotic x P.A. Levels	5	0.0135	0.0719	48
Expt'l. Error	31	0.0124	0.1309	384
Total	45*			

*Two values estimated for analysis of variance.

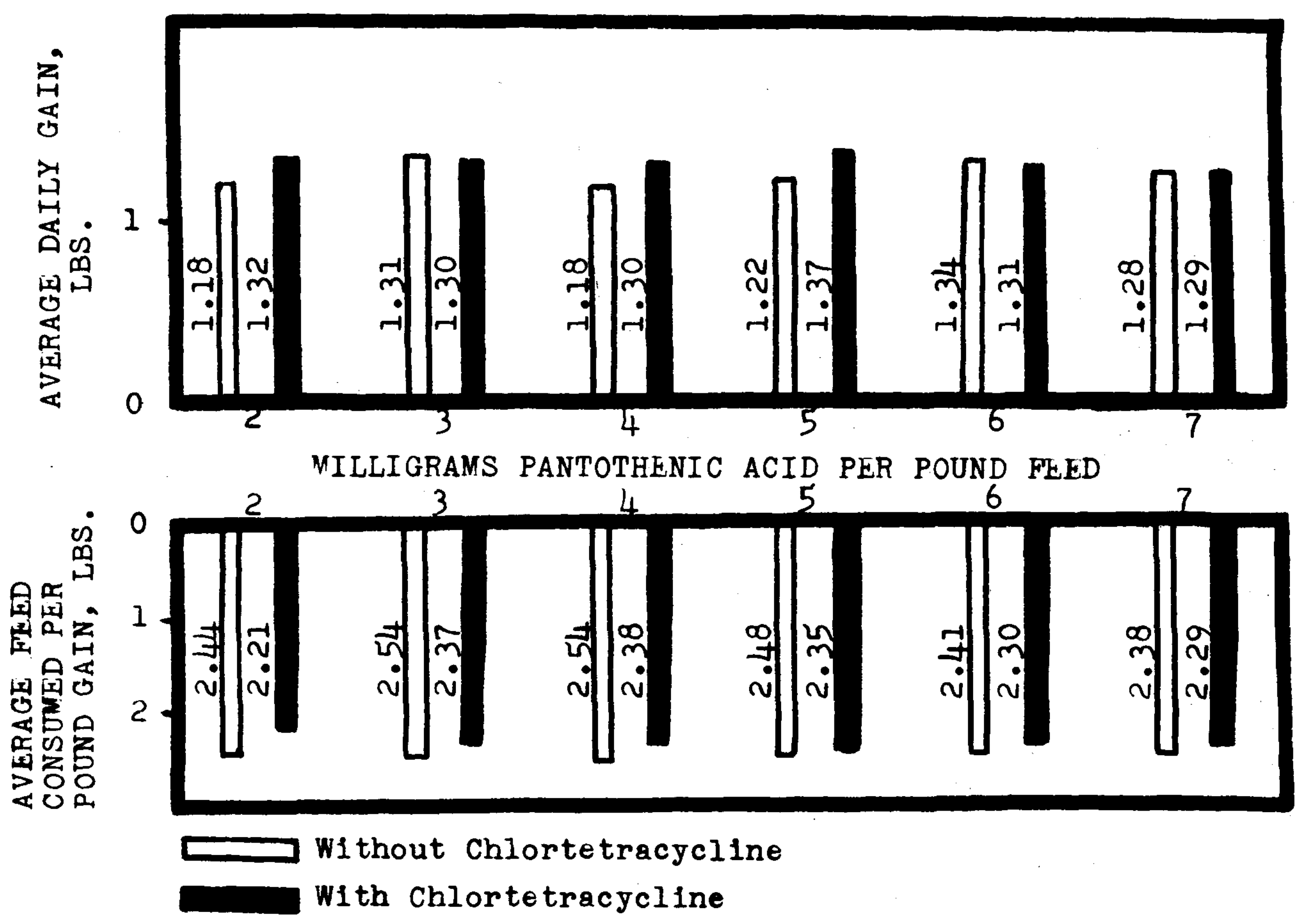


Fig. 4. Average daily gain and feed required per pound of gain for the different ration treatments.

of pantothenic acid without antibiotic, showed none of the degenerative changes in the intestinal tract described by Sharma et al. (1952) as being characteristic of a pantothenic acid deficiency. Doctor Monlux could find no pantothenic acid deficiency symptom upon post mortem examination of this pig. On the basis of the autopsy of this pig and the fact that there were no external symptoms of a pantothenic acid deficiency in any of the pigs no other post mortem examinations were performed.

Daily gain, daily feed intake, and feed efficiency data for these two pigs that were removed from the experiment before reaching 100 pound weights were estimated by the following formula, Snedecor (p. 268, 1946):

$$X = \frac{tT + bB - S}{(t - 1)\ (b - 1)}$$

When the pigs were weighing between 75 and 100 pounds a blood sample was obtained from each pig. These blood data are summarized in Table 7. The analyses of variance for these data are presented in Table 8. There were no significant differences in hemoglobin, red and white blood cell counts, differential counts, hematocrit or clotting time between pigs fed the different rations. None of the blood abnormalities associated with a pantothenic acid deficiency in pigs as reported by Wintrobe et al. (1939)

Table 7. Summary of blood data.
(Averages)

Mg. of PA per Lb. Feed	Hemo-globin Grams Per 100 ml.	Red Blood Cell Count Per cu. mm. x 1000	White Blood Cell Count Per cu. mm.	Hemato-crit %
		Without Chlortetracycline		
2	12	6,860	16,200	38
3	13	6,958	12,850	39
4	13	7,273	21,950	37
5	13	7,093	17,500	39
6	13	7,483	19,525	41
7	12	7,158	16,950	37
		With Chlortetracycline		
2	13	7,323	15,550	40
3	14	7,000	22,125	40
4	13	7,263	20,775	38
5	13	7,550	18,525	44
6	12	7,183	20,950	38
7	13	7,213	18,775	39

Differential White Cell Count					Clotting Time Seconds
Neutro-phils	Lympho-cytes	Eosino-phils	Mono-cytes	Baso-phils	
		Without Chlortetracycline			
21	68	6	5	0	19
32	60	3	5	0	26
28	63	4	5	0	41
31	64	5	4	0	26
23	69	4	5	0	26
31	61	5	4	0	30
		With Chlortetracycline			
30	59	4	7	0	30
23	71	1	5	1	38
26	70	3	3	1	23
28	64	5	3	1	26
25	65	4	6	0	53
29	62	2	7	0	45

Table 8. Analyses of variance blood data.

Source of Variation	Degrees of Freedom	Mean Squares Red Cell Count*	White Cell Count*	Neutrophils*
Replications	3	9.60	24.75	240.52
Antibiotic	1	5.20	14.96	2.52
P. A. Levels	5	5.53	16.17	18.76
Antibiotic x P.A. Levels	5	8.65	7.40	34.23
Expt'l. Error	33	36.57	11.46	41.36
Total	47			

*Original values changed to angles (Snedecor p. 449, 1946).

Mean Squares					
Lymphocytes*	Eosinophils*	Monocytes*	Hematocrit	Clotting Time	Hemoglobin
218.53	44.38	34.18	17	1281	9
7.76	56.12	2.34	24	675	3
12.74	29.24	23.99	14	281	1.4
39.92	15.74	19.97	12	472	2.2
47.98	23.58	21.08	11	344	1.42

(1943) were observed. That there were no significant differences in red blood cell counts, hemoglobin, and hematocrits between the pigs receiving chlortetracycline and those not being fed the antibiotic is in agreement with the report of Squibb and associates (1953).

Microbiological assays of the urine samples collected from each pig prior to being placed on the experimental rations and when each pig reached 75 pounds were made for pantothenic acid. Growth in the assay tubes was determined turbidimetrically after 24 hours of incubation, and acidimetrically after having been incubated 72 hours. The standard curves for these assays are presented in Figures 5 and 6. Each point on these curves represents an average of four values. It will be noted that there is rather close agreement between the acidimetric curves and the turbidimetric curves even though variables such as difference in incubation time and possible human errors in titrating are involved.

Assay values were determined from the turbidimetric reading for pantothenic acid by the methods previously described. The total urine excretion for 48 hours, calcium pantothenate concentration of the urine, and total calcium pantothenate excreted for the 48 hour period have all been summarized according to the various ration treatments and these data are presented in Table 9. To

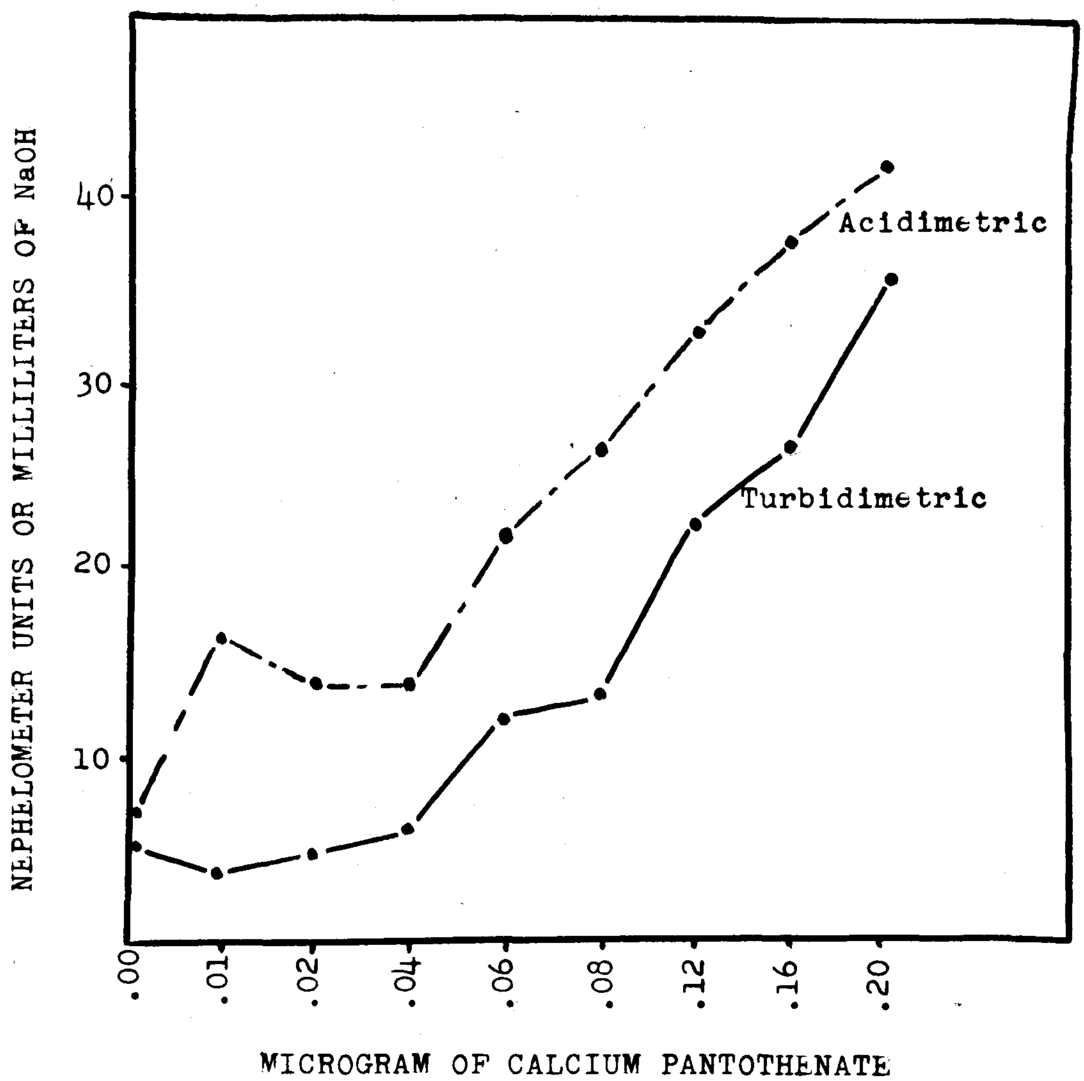


Fig. 5. Standard curve for pantothenic acid assay of initial urine samples using acidimetric and turbidimetric methods.

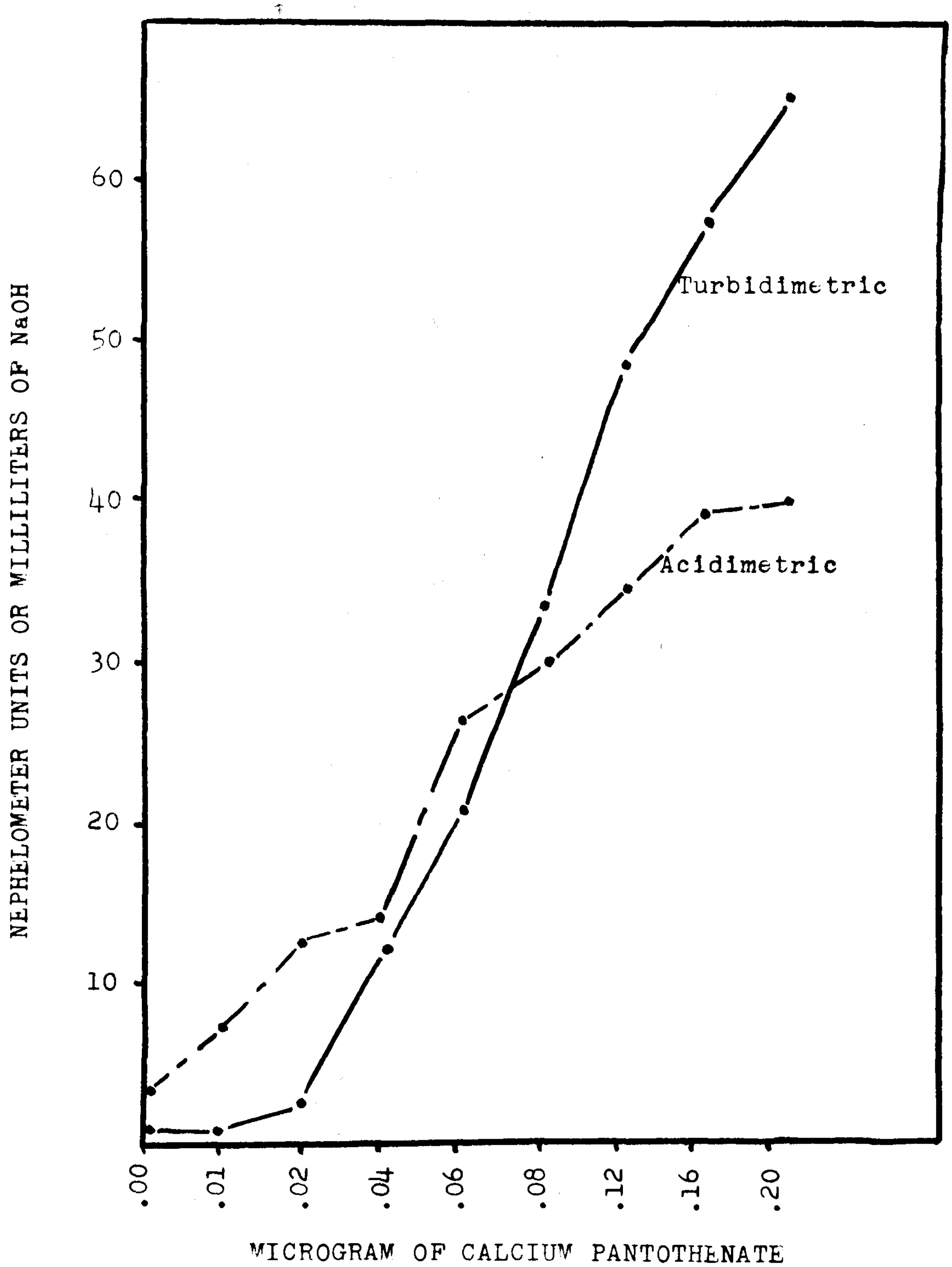


Fig. 6. Standard curve for pantothenic acid assay of final urine samples using acidimetric and turbidimetric methods.

Table 9. Summary of urine data, average of 4 pigs per treatment.

Mg. of P.A. per lb. Feed	Total Urine Excreted, Final 48 Hr. Collection, ml.	Calcium Pantothenate mcg/ml. Urine, Final Collection	Total Ca. Pantothenate Excreted, Final 48 Hr. Collection, mg.	Difference Between Initial and Final Collection in Total Ca. Pantothenate Excreted, 48 Hrs., mg.
		Without Chlortetracycline		
2	2413	2.27	4.96	4.66
3	2400	2.44	5.83	5.34
4	2855	3.09	7.43	6.64
5	2963	5.66	16.73	16.37
6	2089	8.63	16.82	16.54
7	1948	12.08	22.72	22.15
		With Chlortetracycline		
2	2491	1.28	3.36	3.08
3	2399	2.55	6.04	5.41
4	2593	3.10	8.77	8.22
5	2478	4.63	11.40	11.18
6	2708	7.36	20.26	19.93
7	2666	8.04	21.53	21.25

rule out any possible biological differences within the pigs the average difference between the initial and final total 48 hour excretion of calcium pantothenate was also calculated for each ration treatment and is included in Table 9. As would be expected, since the initial excretion values of all pigs were nearly the same (Appendix Table I), the trend between the final 48 hour excretion of calcium pantothenate and the difference in excretion between the initial collection and the final collection is very similar. An analysis of variance of the difference between the initial and final 48 hour excretion of calcium pantothenate is presented in Table 10. The difference between the initial and final 48 hour excretion of calcium pantothenate by the pigs fed the different levels of pantothenic acid with and without chlortetracycline is graphically presented in Figure 7. Statistical tests show the slope from 2 to 4 milligrams is significantly different from the slope from the 5 to 7 milligram level. The data presented in Table 9 and Figure 7 clearly indicate that the excretion of pantothenic acid increases as the levels of the vitamin fed are increased. This observation has been reported by Elvehjem et al. (1941) and Henderson and associates (1942) working with rats, by Silber (1944) in dogs, Pearson and Schmidt (1948) in ponies and Wiese and

Table 10. Analysis of variance of 48 hour calcium pantothenate excretion (final minus initial collection).

Source of Variation	Degrees of Freedom	Mean Squares
Replications	3	26.3183
Antibiotic	1	2.3232
P. A. Levels	5	426.3614
Antibiotic x P. A. Levels	5	17.2287
Expt'l. Error	33	24.0883
Total	47	

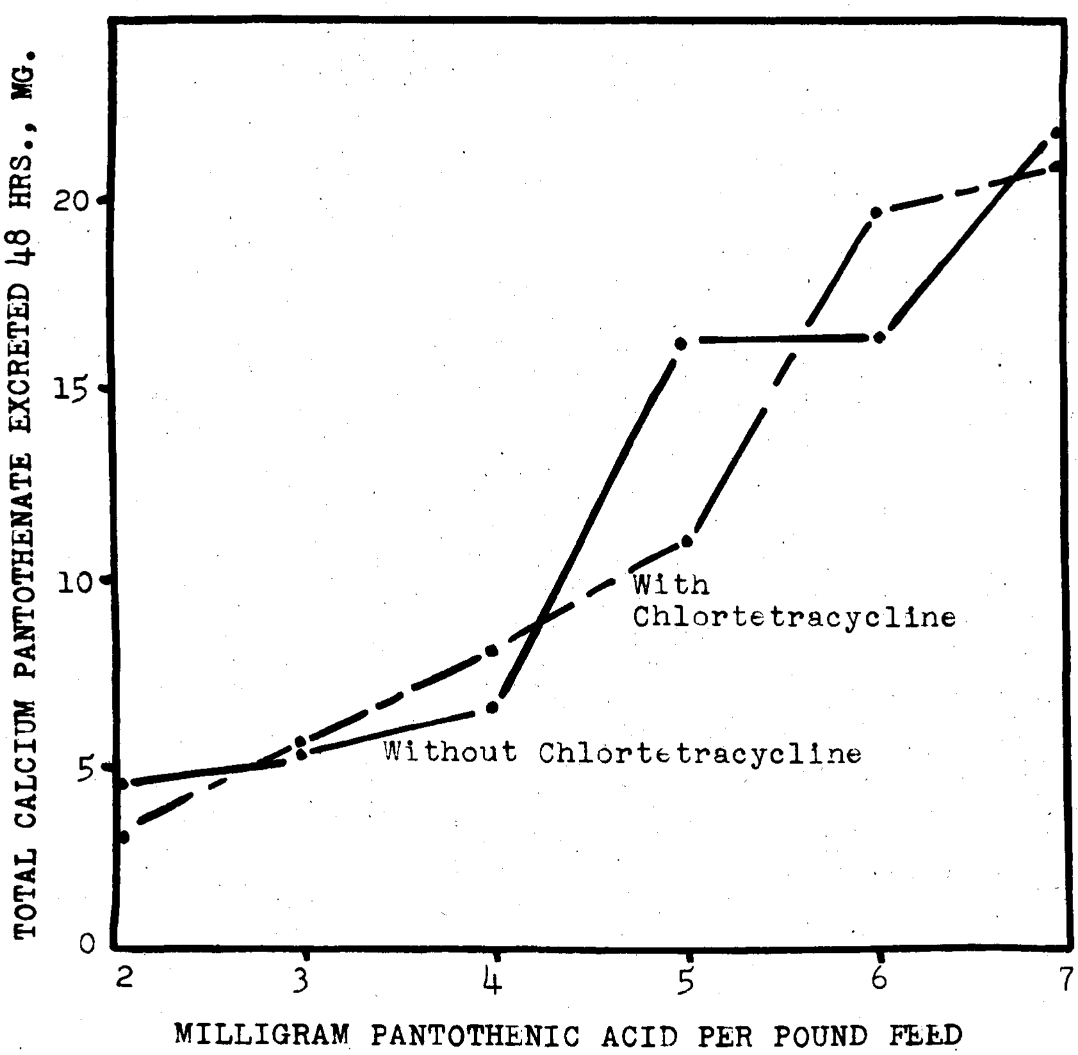


Fig. 7. Difference between total calcium pantothenate excreted during initial and final 48 hour collection periods.

co-workers (1951) in baby pigs.

Results of the microbiological plate counts made on fecal samples collected from all pigs fed the 2, 4 and 7 milligram levels of pantothenic acid with and without chlortetracycline are summarized in Table 11. There were fewer lactobacilli, molds, yeast, fungi, and anaerobes in the feces from pigs fed the antibiotic. Also the total count was less for the group receiving the antibiotic in their ration, while on the other hand the coliforms and streptococci counts were greater in the feces from the antibiotic fed pigs as compared to those pigs fed no antibiotic. Levels of pantothenic acid seemed to have little affect on the number of lactobacilli and anaerobes. Molds, yeasts, fungi, streptococci, and coliforms were fewer in numbers in fecal samples collected from pigs fed 7 milligrams of pantothenic acid than in samples from pigs fed lower pantothenic acid levels. The total count was considerably less in the feces from pigs fed the 7 milligram level of pantothenic acid than in the feces collected from pigs fed either 2 or 4 milligrams of pantothenic acid per pound of feed.

It is noted in Table 12 that the dry matter of the feces collected from antibiotic fed pigs was 10.2 per cent greater than that of feces collected from the pigs

Table 11. Microbiological plate counts made on fecal samples collected when pigs weighed between 75 and 100 pounds. (Values x 10^3 for 1 gram feces dry matter basis) (Grand averages)

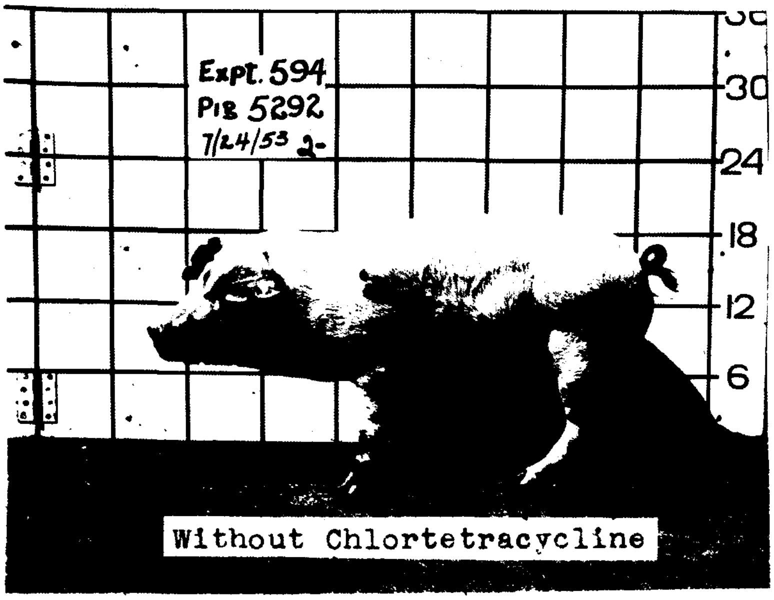
Mg. of PA per lb. Feed	Lacto-bacilli	Littman Oxgall (Molds, Yeast, Fungi)	Linden Thio-glycollate (Anaerobes)	Mitis-Salivarius (Strepto-cocci)	Tryptone Glucose Extract (Total Count)	Violet Red Bile (Coliforms)
			Without Chlortetracycline			
2	3022	5494	26056	5018	42152	8407
4	377	339	38251	3406	41504	17491
7	3980	1812	41349	3433	1025	5592
			With Chlortetracycline			
2	516	348	22094	311019	14758	28832
4	2343	776	53858	22214	40083	18757
7	202	630	7140	4274	6182	4157
Ave. of Treatments Without Chlortetra-cycline	1230	1274	17609	1976	15650	5248
Ave. of Treatments With Chlor-tetracycline	510	292	13827	6251	10170	8624

Table 12. Dry matter of feces.
(Average of 2 samples)

Level of Pantothenic Acid (Mg. per lb. ration)	2		4		7		Average of All Levels
	Pig No.	% Dry Matter	Pig No.	% Dry Matter	Pig No.	% Dry Matter	
Without Chlortetracycline	5292	50.6	5138	47.2	5345	33.5	
	5231	14.2	5210	32.8	5148	30.9	
	5204	45.0	5290	13.1	5142	23.5	
	5141	25.4	5205	20.8	5291	37.0	
Average		33.8		28.5		31.2	31.2
With Chlortetracycline	5257	29.2	5226	66.6	5316	42.7	
	5240	28.0	5137	37.5	5135	36.0	
	5250	55.1	5144	28.2	5150	42.0	
	5149	41.4	5200	48.8	5228	44.1	
Average		38.4		45.3		41.2	
Average of Levels		36.1		36.9		36.2	41.6

fed rations not containing antibiotic. No differences in dry matter of the feces appeared to be due to pantothenic acid levels.

Toward the end of the feeding period it was noted that some of the pigs being fed 2 and 3 milligram levels of pantothenic acid in their ration plus chlortetracycline had rougher hair coats and more dermatitis than pigs fed the same levels of pantothenic acid without chlortetracycline. Although these pigs made equally good gains and displayed no symptoms of "goose stepping" or incoordination, they may have been bordering on a pantothenic acid deficiency. This suggests that the antibiotic might have inhibited intestinal flora that synthesize pantothenic acid, or perhaps the antibiotic was favorable to a group of organisms that compete with the pig for pantothenic acid. This observation is similar to that reported by Richardson et al. (1951) in connection with a study of the vitamin B_{12} requirement of pigs. However, both Alston (1953) and Catron and associates (1953), working with pigs, have reported that chlortetracycline spared pantothenic acid. Photographs presented in Figures 8 and 9 illustrate these hair and skin differences that were observed, as compared to photographs of pigs fed 7 milligrams of pantothenic acid per pound of feed illustrated in Figure 10. Whether or not this hair and



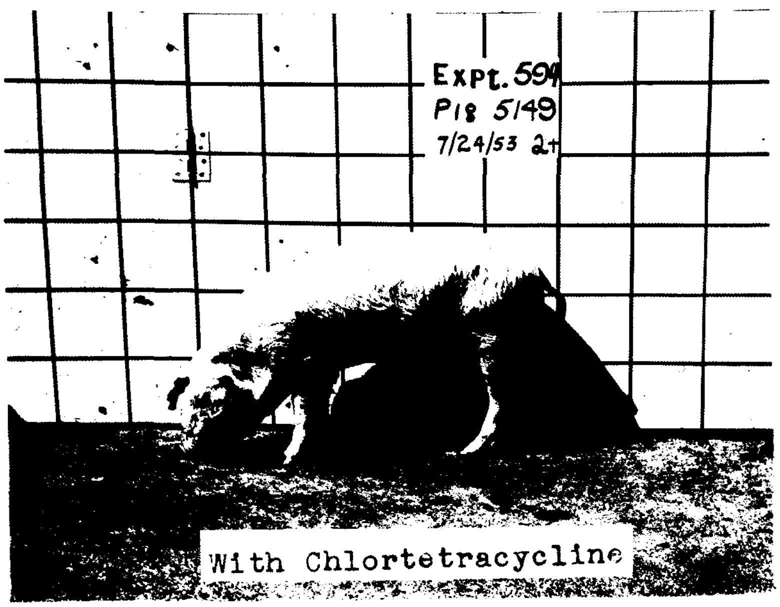


Fig. 8. Pigs fed 2 milligrams of pantothenic acid per pound of feed with and without chlortetracycline. (Pictured when terminated from experiment.)

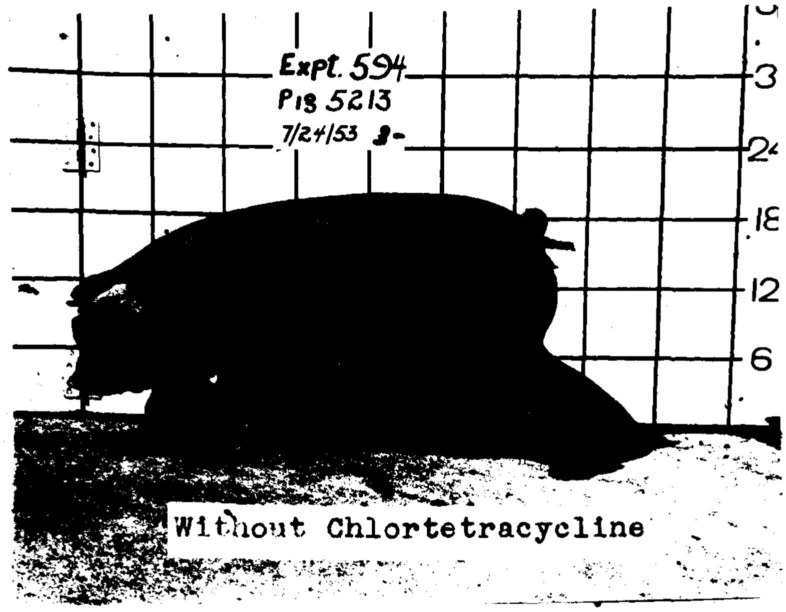
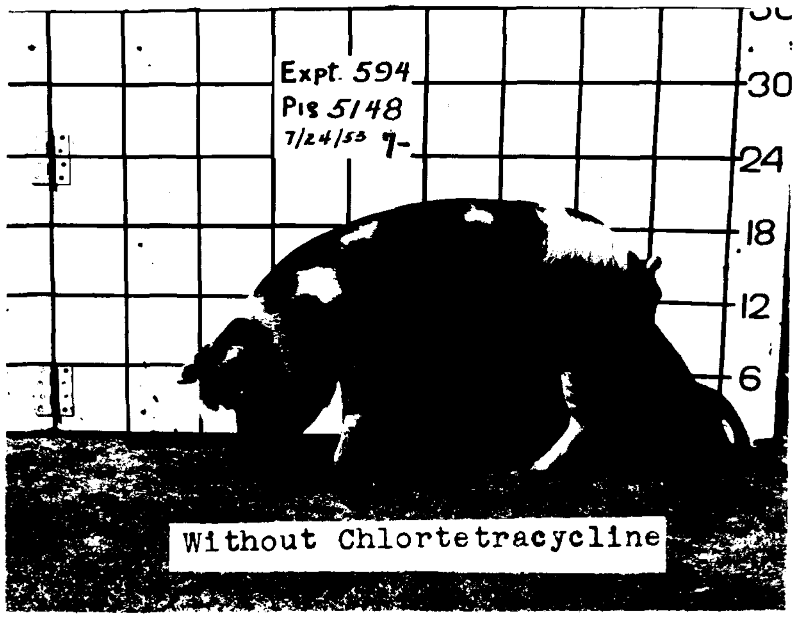


Fig. 9. Pigs fed 3 milligrams of pantothenic acid per pound of feed with and without chlortetracycline. (Pictured when terminated from experiment.)



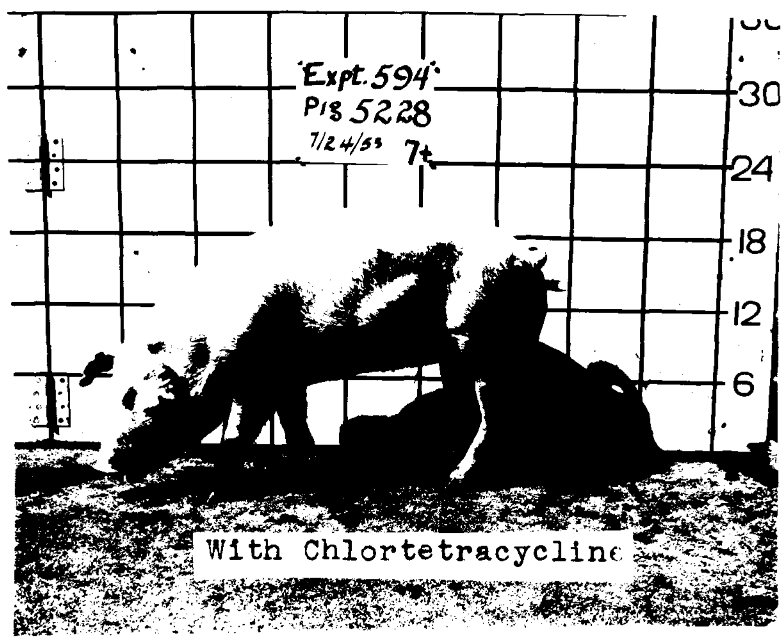


Fig. 10. Pigs fed 7 milligrams of pantothenic acid per pound of feed with and without chlortetracycline. (Pictured when terminated from experiment.)

skin condition was due to an interrelationship of the antibiotic and the low level of pantothenic acid, further investigation would be necessary before definite conclusions could be drawn.

SUMMARY

Forty-eight Duroc x Poland China x Landrace crossbred pigs were allotted according to outcome groups to 12 different ration treatments to determine the pantothenic acid requirement of weanling pigs. A purified ration with levels of 2, 3, 4, 5, 6 and 7 milligrams of pantothenic acid with and without chlortetracycline was fed. The pigs ranged in weight from 17 to 33 pounds at the start of the experiment and were fed to a final weight of approximately 100 pounds. The pigs were confined to wire floored individual crates for the entire feeding period.

The pigs were individually weighed and the feed weighed back each week. A 48 hour collection of urine was made from each pig immediately prior to placing the pigs on the experimental ration treatments and again when each weighed approximately 75 pounds. The volume of urine from each pig was measured and an aliquot was stored for a pantothenic acid assay. Blood samples were drawn when the pigs weighed 75 pounds and hemoglobin, red and white blood cell counts, differential white cell counts, hematocrit and clotting time were

all determined. Fecal samples were collected on two days and microbiological plate counts made.

There were no significant differences in the rate of gain, daily feed consumed, or feed required for a pound of gain between the pigs being fed the different ration treatments. Neither were there any significant differences in hemoglobin, red blood cell count, white blood cell count, differential white blood cell count, hematocrit, or clotting time between the pigs on the 12 ration treatments. The amount of calcium pantothenate excreted when the pigs were weighing 75 pounds was found to be closely related to the level of pantothenic acid the pigs were receiving in their ration.

There were fewer lactobacilli, molds, yeast, fungi, and anaerobes and the total count was less in the feces from pigs fed the antibiotics. However, the coliforms and the streptococci organisms were in larger numbers in the feces of antibiotic fed pigs. Molds, yeasts, fungi, streptococci, and coliforms were fewer in numbers in fecal samples produced by pigs fed 7 milligrams of pantothenic acid than in samples from pigs fed lower levels of the vitamin. However, these differences in numbers of microorganisms in the feces apparently had little or no influence upon the performance of the pigs since these differences cannot be correlated with any differences in gain, feed efficiency or deficiency symptoms.

Statistical treatment of the difference in calcium pantothenate excreted between the initial and final collection shows a significant difference in the excretion of the pigs fed the 2 to 4 milligram pantothenic acid levels and the 5 to 7 milligram levels. Considering this along with growth rate, feed efficiency and the failure to detect any of the deficiency symptoms of a pantothenic acid deficiency as criteria, 2 to 4 milligrams of pantothenic acid per pound of feed appears to be adequate for normal growth of pigs under the conditions of this experiment. This is in agreement with the work of Hughes and Ittner (1942). Several workers have reported higher levels of pantothenic acid necessary for normal growth of pigs. However, these requirements have been established using natural feed ingredients as a source of part or all of the pantothenic acid and it is entirely likely that part of the pantothenic acid in natural feedstuffs is not available to the pig. Hegsted and Lipman (1948) reported that pantothenic acid in coenzyme A is only 66 per cent available to the chick. Lipman et al. (1947) found that much of the pantothenic acid in natural feeds is combined in the complex compound coenzyme A.

CONCLUSIONS

From the results of the experimental work reported herein the following conclusions seem justified.

1. Under the conditions of this experiment, using a purified ration, the pantothenic acid requirement of weanling pigs fed to 100 pounds appears to be between 2 to 4 milligrams per pound of feed.
2. Chlortetracycline exerts no apparent sparing effect on the amount of pantothenic acid required by pigs fed a purified ration.
3. The addition of chlortetracycline to the purified ration fed in this experiment does not significantly increase the rate of gain or improve the feed efficiency of pigs.
4. Excretion of pantothenic acid in the urine increases as increased levels of the vitamin are fed in the ration.
5. Chlortetracycline nor the 6 different levels of pantothenic acid fed does not significantly affect the red blood cell count, white blood cell count, differential white blood cell count, hematocrit or clotting time of pig blood.

6. The inclusion of chlortetracycline in the ration appears to reduce the lactobacilli, molds, yeast, fungi, anaerobes and total count in the feces of pigs. The coliforms and the streptococci organisms are increased when the antibiotic is fed.
7. Seven milligrams of pantothenic acid per pound of feed tends to inhibit the numbers of molds, yeasts, fungi, streptococci, and coliform organism of pigs' feces as compared to lower levels of pantothenic acid.
8. Pigs fed a purified ration composed of starch, cerelose, woodflock, Drackett protein, minerals, and vitamins may be expected to make satisfactory gains while being confined to small wire floored crates from weaning to a 100 pound weight.

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APPENDIX

Table A. Composition of vitamin premix.

	Added per lb. ration	For 60 lbs. Premix
Alpha-tocopherol Acetate	3.0 mg.	9.0 gm.
Biotin	0.2 mg.	0.6 gm.
Ascorbic Acid	50.0 mg.	150.0 gm.
Choline Chloride	450.0 mg.	1350.0 gm.
Ca. Pantothenate	1.77 mg.	5.3 gm.
Folic Acid	0.5 mg.	1.5 gm.
Niacin	14.5 mg.	43.5 gm.
Riboflavin	1.5 mg.	4.5 gm.
Thiamin HCl.	3.0 mg.	9.0 gm.
Pyridoxin	1.0 mg.	3.0 gm.
Vitamin K. (Menadione)	1.0 mg.	3.0 gm.
PABA	0.5 mg.	1.5 gm.
Inositol	200.0 mg.	600.0 gm.
Vitamin B_{12} (9.5 mg/lb.)	5.0 mcg.	716.9 gm.
Vitamin A (Nopkay - 20 Type III 21,400 I.U./g)	2525.0 I.U.	354.0 gm.
Vitamin D_2 (142-F Irrad. Yeast 142,000 I.U./gm.)	400.0 I.U.	8.5 gm.
Pearl Starch	---	52.82 lbs.

Table B. Composition of trace mineral mixture.

Ingredients	Per cent
Tee Mangam	1.33
$Fe\ SO_4 \cdot 7\ H_2O$	6.00
Copper Carbonate (55% Copper)	0.046
Cobalt Sulfate (33% Cobalt)	0.032
Zinc Sulfate (33% Zinc)	0.30
Magnesium Sulfate	17.00
Potassium Sulfate	29.50
Sodium Chloride	17.00
KI Calcium Stearate	0.002
Di Calcium Phosphate	28.79

Table C. Average daily gain of individual pigs fed to 100 pounds live weight.

	Level of Pantothenic Acid (Mg. per lb. ration)											
	2		3		4		5		6		7	
	Pig No.	Av. Daily Gain lbs.	Pig No.	Av. Daily Gain lbs.	Pig No.	Av. Daily Gain lbs.	Pig No.	Av. Daily Gain lbs.	Pig No.	Av. Daily Gain lbs.	Pig No.	Av. Daily Gain lbs.
Without Anti-biotic	5292	1.30	5213	1.37	5138	1.39	5295	1.17	5258	1.41	5148	1.31
	5204	1.19	5151	1.47	5205	1.14	5255	1.54	5139	1.41	5345	1.30
	5231	1.08	5015	1.29	5290	1.11	5253	1.03	5011	1.51	5142	1.21
	5141	1.14	5232	1.11	5210	1.08	5233	1.13	5212	1.05	5291	1.30
Average		1.18		1.31		1.18		1.22		1.34		1.28
With Anti-biotic	5149	1.41*	5254	1.47	5226	1.39	5203	1.57	5158	1.32	5316	1.37
	5257	1.30	5207	1.17	5137	1.30	5294	1.36	5214	1.41	5228	1.25
	5250	1.29	5251	1.34	5200	1.24	5132	1.25	5143	1.29	5135	1.23
	5240	1.27	5133	1.22	5144	1.25	5130	1.30	5242	1.23*	5150	1.32
Average		1.32		1.30		1.30		1.37		1.31		1.29
Average of Levels		1.25		1.30		1.24		1.29		1.33		1.29

*Calculated values.

Table D. Average daily feed consumed per pig for entire period.

	Level of Pantothenic Acid (Mg. per lb. ration)											
	2		3		4		5		6		7	
	Pig No.	Av. Daily Feed Con-sumed lbs.	Pig No.	Av. Daily Feed Con-sumed lbs.	Pig No.	Av. Daily Feed Con-sumed lbs.	Pig No.	Av. Daily Feed Con-sumed lbs.	Pig No.	Av. Daily Feed Con-sumed lbs.	Pig No.	Av. Daily Feed Con-sumed lbs.
Without Anti-biotic	5292	3.14	5213	3.80	5138	3.82	5295	2.83	5258	4.08	5148	3.18
	5204	3.17	5151	3.98	5205	3.17	5255	4.07	5139	3.65	5345	3.68
	5231	2.57	5015	2.91	5290	2.54	5253	2.36	5011	3.04	5142	2.70
	5141	2.62	5232	2.70	5210	2.51	5233	2.87	5212	2.24	5291	2.64
Average		2.88		3.35		3.01		3.03		3.26		3.05
With Anti-biotic	5149	3.22*	5254	3.39	5226	3.14	5203	4.17	5158	3.16	5316	2.96
	5257	3.11	5207	3.17	5137	3.93	5294	2.77	5214	3.54	5228	3.12
	5250	2.80	5251	2.91	5200	2.76	5132	3.09	5143	2.77	5135	2.77
	5240	2.55	5133	2.81	5144	2.56	5130	2.91	5242	2.62*	5150	2.96
Average		2.92		3.07		3.10		3.24		3.03		2.95
Average of Levels		2.90		3.21		3.05		3.13		3.14		3.00

*Calculated values.

Table E. Average amount feed required per pound of gain per pig for entire period.

	Level of Pantothenic Acid (Mg. per lb. ration)											
	2		3		4		5		6		7	
	Pig No.	Feed Consumed per lb. Gain lbs.	Pig No.	Feed Consumed per lb. Gain lbs.	Pig No.	Feed Consumed per lb. Gain lbs.	Pig No.	Feed Consumed per lb. Gain lbs.	Pig No.	Feed Consumed per lb. Gain lbs.	Pig No.	Feed Consumed per lb. Gain lbs.
Without Antibiotic	5292	2.41	5213	2.78	5138	2.75	5295	2.41	5258	2.90	5148	2.44
	5204	2.67	5151	2.71	5205	2.78	5255	2.65	5139	2.59	5345	2.82
	5231	2.38	5015	2.26	5290	2.29	5253	2.29	5011	2.01	5142	2.22
	5141	2.29	5232	2.42	5210	2.32	5233	2.55	5212	2.14	5291	2.03
Average		2.44		2.54		2.54		2.48		2.41		2.38
With Antibiotic	5149	2.27*	5254	2.31	5226	2.26	5203	2.67	5158	2.39	5316	2.16
	5257	2.38	5207	2.71	5137	3.01	5294	2.04	5214	2.51	5228	2.50
	5250	2.18	5251	2.17	5200	2.23	5132	2.47	5143	2.15	5135	2.25
	5240	2.01	5133	2.30	5144	2.04	5130	2.23	5242	2.13*	5150	2.24
Average		2.21		2.37		2.38		2.35		2.30		2.29
Average of Levels		2.32		2.46		2.46		2.41		2.35		2.33

*Calculated values.

Table F. Summary of blood data.

Pig No.	Hemoglobin Grams Per 100 ml.	Red Blood Cell Count Per cu. mm. x 1000	White Blood Cell Count Per cu. mm.	Hematocrit %
		Lot I.		
	2 mg. Pantothenic Acid per lb. Feed.			
5292	12	6,950	14,500	36
5204	13	6,970	20,000	40
5231	11	6,740	14,900	36
5141	10	6,780	15,400	39
Average	12	6,860	16,200	38
		Lot II.		
	3 mg. Pantothenic Acid per lb. Feed.			
5213	14	9,020	20,800	42
5151	13	6,380	11,900	36
5015	14	6,000	14,900	41
5232	11	6,430	13,800	36
Average	13	6,958	12,850	39
		Lot III.		
	4 mg. Pantothenic Acid per lb. Feed.			
5138	14	7,790	25,600	42
5205	13	8,460	24,200	40
5290	13	7,820	15,700	33
5210	11	5,020	22,300	33
Average	13	7,273	21,950	37
		Lot IV.		
	5 mg. Pantothenic Acid per lb. Feed.			
5253	14	7,240	25,000	40
5233	12	7,930	18,600	42
5295	13	6,990	14,200	35
5255	11	6,210	12,200	39
Average	13	7,093	17,500	39
		Lot V.		
	6 mg. Pantothenic Acid per lb. Feed.			
5139	14	7,080	16,000	42
5258	13	7,220	15,500	42
5011	10	7,160	28,900	38
5212	14	8,470	17,700	40
Average	13	7,483	19,525	41
		Lot VI.		
	7 mg. Pantothenic Acid per lb. Feed.			
5142	14	7,610	17,100	38
5291	10	6,340	20,800	34
5148	12	7,800	14,200	42
5345	11	6,880	15,700	32
Average	12	7,158	16,950	37

Differential White Cell Count					Clotting
Neutro-phils	Lympho-cytes	Eosino-phils	Mono-cytes	Baso-phils	Time Seconds
		Lot I. 2 mg. Pantothenic Acid per lb. feed.			
13	74	7	6		30
24	66	7	2	1	15
9	73	7	11		15
38	59	1	2		15
21	68	6	5	0	19
		Lot II. 3 mg. Pantothenic Acid per lb. feed.			
30	65	2	2	1	30
29	61	7	3		30
26	68	3	4		15
43	47	1	9		30
32	60	3	5	0	26
		Lot III. 4 mg. Pantothenic Acid per lb. feed.			
38	56		6		30
24	60	11	4	1	60
23	66	5	6		45
27	68	1	4		30
28	63	4	5	0	41
		Lot IV. 5 mg. Pantothenic Acid per lb. feed.			
27	59	7	6	1	30
43	54	2	1		15
17	75	5	3		30
35	66	4	5		30
31	64	5	4	0	26
		Lot V. 6 mg. Pantothenic Acid per lb. feed.			
16	79	1	4		30
33	56	3	8		30
22	71	3	4		30
19	69	7	5		15
23	69	4	5	0	26
		Lot VI. 7 mg. Pantothenic Acid per lb. feed.			
37	46	8	9		15
49	42	6	3		15
17	79	1	3		30
19	75	3	2		60
31	61	5	4	0	30

Table F. Summary of blood data. (Continued)

Pig No.	Hemo-globin Grams Per 100 ml.	Red Blood Cell Count Per Cu. mm. x 1000	White Blood Cell Count Per Cu. mm.	Hemato-crit %
		Lot VII.		
2 mg. Pantothenic Acid per lb. Feed + Chlortetracycline.				
5149	15	6,390	18,100	43
5257	13	7,140	12,200	38
5250	14	7,260	16,200	40
5240	11	8,490	15,700	37
Average	13	7,323	15,550	40
		Lot VIII.		
3 mg. Pantothenic Acid per lb. Feed + Chlortetracycline.				
5254	13	6,630	14,000	39
5207	14	7,930	17,900	37
5251	14	7,300	16,600	41
5133	13	6,150	40,000	43
Average	14	7,000	22,125	40
		Lot IX.		
4 mg. Pantothenic Acid per lb. Feed + Chlortetracycline.				
5200	14	7,440	18,700	42
5144	12	6,960	23,300	34
5226	14	7,230	21,000	40
5137	13	7,420	20,100	36
Average	13	7,263	20,775	38
		Lot X.		
5 mg. Pantothenic Acid per lb. Feed + Chlortetracycline.				
5203	14	7,630	15,100	43
5294	11	7,170	19,100	40
5132	12	8,520	18,100	48
5130	13	6,880	21,800	43
Average	13	7,550	18,525	44
		Lot XI.		
6 mg. Pantothenic Acid per lb. Feed + Chlortetracycline.				
5143	12	7,200	18,200	40
5242	9	6,630	25,200	33
5214	14	8,170	21,700	42
5158	11	6,730	18,700	36
Average	12	7,183	20,950	38
		Lot XII.		
7 mg. Pantothenic Acid per lb. Feed + Chlortetracycline.				
5316	14	6,930	17,900	40
5228	12	7,820	16,500	43
5135	14	5,700	15,500	34
5150	13	8,400	25,200	40
Average	13	7,213	18,775	39

Differential White Cell Count					Clotting
Neutrophils	Lymphocytes	Eosinophils	Monocytes	Basophils	Time Seconds
Lot VII.					
2 mg. Pantothenic Acid per lb. Feed + Chlortetracycline					
26	63		10	1	45
18	71	7	4		30
24	66	4	6		30
50	37	5	8		15
30	59	4	7	0	30
Lot VIII.					
3 mg. Pantothenic Acid per lb. Feed + Chlortetracycline					
13	84	1		2	45
14	85	1			30
21	76		2	1	30
43	39	1	17		45
23	71	1	5	1	38
Lot IX.					
4 mg. Pantothenic Acid per lb. Feed + Chlortetracycline					
12	86		2		15
23	68	3	5	1	15
27	68	7	2	1	30
43	54	2	1		30
26	70	3	3	1	23
Lot X.					
5 mg. Pantothenic Acid per lb. Feed + Chlortetracycline					
30	65	4	1		30
12	81	4	2	1	30
32	51	10	6	2	30
38	57	2	3		15
28	64	5	3	1	26
Lot XI.					
6 mg. Pantothenic Acid per lb. Feed + Chlortetracycline					
12	83	2	3		15
32	57	3	8		30
38	54	4	4		30
19	65	8	7	1	135
25	65	4	6	0	53
Lot XII.					
7 mg. Pantothenic Acid per lb. Feed + Chlortetracycline					
22	70	2	6		30
23	66	3	7	1	75
26	62	2	10		15
46	50		4		60
29	62	2	7	0	45

Table G. Estimation formulae for assay of initial urine collections for unequal dose interval situations.

.02 .04 .06[a]

$$3b = U_3 - U_1 + 0.5850\ (12) - 5 + 0.1383\ (25).$$

$$= \frac{U_3 - U_1 + 7.02 - 5 + 3.4575}{1.0949}$$

$$= \frac{U_3 - U_1 + 5.4775}{1.0949}$$

$$M = \frac{U-S}{3b} - 0.1383$$

.04 .06 .12

$$\frac{3b = S_3 - S_1\ .5849 - S_T\ .1384 + U_3 - U_1}{1.0949}$$

$$\frac{= 23 - .46792 - 5.9512 + U_3 - U_1}{1.0949}$$

$$= \frac{12.3696 + U_3 - U_1}{1.09.49} \qquad M = \frac{U-S}{36} + 0.1384$$

.06 .12 .20

$$\frac{3b = .7373\ (37) - 12 + .0909\ (72) + U_3 - U_1}{1.1729}$$

$$\frac{= 27.2801 - 12 + 6.5448 + U_3 - U_1}{1.1729}$$

$$= \frac{21.8249 + U_3 - U_1}{1.1729} \qquad M = \frac{U-S}{36} - 0.0909$$

.12 .16 .20

$$\frac{36 = .3219\ (37 - .4150\ (23) + .0310\ (92) + U_3\text{-}U_1}{0.7576}$$

$$= \frac{11.9103 - 9.5450 + 2.8520 + U_3 - U_1}{0.7576}$$

$$3b = \frac{5.2173 + U_3 - U_1}{0.7576} \qquad M = \frac{U-S}{36} - .0310$$

[a]PA concentrations used in standard test solutions.

Table H. Individual data on initial urine assay.

Pig No.	Tube No.	Ml. Urine Per Tube	Turbidimetric Reading on Nephelometer	Acidimetric Ml. of .017 N. NaOH
5292	82	1	5	9.1
	83	2	6	16.3
	84	4	12	24.2
5204	127	1	7	18.9
	128	2	13	25.8
	129	4	21	37.2
5231	31	1	6	11.2
	32	2	8	15.5
	33	4	16	28.3
5141	4	1	10	21.5
	5	2	19	31.8
	6	4	43	49.1
5213	34	1	6	16.9
	35	2	6	6.9
	36	4	13	22.2
5151	103	1	9	14.5
	104	2	8	22.6
	105	4	20	36.1
5015	1	1	5	13.3
	2	2	10.5	20.3
	3	4	24	34.5
5232	112	1	8	19.1
	113	2	12.5	28.7
	114	4	29.5	43.4
5138	25	1	6	21.7
	26	2	2	4.5
	27	4	5	13.7
5205	115	1	11	22.5
	116	2	17	30.3
	117	4	42	50.5
5290	28	1	6.5	11.6
	29	2	11	29.9
	30	4	21	34.3
5210	88	1	10	23.7
	89	2	20.5	35.7
	90	4	39.5	51.7
5253	19	1	5	13.0
	20	2	7	14.9
	21	4	20	40.0
5233	130	1	3	13.4
	131	2	7.5	19.6
	132	4	14	31.7

Table H. (Continued)

Pig No.	Tube No.	Ml. Urine Per Tube	Turbidimetric Reading on Nephelometer	Acidimetric Ml. of .017 N. NaOH
5295	13	1	5	8.1
	14	2	10	18.8
	15	4	3	3.7
5255	85	1	7	18.4
	86	2	12	28.4
	87	4	26	40.6
5139	16	1	6	11.0
	17	2	7	16.7
	18	4	15	28.1
5258	106	1	7	25.9
	107	2	8	17.0
	108	4	11	24.7
5011	7	1	6.5	13.7
	8	2	9	20.0
	9	4	16	29.2
5212	133	1	10	24.5
	134	2	11	25.9
	135	4	36	46.9
5142	100	1	15.5	29.4
	101	2	34	56.0
	102	4	59	59.3
5291	22	1	5	20.5
	23	2	6	33.0
	24	4	12	51.4
5148	109	1	7	--
	110	2	12	29.5
	111	4	22	39.9
5345	10	1	5	13.7
	11	2	9	23.4
	12	4	25	37.2
5149	136	1	7	20.6
	137	2	14.5	30.7
	138	4	23	40.5
5257	76	1	6	22.2
	77	2	4	6.2
	78	4	7	19.0
5250	58	1	5	18.5
	59	2	5	7.2
	60	4	10	21.2
5240	70	1	5	17.7
	71	2	10	--
	72	4	13	24.4

Table H. (Continued)

Pig No.	Tube No.	Ml. Urine Per Tube	Turbidimetric Reading on Nephelometer	Acidimetric Ml. of .017 N. NaOH
5254	121	1	9	23.2
	122	2	19	37.7
	123	4	37	49.5
5207	91	1	5	15.5
	92	2	8	18.4
	93	4	12	26.6
5251	46	1	24	37.2
	47	2	46	46.0
	48	4	63	70.7
5133	37	1	4	21.5
	38	2	5	9.5
	39	4	8	17.5
5200	139	1	6	18.6
	140	2	14	27.7
	141	4	31	43.7
5144	67	1	5	39.5
	68	2	7	13.1
	69	4	11	19.6
5226	94	1	5	12.7
	95	2	7	18.0
	96	4	14	30.7
5137	40	1	5	10.1
	41	2	5	11.8
	42	4	8.5	16.6
5203	43	1	3	3.6
	44	2	23	30.8
	45	4	32.5	40.8
5294	52	1	5	9.7
	53	2	8	13.4
	54	4	14	23.9
5132	31	1	7	11.2
	32	2	8	15.5
	33	4	6	28.3
5130	97	1	7	21.9
	98	2	7	15.6
	99	4	11.5	23.4
5143	79	1	6	19.6
	80	2	8	16.0
	81	4	16	30.7
5242	55	1	5	8.6
	56	2	7	11.7
	57	4	11	19.8

Table H. (Continued)

Pig No.	Tube No.	Ml. Urine Per Tube	Turbidimetric Reading on Nephelometer	Acidimetric Ml. of .017 N. NaOH
5214	64	1	11	22.8
	65	2	10	21.9
	66	4	6.5	6.9
5158	124	1	9	20.9
	125	2	17	32.3
	126	4	35	46.8
5316	61	1	8	18.1
	62	2	3	3.9
	63	4	36	43.9
5228	49	1	7	8.5
	50	2	8	15.2
	51	4	15	24.2
5135	142	1	5	26.2
	143	2	9	18.0
	144	4	11	24.4
5150	73	1	4.5	14.9
	74	2	7	12.7
	75	4	8	18.3

Table I. Summary of urine data collected immediately prior to placing pigs on ration treatments.

Pig No.	Total Urine Excreted 48 hrs., ml.	Calcium Pantothenate mcg./ml. Urine	Total Ca. Pantothenate Excreted, 48 hrs., mg.
5292	360	0.59	0.21
5231	400	0.63	0.25
5204	340	0.69	0.23
5141	300	1.69	0.51
5213	475	0.55	0.26
5015	560	0.85	0.48
5151	315	0.89	0.28
5232	850	1.09	0.93
5138	1075	1.38	1.48
5290	365	0.86	0.31
5205	200	1.64	0.33
5210	625	1.64	1.03
5295	355	0.75	0.27
5253	375	0.70	0.26
5255	350	1.03	0.36
5233	1000	0.53	0.53
5139	475	0.60	0.29
5011	525	0.69	0.36
5258	595	0.53	0.27
5212	160	1.25	0.20
5148	325	0.94	0.31
5142	375	2.83	1.06
5345	260	0.90	0.23
5291	410	1.61	0.66
5149	230	1.02	0.23
5250	835	0.38	0.32
5257	270	0.30	0.08
5240	775	0.60	0.47
5254	225	1.43	0.32
5251	465	3.91	1.82
5207	330	0.55	0.18
5133	550	0.30	0.17
5226	2200	0.55	1.21
5200	450	1.11	0.50
5137	225	0.34	0.08
5144	950	0.48	0.45
5203	205	1.26	0.26
5132	425	0.28	0.12
5294	390	0.42	0.16
5130	675	0.53	0.36
5158	265	1.49	0.39
5143	425	0.66	0.28

Table I. (Continued)

Pig No.	Total Urine Excreted 48 hrs., ml.	Ca. Pantothenate mcg./ml. Urine	Total Ca. Pantothenate Excreted, 48 hrs., mg.
5214	385	0.82	0.32
5242	750	0.45	0.34
5316	250	1.34	0.34
5135	935	0.50	0.47
5228	190	0.67	0.13
5150	510	0.38	0.19

Table J. Individual data on final urine assay.

Pig No.	Tube No.	Ml. Urine Per Tube	Turbidimetric Reading on Nephelometer	Acidimetric Ml. of .027N NaOH
	Lot I.	2 mg. Pantothenic Acid per lb. feed.		
5292	22	4	47	43.0
	23	2	19	23.8
	24	1	5	15.0
5204	67	4	77	47.4
	68	2	59	37.8
	69	1	33	28.2
5231	76	4	61	41.9
	77	2	37	31.2
	78	1	13	25.6
5141	139	4	48	37.3
	140	2	24	26.9
	141	1	10	17.6
	Lot II.	3 mg. Pantothenic Acid per lb. feed.		
5213	1	4	73	60.6
	2	2	54	31.1
	3	1	30	40.0
5151	70	4	68	39.9
	71	2	44	32.9
	72	1	17	22.4
5015	91	4	63	42.4
	92	2	33	33.1
	93	1	16	24.3
5232	130	4	49	38.2
	131	2	26	25.3
	132	1	5	16.9
	Lot III.	4 mg. Pantothenic Acid per lb. feed.		
5138	19	4	42	33.4
	20	2	17	24.9
	21	1	3	14.4
5205	46	4	76	47.5
	47	2	56	37.2
	48	1	34	40.5
5290	97	4	17	27.3
	98	2	7	15.5
	99	1	3	9.1
5210	142	4	69	42.3
	143	2	--	--
	144	1	16	23.4

Table J. (Continued)

Pig No.	Tube No.	Ml. Urine Per Tube	Turbidimetric Reading on Nephelometer	Acidimetric Ml. of .027N NaOH
	Lot IV. 5 mg. Pantothenic Acid per lb. feed.			
5253	73	4	54	39.3
	74	2	27	30.4
	75	1	8	19.1
5233	136	4	45	19.5
	137	2	28	27.0
	138	1	7	16.0
5295	4	4	43	31.7
	5	2	22	28.0
	6	1	6	19.5
5255	52	4	80	59.0
	53	2	63	41.9
	54	1	41	34.0
	Lot V. 6 mg. Pantothenic Acid per lb. feed.			
5139	7	4	56	46.4
	8	2	36	21.8
	9	1	6	19.2
5258	64	4	77	47.2
	65	2	52	36.2
	66	1	28	28.2
5011	94	4	53	34.8
	95	2	34	32.9
	96	1	14	22.3
5212	118	4	71	53.5
	119	2	44	34.9
	120	1	17	35.5
	Lot VI. 7 mg. Pantothenic Acid per lb. feed.			
5142	79	4	73	46.1
	80	2	49	38.2
	81	1	25	28.4
5291	121	4	62	30.6
	122	2	49	33.9
	123	1	24	26.6
5148	25	4	66	40.2
	26	2	41	34.4
	27	1	21	26.3
5345	49	4	78	59.7
	50	2	58	39.5
	51	1	29	21.8

Table J. (Continued)

Pig No.	Tube No.	Ml. Urine Per Tube	Turbidimetric Reading on Nephelometer	Acidimetric Ml. of .027N NaOH
		Lot VII. 2 mg. Pantothenic Acid per lb. feed + Chlortetracycline		
5149	40	4	13	22.7
	41	2	5	11.8
	42	1	3	9.2
5257	13	4	35	27.1
	14	2	16	26.7
	15	1	4	13.8
5250	112	4	66	42.5
	113	2	36	32.0
	114	1	15	23.6
5240	88	4	35	31.9
	89	2	15	24.1
	90	1	4	15.1
		Lot VIII. 3 mg. Pantothenic Acid per lb. feed + Chlortetracycline		
5254	58	4	75	51.0
	59	2	55	46.2
	60	1	26	27.9
5207	34	4	65	42.1
	35	2	39	33.9
	36	1	15	23.2
5251	133	4	64	43.3
	134	2	39	34.2
	135	1	15	24.2
5133	103	4	62	40.1
	104	2	35	32.3
	105	1	14	24.1
		Lot IX. 4 mg. Pantothenic Acid per lb. feed + Chlortetracycline		
5200	127	4	75	50.0
	128	2	55	38.7
	129	1	28	29.9
5144	85	4	51	37.9
	86	2	22	26.6
	87	1	6	17.0
5226	55	4	62	49.9
	56	2	30	29.5
	57	1	10	19.5
5137	16	4	30	30.8
	17	2	11	23.7
	18	1	2	11.9

Table J. (Continued)

Pig No.	Tube No.	Ml. Urine Per Tube	Turbidimetric Reading on Nephelometer	Acidimetric Ml. of .027N NaOH
	Lot X. 5 mg. Pantothenic Acid per lb. feed + Chlortetracycline			
5203	37	4	66	45.4
	38	2	45	32.9
	39	1	17	33.9
5294	28	4	36	32.9
	29	2	8	12.1
	30	1	6	13.6
5132	130	4	48	38.2
	131	2	17	25.3
	132	1	5	16.9
5130	106	4	54	39.0
	107	2	29	30.5
	108	1	9	19.3
	Lot XI. 6 mg. Pantothenic Acid per lb. feed + Chlortetracycline			
5143	115	4	63	43.3
	116	2	38	33.2
	117	1	18	24.8
5242	82	4	38	33.0
	83	2	15	23.2
	84	1	1	8.9
5214	10	4	59	41.8
	11	2	34	32.8
	12	1	9	31.6
5158	61	4	69	54.4
	62	2	50	33.8
	63	1	25	25.9
	Lot XII. 7 mg. Pantothenic Acid per lb. feed + Chlortetracycline			
5316	43	4	59	39.5
	44	2	35	29.8
	45	1	12	21.9
5228	31	4	52	36.9
	32	2	31	28.4
	33	1	9	18.0
5135	109	4	54	38.2
	110	2	30	27.3
	111	1	13	18.8
5150	100	4	62	39.8
	101	2	44	33.9
	102	1	15	22.8

Table K. Total 48 hour excretion of calcium pantothenate of individual pigs when weighing 75 pounds.

Level of Pantothenic Acid (Mg. per lb. Ration)	2		3		4	
	Pig No.	Total Ca.Pa. Excreted 48 hrs. mg.	Pig No.	Total Ca.Pa. Excreted 48 hrs. mg.	Pig No.	Total Ca.Pa. Excreted 48 hrs. mg.
Without Chlortetracycline	5292	5.16	5213	8.85	5138	8.10
	5204	6.54	5015	4.56	5290	3.61
	5231	3.41	5151	5.59	5205	9.34
	5141	4.74	5232	4.32	5210	8.65
Average		4.96		5.83		7.43
With Chlortetracycline	5149	0.97	5254	7.47	5226	8.22
	5250	6.17	5251	6.15	5200	17.78
	5257	3.70	5207	4.79	5137	2.65
	5240	2.60	5133	5.72	5144	6.45
Average		3.36		6.04		8.77
Average of Levels		4.16		5.93		8.10

	5		6		7	
Pig No.	Total Ca.Pa. Excreted 48 hrs. mg.	Pig No.	Total Ca.Pa. Excreted 48 hrs. mg.	Pig No.	Total Ca.Pa. Excreted 48 hrs. mg.	Average of All Levels
5295	13.51	5139	19.00	5148	27.95	
5253	12.08	5011	16.82	5142	23.46	
5255	32.20	5258	17.19	5345	18.52	
5233	9.12	5212	14.29	5291	20.93	
	16.73		16.82		22.72	12.41
5203	16.09	5158	26.92	5316	20.81	
5132	11.00	5143	22.11	5135	19.05	
5294	8.50	5214	24.25	5228	18.64	
5130	10.01	5242	7.76	5150	27.63	
	11.40		20.26		21.53	11.89
	14.06		18.54		22.12	

Table L. Summary of urine data collected when pigs weighed 75 pounds.

Pig No.	Total Urine Excreted, 48 hrs. ml.	Ca. Pantothenate mcg/ml. Urine	Total Ca. Pantothenate Excreted, 48 hrs., mg.
Lot I. 2 mg. Pantothenic Acid per lb. feed.			
5292	3485	1.48	5.16
5231	1585	2.15	3.41
5204	1725	3.79	6.54
5141	2855	1.66	4.74
Average	2413	2.27	4.96
Lot II. 3 mg. Pantothenic Acid per lb. feed.			
5213	2550	3.47	8.85
5015	2100	2.17	4.56
5151	2200	2.54	5.59
5232	2750	1.57	4.32
Average	2400	2.44	5.83
Lot III. 4 mg. Pantothenic Acid per lb. feed.			
5138	4050	2.00	8.10
5290	3375	1.07	3.61
5205	1695	5.51	9.34
5210	2300	3.76	8.65
Average	2855	3.09	7.43
Lot IV. 5 mg. Pantothenic Acid per lb. feed.			
5295	3700	3.65	13.51
5253	2810	4.30	12.08
5255	2965	10.86	32.20
5233	2375	3.84	9.12
Average	2963	5.66	16.73
Lot V. 6 mg. Pantothenic Acid per lb. feed.			
5139	2870	6.62	19.00
5011	2485	6.77	16.82
5258	1425	12.06	17.19
5212	1575	9.07	14.29
Average	2089	8.63	16.82
Lot VI. 7 mg. Pantothenic Acid per lb. feed.			
5148	2735	10.22	27.95
5142	1920	12.22	23.46
5345	1260	14.70	18.52
5291	1875	11.16	20.93
Average	1948	12.08	22.72

Table L. (Continued)

Pig No.	Total Urine Excreted, 48 hrs. ml.	Ca. Pantothenate mcg/ml. Urine	Total Ca. Pantothenate Excreted, 48 hrs., mg.
	Lot VII.		
2 mg. Pantothenic Acid per lb. Feed + Chlortetracycline.			
5149	1535	0.63	0.97
5250	2660	2.32	6.17
5257	3360	1.10	3.70
5240	2410	1.08	2.60
Average	2491	1.28	3.36
	Lot VIII.		
3 mg. Pantothenic Acid per lb. Feed + Chlortetracycline.			
5254	2185	3.42	7.47
5251	2675	2.30	6.15
5207	2075	2.31	4.79
5133	2660	2.15	5.72
Average	2399	2.55	6.04
	Lot IX.		
4 mg. Pantothenic Acid per lb. Feed + Chlortetracycline.			
5226	2785	2.95	8.22
5200	3425	5.19	17.78
5137	1935	1.37	2.65
5144	2225	2.90	6.45
Average	2593	3.10	8.77
	Lot X.		
5 mg. Pantothenic Acid per lb. Feed + Chlortetracycline.			
5203	2550	6.31	16.09
5132	2350	4.68	11.00
5294	2750	3.09	8.50
5130	2260	4.43	10.01
Average	2478	4.63	11.40
	Lot XI.		
6 mg. Pantothenic Acid per lb. Feed + Chlortetracycline.			
5158	2525	10.66	26.92
5143	2710	8.16	22.11
5214	3525	6.88	24.25
5242	2070	3.75	7.76
Average	2708	7.36	20.26
	Lot XII.		
7 mg. Pantothenic Acid per lb. Feed + Chlortetracycline.			
5316	2550	8.16	20.81
5135	2560	7.44	19.05
5228	2640	7.06	18.64
5150	2915	9.48	27.63
Average	2666	8.04	21.53

Table M. Microbiological plate counts made on fecal samples collected when pigs weighed between 75 and 100 pounds. (Values x 10^3 for 1 gram feces dry matter basis)

Pig No.	Sample*	Lactobacilli	Littman Oxgall Molds, Yeast, Fungi	Linden Thioglycollate Anaerobes	Mitis Salivarius Streptococci	Tryptone Glucose Extract Total Count	Violet Red Bile Coliforms
			Lot I. 2 mg. Pantothenic Acid per lb. feed.				
5292	A	15016	42841	2215	7129	9088	2336
	B	6416	796	2367	679	--	--
Ave.		10325	36835	2315	3904	4544	1168
5231	A	779	107	13309	8164	15433	6604
	B	562	---	5489	3627	3169	--
Ave.		678	54	9834	5328	9301	3302
5204	A	109	27	13354	5010	14390	13740
	B	254	85	169898	13877	291327	40823
Ave.		205	56	91626	8951	152858	27281
5141	A	359	24	1814	238	1175	123
	B	678	78	--	1423	2635	3628
Ave.		541	51	907	475	1706	2460
Grand Ave.		3022	5494	26056	5018	42152	8407
			Lot III. 4 mg. Pantothenic Acid per lb. feed.				
5138	A	568	2131	2421	762	3914	6066
	B	--	335	6802	109	1530	68468
Ave.		284	1105	4173	525	2552	43507
5210	A	--	57	3983	1798	3661	3469
	B	--	--	9471	2064	--	4379
Ave.		--	29	7642	1916	1831	3924

Table M. (Continued)

Pig No.	Sample*	Lacto-bacilli	Littman Oxgall Molds Yeast Fungi	Linden Thio-glycollate Anaerobes	Mitis Salivarius Strepto-cocci	Tryptone Glucose Extract Total Count	Violet Red Bile Coliforms
5290	A	190	20	1303	3629	14883	282
	B	1898	54	98772	--	2333	2704
Ave.		1329	42	50037	1815	15863	1493
5204	A	109	27	13354	5010	14390	13740
	B	254	85	169898	13877	291327	40823
Ave.		205	56	13354	8951	152858	27281
Grand Ave.		377	339	38251	3406	41504	17491
		Lot VI. 7 mg. Pantothenic Acid per lb. feed					
5345	A	349	1404	88	17203	1203	---
	B	---	9727	5886	---	17172	---
Ave.		175	5565	3954	8602	6526	---
5148	A	---	24	5114	17	1424	505
	B	---	17	---	763	1303	682
Ave.		---	20	2557	515	1355	611
5142	A	28903	36	44620	884	19992	1112
	B	1069	---	230495	439	1810	1685
Ave.		13440	18	137558	693	16961	1276
5291	A	114	38	44582	5381	32455	38052
	B	1405	3249	---	2776	6611	2701
Ave.		975	1414	22291	3892	19532	22340
Grand Ave.		3980	1812	41349	3433	1025	5592
		Lot VII. 2 mg. Pantothenic Acid per lb. feed + Chlortetracycline.					
5257	A	189	776	129	---	342	---
	B	134	800	---	---	217	---
Ave.		152	788	65	---	279	---

Table M. (Continued)

Pig No.	Sample	Lactobacilli	Littman Oxgall Molds Yeast Fungi	Linden Thioglycollate Anaerobes	Mitis Salivarius Streptococci	Tryptone Glucose Extract Total Count	Violet Red Bile Coliforms
5240	A	1644	145	2794	1465	2210	590
	B	---	---	1119	1589	6113	772
Ave.		822	73	2235	1490	4162	650
5250	A	68	66	56828	22368	53277	20972
	B	---	---	---	27939	32318	179091
Ave.		34	33	28414	23888	50730	78470
5149	A	2096	224	100400	19357	22097	21072
	B	---	775	15481	15435	1487	8159
Ave.		1048	469	86246	17178	13264	18489
Grand Ave.		516	348	22094	11019	14758	28832
Lot IX. 4 mg. Pantothenic Acid per lb. feed + Chlortetracycline							
5226	A	384	952	3242	3242	3190	806
	B	---	2799	2997	59439	3885	---
Ave.		192	2183	3171	33895	3468	403
5137	A	2158	2152	40767	2360	40767	55048
	B	489	12	2125	---	487	---
Ave.		1323	1724	15005	1180	16599	27524
5144	A	13306	92	64815	49583	55772	3056
	B	2109	143	309244	44357	208334	91146
Ave.		8507	114	204489	47344	132153	20675
5200	A	180	35	7672	5536	5693	---
	B	119	19	---	13197	2534	---
Ave.		145	24	3836	8820	4429	---
Grand Ave.		2343	776	53858	22214	40083	18757

Table M. (Continued)

Pig No.	Sample*	Lactobacilli	Littman Oxgall Molds Yeast Fungi	Linden Thioglycollate Anaerobes	Mitis Salivarius Streptococci	Tryptone Glucose Extract Total Count	Violet Red Bile Coliforms
			Lot XII. 7 mg. Pantothenic Acid per lb. feed + Chlortetracycline				
5316	A	---	4019	99	197	340	2798
	B	---	---	10591	3919	5804	---
Ave.		---	2010	8493	2855	3983	1399
5135	A	65	13	1217	10378	1570	600
	B	---	56	12576	7089	2282	---
Ave.		33	44	8789	8734	1966	300
5150	A	113	53	16303	2236	3674	12379
	B	---	36	9608	657	7059	7844
Ave.		57	47	14390	1334	4803	10867
5228	A	102	19	6722	6609	10288	962
	B	1339	841	---	3106	12298	8671
Ave.		927	567	3361	3886	11494	5587
Grand Ave.		202	630	7140	4274	6182	4157
Ave. of Treatments Without Chlortetracycline		1230	1274	17609	1976	15650	5248
Ave. of Treatments With Chlortetracycline		510	292	13827	6251	10170	8624

*Samples A and B were taken 1 day apart.

Table N. Condition of Hair Coat and Skin of Pigs.

Pig No.	Hair Coat	Skin
Lot I. 2 mg. Pantothenic Acid per lb. feed.		
5292	Smooth	Clean
5204	Smooth	Clean
5231	Coarse	Clean
5141	Coarse	Clean
Lot II. 3 mg. Pantothenic Acid per lb. feed.		
5213	Smooth	Some dermatitis
5151	Smooth	Clean
5015	Smooth	Clean
5232	Smooth	Clean
Lot III. 4 mg. Pantothenic Acid per lb. feed.		
5138	Smooth	Clean
5205	Smooth	Clean
5290	Slightly rough	Clean
5210	Smooth	Clean
Lot IV. 5 mg. Pantothenic Acid per lb. feed.		
5253	Smooth	Clean
5233	Smooth	Clean
5295	Smooth	Clean
5255	Smooth	Clean
Lot V. 6 mg. Pantothenic Acid per lb. feed.		
5139	Smooth	Clean
5258	Smooth	Clean
5011	Smooth	Clean
5212	Smooth	Clean
Lot VI. 7 mg. Pantothenic Acid per lb. feed.		
5142	Smooth	Clean
5291	Smooth	Clean
5148	Smooth	Clean
5345	Smooth	Clean
Lot VII. 2 mg. Pantothenic Acid per lb. feed + Chlortetracycline		
5149	Rough	Dermatitis
5257	Coarse	Dermatitis
5250	Coarse	Clean
5240	Smooth	Clean

Table N. (Continued)

Pig No.	Hair Coat	Skin
	Lot VIII. 3 mg. Pantothenic Acid per lb. feed + Chlortetracycline	
5254	Very rough	Dermatitis
5207	Coarse	Dermatitis
5251	Smooth	Clean
5133	Smooth	Clean
	Lot IX. 4 mg. Pantothenic Acid per lb. feed + Chlortetracycline	
5200	Smooth	Clean
5144	Slightly coarse	Clean
5226	Smooth	Clean
5137	Smooth	Clean
	Lot X. 5 mg. Pantothenic Acid per lb. feed + Chlortetracycline	
5203	Smooth	Clean
5294	Smooth	Clean
5132	Smooth	Clean
5130	Smooth	Clean
	Lot XI. 6 mg. Pantothenic Acid per lb. feed + Chlortetracycline	
5143	Smooth	Clean
5242	Smooth	Clean
5214	Smooth	Clean
5158	Smooth	Clean
	Lot XII. 7 mg. Pantothenic Acid per lb. feed + Chlortetracycline	
5316	Smooth	Clean
5228	Slightly coarse	Clean
5135	Smooth	Clean
5150	Smooth	Clean

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