CALCIUM REQUIREMENTS OF GROWING PIGS

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INTRODUCTION

The role of calcium and phosphorus in animal nutrition has received much attention in recent years, and many studies have been made to determine the need of these minerals in the nutrition of the pig. Much of the work has dealt with deficient rations and means of correcting the deficiencies. Recently the individual minimum requirements of these minerals have received the attention of investigators. Vitamin D in connection with these requirements has also been investigated.

REVIEW OF LITERATURE

The requirements of phosphorus in the presence of vitamin D for the growing pig have been worked out by Aubel, Hughes, and Lienhardt (1), who place the minimum value between 0.27 and 0.30 percent when the calcium level is 0.8 percent. Spildo (11) and Axelsson (2) place the minimum value at 0.38 and 0.20 percent, respectively, and Mitchell and McClure (10) estimate it at 0.37 percent for a 30-pound pig and at 0.18 percent for a 200-pound pig. The lowest level fed by Dunlop (6) was 0.53 percent, at which level, with adequate calcium and vitamin D, he obtained satisfactory development. He does not report feeding a ration containing less than 0.53 percent phosphorus, and this, therefore, cannot be said to be a minimum level. Thus the minimum percentages of phosphorus required in the ration as so far determined are generally in fairly close agreement.

The requirement of calcium when vitamin D is supplied is reported by Dunlop (6) to be 0.34 percent, and he found a normal development of blood, bones, and body growth at this level whether or not vitamin D was supplied. Dunlop places considerable stress on the calcium-phosphorus ratio. He says, "A calcium level adequate at one ratio of calcium-phosphorus may be inadequate at another." In ascertaining his minimum calcium level Dunlop fed varying amounts of calcium with phosphorus levels at 0.53 percent or higher.

Other investigators have also reported the calcium requirements of pigs in the presence of vitamin D. Spildo (11) obtained satisfactory results with pigs which received 0.34 percent of calcium and 0.41 percent of phosphorus. Theiler and his associates (12) conducted experiments primarily on the effect of rations deficient in phosphorus or calcium or both. Their rations were deficient in calcium at a level of 0.10 percent and were adequate at a level of 2.0 percent. They did not feed any pigs a ration at a 0.30-percent level of phosphorus. Axelsson (2) estimates the percentage requirement of calcium at 0.37. His phosphorus level for this level of calcium was 0.41 percent.

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2 The authors wish to give credit to Prof. D. L. Mackintosh, of the Department of Animal Husbandry, for assistance in slaughtering and to Dr. L. M. Roderick, of the Department of Veterinary Medicine, for pathological inspection of the carcasses.
3 Italic numbers in parentheses refer to Literature Cited, p. 542.
0.20 percent. Bohstedt (5) reports the most satisfactory results with levels of calcium at 0.32 and 0.41 percent in the presence of 0.28 and 0.29 percent of phosphorus. Aubel and his associates (1) produced satisfactory pigs with 0.8 percent of calcium and 0.3 percent of phosphorus. The calcium requirements in their study, however, were not directly under scrutiny. A level of 0.8 percent was fed so as to be sure that the pigs received ample calcium. Mitchell and McClure (10), on the basis of the composition of the body, estimate the requirements of calcium for a 30-pound pig to be 0.53 percent and state that it decreases gradually as the pig increases in weight, so that a 200-pound pig requires only 0.20 percent of calcium.

From these observations it would appear that with the exception of the work of Bohstedt (5), for which detailed data on blood and bone composition are not available, the minimum calcium requirements for growing pigs fed 0.3 percent of phosphorus, has not been determined. Aubel and his associates (1) found 0.3 percent of phosphorus to be the minimum level, a value which generally is approximated by the findings of other workers.

In view of the variations in the calcium requirements of pigs reported in the literature it seemed desirable to examine this question further. It is, therefore, the purpose of this paper to give information not only on the effects of a deficiency of calcium in the ration on the development of young pigs, but also to show the minimum requirements of calcium necessary to insure normal growth and bone and blood formation, when the phosphorus level is maintained at 0.3 percent and ample vitamin D is supplied.

**EXPERIMENTAL PROCEDURE**

Similar groups of pigs were fed rations which contained the same amounts of digestible nutrients, minerals, and vitamins, but different amounts of calcium. The response of the pigs, as reflected in body and bone growth, utilization of feed, and blood composition, was taken as the criterion for determining the amount of calcium necessary to meet the requirements for normal development.

The animals in each experiment were a uniform-appearing lot of purebred Hampshire pigs about 9 weeks of age and weighing about 40 pounds when the experiments were started shortly after weaning. Before being put on test the pigs were immunized against hog cholera and treated for roundworm. All pigs were housed in a well-lighted and well-ventilated building provided with individual concrete paved pens 6 by 8 feet in size. Each pen was provided with an outside concrete paved exercise area fenced with wire. The outside area allowed the pigs access to the direct rays of the sun and thus they were exposed to ultraviolet rays in considerable amount.

The animals were fed individually twice a day, the amount being determined by the normal-appearing pig with the smallest appetite. This arrangement insured all the pigs ingesting the same amount of food, so that differences in gains in weight and growth could not be attributed to variations in intake of food.

The basal ration consisted of 74 percent of pearl hominy, 10 percent of tapioca roots, 10 percent of blood meal, 4 percent of dehydrated alfalfa-leaf meal, 1.5 percent of dried brewer's yeast,\(^4\) and 0.5 percent of iodized salt. Each pig received 5 cc. of cod-liver oil per

\(^4\) This yeast was the Red Label brand of the Vitamin Food Company, Inc., New York City.
day. Enough monocalcium phosphate was used to raise the phos-
phorus content to 0.30 percent in all lots except lot 4, in experiment 2. 
In this lot, monosodium phosphate was used so that the calcium could 
be kept at 0.10 percent. Supplemental additions of calcium to vary 
the calcium level were made in the form of calcium carbonate. This 
ration was thought to contain, with the exception of the calcium, an 
adequate amount of all the elements known to be necessary for the 
normal growth of a pig.

The pigs were weighed every 28 days throughout the experiments. 
A determination of the calcium, inorganic phosphorus, and phos-
phatase in the blood was made at the beginning of each experiment 
and at the end of each 28-day period. A single sample of blood was 
drawn from the tail for these determinations. The Wang (13) method 
was used for the determination of calcium; phosphorus was determined 
by the Fiske and Subbarow (7) method, and phosphatase by the 
Bodansky (4) method.

The feeding period for each experiment was 24 weeks, at the end 
of which time the animals were killed and a pathological inspection 
of the carcasses was made. The femur and humerus bones of the 
right side of each pig were saved for chemical and physical analyses. 
A 75,000-pound Southwark-Emery hydraulic compression testing 
machine was used to determine the breaking strength of the bones.

**EXPERIMENT 1**

In experiment 1, conducted from December 2, 1938, to May 19, 
1939, three lots of pigs were used. Lot 1 contained five pigs, and 
lots 2 and 3 four pigs each. The levels of calcium fed were 0.6 percent 
for lot 1; 0.8 percent for lot 2; and 1.0 percent for lot 3. The 1.0-
percent level was included in order to observe the effect of an excess 
over the previously observed satisfactory level of 0.8 percent (1), and 
the 0.6-percent level was fed in an effort to locate a minimum level.

The growth, feed records, and composition of the blood and bone 
are shown in table 1, and the growth curves in figure 1.

**Table 1.—Effect of different calcium intakes, at higher levels, on the growth, the 
feed utilization, the blood composition, and bone formation in the pigs in 
experiment 1**

<table>
<thead>
<tr>
<th>Lot No.</th>
<th>Pigs in lot</th>
<th>Calcium in ration</th>
<th>Phosphorus in ration</th>
<th>Average initial weight</th>
<th>Average final weight after 24 weeks’ feeding</th>
<th>Average daily gain</th>
<th>Average daily feed</th>
<th>Feed required per 100 pounds of gain in weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>0.60</td>
<td>0.30</td>
<td>39.6</td>
<td>237.0</td>
<td>1.17</td>
<td>4.28</td>
<td>365.8</td>
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<td>2</td>
<td>4</td>
<td>0.80</td>
<td>0.30</td>
<td>40.4</td>
<td>237.5</td>
<td>1.17</td>
<td>4.28</td>
<td>365.8</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>1.00</td>
<td>0.30</td>
<td>41.6</td>
<td>236.7</td>
<td>1.16</td>
<td>4.28</td>
<td>398.9</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Blood analysis at end of experiment</th>
<th>Bone analysis (dry fat-free basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lot No.</td>
<td>Average calcium in 100 cc. serum</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>13.4</td>
</tr>
<tr>
<td>2</td>
<td>12.2</td>
</tr>
<tr>
<td>3</td>
<td>13.6</td>
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</tbody>
</table>
RESULTS

All the pigs in experiment 1 developed normally. It can be seen from the data in table 1, and from the curves in figure 1, that they were similar in all respects. They made almost the same daily gains, consumed the same amount of feed, had practically identical efficiency in utilizing their feed, had normal blood-serum calcium, phosphorus, and phosphatase content, and the bone formation was normal as evidenced by the ash content and breaking strength of the bones. It is apparent from these data that a calcium level as high as 1.0 percent, and a level as low as 0.6 percent can be fed without abnormal results when ample vitamin D is supplied, and the phosphorus level is 0.3 percent of the ration. Under the conditions of this experiment, the requirements of calcium for the growing pig do not exceed 0.6 percent, the lowest level fed.
EXPERIMENT 2

The second experiment, conducted from December 6, 1939, to May 22, 1940, included four lots of pigs. Lot 4 contained three pigs, lot 5 five pigs, and lots 6 and 7 four pigs each.

In order that satisfactory comparisons might be made, experiment 2 was conducted with pigs of the same size and origin and in precisely the same manner as the first experiment. Lot 4 of experiment 2 received 0.10 percent of calcium; lot 5, 0.25 percent; lot 6, 0.41 percent; and lot 7, 0.55 percent. The high calcium level of 0.55 percent in this experiment was fixed just under the low level of lot 1 in the first experiment.

It was thought that the level of 0.55 percent in lot 7 would be near enough to the 0.6 percent of lot 1, experiment 1, to serve as a check on that level. In order to facilitate comparison, it was also planned in this experiment to control the intake of feed so that it would be similar to the amount ingested daily by the pigs in the first experiment.

The growth, feed records, and composition of the blood and bone of the second experiment are given in table 2 and the growth curves in figure 2.

### Table 2.—Effect of different calcium intakes, at lower levels, on the growth, the feed utilization, the blood composition, and bone formation in the pigs in experiment 2

<table>
<thead>
<tr>
<th>Lot No.</th>
<th>Pigs in lot</th>
<th>Calcium in ration</th>
<th>Phosphorus in ration</th>
<th>Average initial weight</th>
<th>Average final weight after 24 weeks of feeding</th>
<th>Average daily gain</th>
<th>Average daily feed</th>
<th>Feed required per 100 pounds of gain in weight</th>
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<tr>
<td>4</td>
<td>3</td>
<td>0.10</td>
<td>0.31</td>
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<td>.30</td>
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<td>4</td>
<td>.41</td>
<td>.30</td>
<td>41.4</td>
<td>232.5</td>
<td>1.13</td>
<td>4.30</td>
<td>380.5</td>
</tr>
<tr>
<td>7</td>
<td>4</td>
<td>.55</td>
<td>.30</td>
<td>41.9</td>
<td>232.7</td>
<td>1.13</td>
<td>4.27</td>
<td>377.8</td>
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</tbody>
</table>

Blood analysis at end of experiment

<table>
<thead>
<tr>
<th>Lot No.</th>
<th>Average calcium in 100 cc. of serum</th>
<th>Average inorganic phosphorus in 100 cc. of serum</th>
<th>Average specific gravity of serum</th>
<th>Average phosphatase of serum</th>
<th>Average ash in femurs and humeri</th>
<th>Average calcium in femurs and humeri</th>
<th>Average inorganic phosphorus in femurs and humeri</th>
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<tr>
<td>4</td>
<td>7.0</td>
<td>1.147</td>
<td>Pounds</td>
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<td>51.63</td>
<td>19.30</td>
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<tr>
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<td>1.252</td>
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<td>1,085</td>
<td>57.36</td>
<td>23.40</td>
<td>10.59</td>
</tr>
<tr>
<td>6</td>
<td>6.9</td>
<td>1.285</td>
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<td>1,132</td>
<td>60.50</td>
<td>23.15</td>
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<td>7</td>
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<td></td>
<td>1,250</td>
<td>61.76</td>
<td>25.10</td>
<td>11.41</td>
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</tbody>
</table>

1 Data for 1 pig in lot 5 not included.

RESULTS

All pigs in experiment 2 had smooth coats, good appetites, were thrifty, and made good gains throughout the experiment with the following exceptions:

In lot 4 (0.10 percent of calcium) all the pigs showed poor appetite. They developed severe diarrhea almost at the beginning of the ex-
periment and it lasted until the ninth week. During this time the pigs had poor appetites except on two or three occasions when their appetites returned and diarrhea ceased for short periods. They became coarse-haired and were nervous. After the tenth week, two of the pigs recovered to some extent and ate as much as the pigs in the other lots, so that by the end of the experiment they were fairly

smooth in coat, quite thrifty in appearance, and appeared normal except in weight. The third pig in this lot lost appetite the fifth week, developed severe diarrhea, and showed symptoms of weakness in the hindquarters. This pig did not recover its appetite until the twenty-first week. At slaughtering, the pigs in this lot had soft bones. It is significant that all the pigs on this low-level calcium ration exhibited the same calcium-deficiency symptoms described by Theiler and his associates (12). It is also significant that these pigs showed calcium-deficiency symptoms early and that after about 3
months of feeding they improved, especially in food consumption and thri

Two of the five pigs in lot 5, receiving 0.25 percent of calcium, gave
indications of impaired appetite, unthriftiness, and diarrhea early in
the experiment; pig No. 4 by the end of the third week, and pig No.
5, two weeks later. By the seventh week these pigs were obviously
suffering from some deficiency. It was thought that possibly there
might be a deficiency of water-soluble vitamin B in the ration. The
yeast was accordingly increased to 5 percent in the ration of pig No.
4, and 5 mg. of nicotine acid was given orally each day to pig No. 5.
These alterations in the feed were continued for 4 weeks, but there
was no improvement in the condition of the pigs. By this time their
appetites were very poor, they had developed severe diarrhea, and
No. 4 was unsteady on his legs and slightly nervous (fig. 3, A and B).

By the end of 3 months pig No. 4 was paralyzed in the hindquarters and ate his food in a lying position. When it was apparent that
he would not recover he was killed. An autopsy did not show any

lesions that could account for the paralysis or the emaciated condi-
tion. The data in table 2 do not include those for pig No. 4.

Pig No. 5 showed much the same symptoms as pig No. 4, but never
refused feed for more than 2 or 3 days at a time. From the tenth
week until the end of the experiment this pig ate as much feed, most
of the time, as the other pigs in the experiment. Although his appe-
tite and appearance improved he never was as sleek-haired and
thifty as the other three pigs in this lot. Pigs Nos. 4 and 5 had
soft bones when slaughtered.

Two of the five pigs in lot 5, which received 0.25 percent of cal-
cium, showed calcium-deficiency symptoms early in the experiment,
but one had recovered to a considerable extent by the end of the
experiment. The other three seemed normal in appetite and growth,
but at slaughter their bones were found to contain less ash and to
break more easily than the bones of pigs receiving a higher level of
calcium. It would seem, therefore, that the 0.25-percent level of
calcium as fed in this lot might be close to the border line of calcium
requirements for growing pigs.
Symptoms of calcium deficiency were not observed in lot 6 (0.41 percent of calcium) and in lot 7 (0.55 percent of calcium). The pigs in both lots developed and grew normally and had normal bones and blood as compared with lots 1, 2, and 3 of the first experiment.

DISCUSSION OF RESULTS

From the results obtained by feeding different levels of calcium it is evident that under the conditions prevailing in these experiments a level of 0.10 percent of calcium (lot 4, experiment 2) was inadequate for the normal development of pigs; they failed to gain normally, to utilize their feed efficiently, and to develop strong bones with normal ash content.

A 0.25-percent calcium level (lot 5, experiment 2) appeared to be near the border line or slightly below the calcium requirement. Two of the five pigs developed abnormally; the remaining three made normal gains in weight, but their bones contained a subnormal percentage of ash associated with a lowered breaking strength.

All pigs fed a ration containing 0.41 percent or more of calcium appeared to develop normally in every respect. Furthermore the feed consumption, utilization of feed, the composition of the blood, and the formation of the bone were similar with calcium levels ranging from 0.41 to 1.0 percent. These results indicate that raising the calcium level above 0.41 percent does not improve a feed for growing pigs.

Therefore, under the conditions of this experiment, when the level of phosphorus is 0.3 percent and adequate vitamin D is supplied, it would seem that a level of 0.25 percent of calcium is slightly below the minimum requirements while 0.41 percent is definitely adequate for the normal development of pigs.

EFFECT OF LOW-CALCIUM RATIONS ON THE BLOOD COMPOSITION

The effect of low-calcium rations on the composition of the blood has been reported by other investigators. Theiler and his associates (12) stated that the serum calcium was not significantly affected by the calcium of the ration. The findings herein reported are not entirely in agreement with this statement.

The data for the composition of the blood of the pigs in experiment 2 are shown in table 3. An inspection of these data shows that the serum calcium values of the lot 4 pigs and pigs Nos. 4 and 5 of lot 5, which showed calcium-deficiency symptoms, began to show a downward trend after 28 days on the low-calcium ration. This decrease in serum calcium continued for about 56 days, after which it increased, until at the end of the experiment the values were normal.

In the pigs that received an amount of calcium as low as 0.10 percent the blood calcium was not depressed below 8.92 mg. per 100 cc. of serum. It is not surprising, therefore, that low-calcium tetany was not observed in the pigs on a low-calcium diet in this experiment since such symptoms do not appear until blood calcium values fall below this value. It is worthy of note also that only the pigs showing slightly depressed serum calcium manifested any clinical evidence of calcium deficiency, such as loss of appetite, unthrifty appearance, and stiffness. These symptoms disappeared as the serum calcium returned to normal.
The reestablishment of serum calcium to normal after it had been slightly depressed would indicate that although a pig is receiving too little calcium in its diet, the system is able to maintain, apparently at the expense of bone calcium, almost a normal content of calcium in the blood. It should be emphasized, however, that ample vitamin D was provided. It seems surprising that pigs receiving a calcium-deficient diet sufficient to affect the appetite and produce the other clinical symptoms of calcium deficiency, are able to adjust themselves and subsequently recover their appetite and consume enough feed with its attendant amount of calcium to bring about satisfactory gains in body weight and a normal blood picture.

The data in table 3 also show that the inorganic phosphorus of the serum was little affected by the low-calcium rations.

<table>
<thead>
<tr>
<th>Lot No.</th>
<th>Pig No.</th>
<th>Calcium</th>
<th>Inorganic phosphorus</th>
<th>Phosphatase</th>
<th>Calcium</th>
<th>Inorganic phosphorus</th>
<th>Phosphatase</th>
<th>Calcium</th>
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<thead>
<tr>
<th>Lot No.</th>
<th>Pig No.</th>
<th>Calcium</th>
<th>Inorganic phosphorus</th>
<th>Phosphatase</th>
<th>Calcium</th>
<th>Inorganic phosphorus</th>
<th>Phosphatase</th>
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1 Killed for autopsy.  
2 Mean of the lot.

After the pigs had been on experiment 84 days and the blood calcium had dropped to its lowest level, the serum phosphatase was
also somewhat below the level of that in the serum of the pigs receiving an adequate amount of calcium. The average of the five calcium-deficient pigs was 3.9 units per 100 cc. of serum, while that of lots 6 and 7 receiving an adequate amount of calcium and showing no calcium-deficient symptoms was 7.5 units.

![Diagram showing weight gain of pigs over weeks on test]

**Figure 4.**—Weights of the three pigs in lot 4, and pigs Nos. 4 and 5 of lot 5, showing calcium-deficiency symptoms, as compared with the weights of normal pigs, and with those of lots 6 and 7 which received adequate calcium. The calcium intakes of the animals in lots 4, 5, 6, and 7 were 0.10, 0.25, 0.41, and 0.55 percent, respectively. The curve for normal animals was drawn from data supplied by the Division of Animal Husbandry of the University of California and represents the average of the records of 457 pigs that had excellent rations (8).

**Effect of Low-Calcium Rations on Daily Gains and Body Weight**

One of the most interesting results of the feeding of low-calcium rations to young pigs was the effect produced on daily gain and body growth. The data for these two factors are recorded in table 4 and shown graphically in figure 4.
May 1, 1941

Calcium Requirements of Growing Pigs

541

TABLE 4.—Daily gains and body weights of 5 pigs from lots 4 and 5, showing calcium-deficiency symptoms during experiment 2, and the means of these values for the pigs in lots 6 and 7, which received an adequate amount of calcium

[Weights recorded at 28-day intervals]

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<th>Lot No.</th>
<th>Pig No.</th>
<th>Initial body weight</th>
<th>28 days</th>
<th>56 days</th>
<th>84 days</th>
<th>112 days</th>
<th>140 days</th>
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<td>Lb. 109.0</td>
<td>Lb. 1.16</td>
<td>Lb. 141.7</td>
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1 Killed for autopsy.  
2 Mean of lot.

The pigs in lot 4, and pigs Nos. 4 and 5, lot 5, which showed calcium-deficiency symptoms, made slow daily gains and poor body growth almost from the beginning of the experiment until the one hundred and twelfth day. After this period of slow growth daily gains materially improved so that during the latter part of the experiment their gains were almost as good as those of the pigs in lots 6 and 7, which received an adequate amount of calcium (table 4). The initial rate of gain for calcium-deficient pigs was quite different from that of normal pigs or that of the pigs in lots 6 and 7 which received an adequate amount of calcium, as is shown in figure 4.

The recovery in the rapidity of daily gain seems to have preceded the depression and recovery of the serum calcium values discussed previously. Thus it appears that pigs as they increase in age are able to recover from the effects of a limited calcium deficiency even though the level of calcium in the ration is unchanged. This would indicate that the requirements for calcium are greater in early life and become less as the pig matures. These findings support those of Mitchell and McClure (10) in respect to the calcium requirements for pigs.

SUMMARY

The results of an investigation to determine the effects of feeding calcium at different levels in the rations of 28 young pigs are reported.

Two experiments, one with three lots of pigs and one with four, were carried on for 24 weeks.

Data are presented to show (1) the effect of a deficiency of calcium in the ration on the growth and development of pigs, and (2) the minimum amount of calcium necessary in the ration for normal growth and development.

The results obtained indicate that the abnormalities resulting from feeding low-calcium rations are: (1) Anorexia; (2) an unthrifty appearance, characterized by emaciation and a rough coat of hair; (3) usually, but not always, unsteadiness in legs and finally posterior...
paralysis; (4) a failure of normal growth and development of bone; and (5) poor utilization of feed.

Under the conditions of the experiments a level of 0.25 percent of calcium in a ration was found to be inadequate, whereas 0.41 percent was definitely adequate for the normal development of young pigs.

**LITERATURE CITED**

1. **Aubel, C. E., Hughes, J. S., and Lienhardt, H. F.**

2. **Axelsson, Joel.**
   1934. **Svinens kalciumpoch fosforomsättning samt denna reglering medelst foderstatserna.** K. Landtbr. Akad. Handl. och Tidskr. 73: [50]–88; illus.


4. **Bodansky, Aaron.**

5. **Bohstedt, G.**

6. **Dunlop, George.**

7. **Fiske, Cyrus H., and Subbarow, Yellapragada.**

8. **Ittner, N. R., and Hughes, E. H.**


11. **Spildo, Lars S.**

12. **Theiler, A., Du Toit, P. J., and Malan, A. I.**

13. **Wang, Chi Che.**