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The Calcium Requirement of Brood Sows

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The Calcium Requirement of Brood Sows

A. G. HOGAN

Abstract.—The data obtained indicate that rations for brood sows should contain not less than 0.4 per cent of calcium. Two complete failures on rations high in calcium were explained as due to the presence of toxic impurities in the mineral mixture.

It has long been recognized that, except in limited areas, calcium is more likely than any other mineral element to be deficient in the rations of domestic animals. The consequences of a serious deficiency are well known, and a long list of publications has appeared dealing with various phases of calcium metabolism. Most of these are concerned with the stages of rapid growth, or with the period of lactation in dairy cows, and very few have any immediate application to the investigations described in this paper.

Evvard, Cox, and Guernsey¹ have shown that a deficiency of calcium and protein in a sow's ration during gestation decreases the vigor of the pigs at birth. Hart and Steenbock² reported that rations of grain and their by-products, fortified with sodium chloride and hard water, supported mature sows for many months in an apparently normal nutritional state. Finally, however, the animals collapsed. The first litters of these sows were little if any below normal, but they could not be suckled successfully longer than about 4 weeks. In succeeding litters the number of pigs dead at birth greatly increased, and those that lived were less adequately nourished. These authors stressed the mineral deficiencies of the rations as the cause of the nutritional failures. Their animals weighed from 200 to 300 lbs. when placed under observation, and were confined to pens with cement floors.

Baskett³ reported that the addition of mineral salts to the ration of brood sows increased the number of pigs born per litter, and reduced the mortality before weaning. The acidity of the soil was high, and

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presumably this decreased the amount of calcium and phosphorus in the forage consumed by the sows.

Evans⁴ has studied the effect on brood sows of rations deficient in calcium. The animals were kept on cement floors, without access to the soil or green food. These sows had difficulty in farrowing and the flow of milk was greatly reduced. Furthermore the mortality of the pigs was excessively high, and the weaning weights of those that survived were very low. The control animals employed by Evans were subjected to the same experimental conditions, except for the calcium content of the rations. It is worthy of note, however, that over 50 per cent of the pigs born alive died before they were old enough to wean, and that the average weaning weight was less than 22 lbs. This suggests that the experimental conditions were unfavorable in some way, though present knowledge may not enable us to decide in what respect.

The report of Evans is extended somewhat by Davidson⁵. There was an increase in successive litters of atrophic foetuses in the calcium deficient group, also an increase in the number of pigs dead at birth. There was also a reduction in the number of pigs per litter at weaning, and in the average weaning weight.

EXPERIMENTAL

Our first objective was to determine the minimum amount of calcium that can safely be fed female swine, and still permit reasonable success in rearing their young. The pigs were usually placed under observation early in the summer, when weighing 50-100 lbs., and they were expected to farrow the following spring. It was necessary to have careful control of the feed intake, so with a few exceptions the animals were kept off the ground entirely. Originally they were kept in pens 16 feet square, on wooden floors, with adjoining cots to provide shelter. Later they were quartered in a barn, in pens 8 x 11 feet, on cement floors. The animals were fed twice daily, and water was available practically all the time. Shortly before the sows were expected to farrow they were removed to individual pens. They were carefully washed with a disinfectant, and provided with shavings for bedding. Usually the pigs were weaned at 8 weeks, but some were weaned earlier when it was obvious that the flow of milk was inconsequential. The sows were then discarded.

Several different breeds of swine have been used but our data do not indicate that any of them is more resistant than the others to experimental rations. An effort was made to have all the animals of any one year of the same breed, but it happened once that a sufficient number of the

that one sow lost her entire litter within the first day after farrowing, but the other three weaned 17 pigs in all, at an average weight of 24.1 lbs.

TABLE 2.—AVERAGE WEIGHTS OF ANIMALS, AND OF FEED CONSUMED
ADEQUATE RATION

| Year | No. of Sows | Length of Period days | Initial Weight lbs. | Final Weight lbs. | Daily Ration lbs. | Daily Ca Intake gms. | Daily P Intake gms. |
|-----------------|-------------|-----------------------|---------------------|-------------------|-------------------|----------------------|---------------------|
| Growing Stage | | | | | | | |
| 1924-25 | 4 | 219 | 130 | 303 | 4.5 | 29.2 | 17.6 |
| 1925-26 | 4 | 136 | 70 | 220 | 5.2 | 23.1 | 15.1 |
| Gestation Stage | | | | | | | |
| 1924-25 | 4 | 116 | 303 | 414 | 6.7 | 60.1 | 26.2 |
| 1925-26 | 4 | 115 | 220 | 409 | 7.3 | 37.9 | 21.2 |
| Lactation Stage | | | | | | | |
| 1924-25 | 3 | 34 | 358 | 335 | 5.9 | 52.9 | 23.1 |
| 1925-26 | 4 | 57 | 357 | 321 | 8.9 | 44.1 | 25.8 |

TABLE 3.—RECORD OF PIGS AT FARROWING AND AT WEANING
ADEQUATE RATION

| Year | Pigs farrowed | | | | | Pigs weaned | | |
|---------|----------------|---------------------|------|--------------|-----------|----------------|------------------------|-----------------------------|
| | No. of litters | Avg. No. per litter | | Avg. Weights | | No. of litters | Average No. per litter | Average Weight per pig lbs. |
| | | Alive | Dead | Alive lbs. | Dead lbs. | | | |
| 1924-25 | 4 | 6.5 | 0.5 | 2.8 | --- | 3 | 5.7 | 24.1 |
| 1925-26 | 4 | 9.5 | 0.8 | 2.4 | 1.2 | 4 | 5.3 | 19.8 |

Additional Notes, Table 3

Sow 56. Farrowed 3-1-1926. One female pig had only the most rudimentary eyes and ears, but lived until weaning time.

One male pig had a Spina bifida.

Sow 55. Farrowed 3-2-1926. The hind feet of a female pig were doubled back rigidly. It lived only a few hours.

Sow 17. Farrowed 5-1-1926. One pig died in convulsions, 6-6-1926.

One observation made during this year was regarded as somewhat disappointing. The ration was not consumed as readily as expected, so the feed intakes and live weights of the sows were lower than was anticipated. It was suggested that this was due to the large amount of alfalfa meal supplied, so in the following year (1925-26) this was reduced from 15 to 5 per cent. It seemed possible that other improvements might also be made in the ration, so 5 parts of linseed oil meal were substituted for an equal amount of tankage and the mineral mixture was reduced to 2 per cent. In some respects this ration seemed more suitable than the one used the preceding year, as the feed intakes were higher and the gains in weight were more rapid. During the stage of lactation, however, the results were less satisfactory. It had been suggested by other members

of the staff that the protein content of the ration was too high for lactating sows, so this was reduced on June 4, 1926, but it is doubtful that this change was of any significance.

It is evident that the results were not wholly satisfactory, for the weaning weights were only two-thirds or less of what may be expected under optimum conditions. The appearance of the pigs also indicated that some condition was unfavorable to their normal development. They were usually vigorous at birth, and grew well for about two weeks. Following that time, however, the rate of growth decreased, and the pigs became unthrifty in appearance. Various attempts have since been made to determine what are the unfavorable circumstances in our experimental procedure, but the problem is not entirely solved.

II. Results Obtained with a Low Level of Calcium Intake

Since there is little evidence to indicate what is the minimum amount of calcium that may safely be fed to swine, it was decided to begin with rations that are severely restricted in lime content. This procedure was expected to establish approximately the lowest level of calcium intake at which pigs could reach mature size, and would demonstrate the effects during lactation of such severe limitation. Because of the small amount of calcium desired, the choice of constituents in formulating the rations was quite limited. Those first used were made of yellow corn, dried blood, cellulose, cod liver oil, and a mineral mixture. Analysis of the rations as first used (1924-25) showed them to contain slightly less than 0.03 per cent calcium, and the drinking water supplied a small amount in addition. The total quantity consumed was obviously insufficient, for the animals became lame at intervals. Whenever it seemed necessary small quantities of calcium carbonate were added to the ration until they were again able to walk normally. The total amount was evidently below the minimum, however, for one sow broke a leg shortly before she farrowed.

During the following year, 1925-26, the animals received distilled water to drink, so it was possible to determine with more exactness the amount of calcium they received. The experiment started July 26, but early in September some lameness had developed and it seemed the animals were on the verge of a breakdown. On September 3 the amount of calcium in the ration was increased to 0.6 per cent, thus bringing the daily intake up to about 10 grams daily. As the food consumption increased the intake of calcium increased also until Oct. 14 it amounted to about 14 grams daily. The pigs seemed quite normal then so the calcium content of the ration was reduced on October 15 to approximately 0.07 per cent, giving a daily intake of about 1.7 grams per pig. In February and March following it was again necessary to feed

small amounts of calcium carbonate, enough to bring the calcium intake up to between 2 and 3 grams daily. It seemed certain, though, that these animals were always receiving less than could be fed safely. Thus on September 15 one gilt broke a leg and was replaced by No. 67 on October 5. Another sow broke a leg late the following March, was killed, and so is omitted from the records. Two of the sows, Nos. 50 and 54, were unable to expel their litters, so the pigs were removed by Caesarian section. No. 67 farrowed normally, but was unable to nurse her litter. She had only slight udder development, and apparently the litter starved to death. The fact that No. 67 had been subjected to experimental conditions for a shorter period than the others probably explains her greater resistance. Up until the time of farrowing all the animals that survived were quite normal in appearance.

At present it seems impossible to decide whether or not the low calcium rations were adequate in all other respects. A high calcium group as a control was omitted the first year, but examination of the following section shows that in 1925-26 not one of the high calcium sows was able to rear her litter. They also lost their litters in 1926-27, although the low calcium group of that year reared theirs with some degree of success. It seems possible that the mineral mixture of the high calcium group was in some way injurious. A summary of the more important data for the years 1924-26 is given in Tables 4, 5, and 6.

TABLE 4.—COMPOSITION¹ OF RATIONS SEVERELY DEFICIENT IN CALCIUM

| | 1924-25 ² | 1925-26 ³ |
|------------------------------------|----------------------|----------------------|
| Corn..... | 80 | 85 |
| Dried Blood ⁴ | 15 | 10 |
| Cellulose ⁵ | 3 | 3 |
| Cod Liver Oil..... | 2 | 2 |
| Mineral Mixture ⁶ | 4 | 4 |

1. Parts by weight.

2. Beginning July 12, 1924.

3. Beginning July 26, 1925.

4. A special preparation low in calcium obtained from Armour and Co.

5. Lewis Mfg. Co., Walpole, Mass.

| | | | |
|---|------------|--|------------|
| 6. NaCl | 233.6 gms. | K ₂ HPO ₄ | 835.2 gms. |
| MgSO ₄ , 7H ₂ O | 246.0 gms. | KH ₂ PO ₄ | 326.4 gms. |
| Na ₂ HPO ₄ , 12H ₂ O | 429.2 gms. | Fe(C ₆ H ₅ O ₇), 3H ₂ O | 59.8 gms. |
| NaH ₂ PO ₄ , H ₂ O | 115.2 gms. | KI | 7.6 gms. |

Obviously the low calcium ration was grossly deficient. In addition to recurrent lameness during gestation, some of the sows had difficulty in farrowing, and in no case had the udders developed as would be expected in a normally lactating sow. The secretion of milk was scanty, and the only litter that survived was rescued from starvation by supplementary feeding with cow's milk.

TABLE 5.—WEIGHTS OF ANIMALS AND OF FEED CONSUMED
LOW CALCIUM RATION

| Year | Sow No. | Length of Period days | Initial Weight lbs. | Final Weight lbs. | Daily Ration lbs. | Daily Ca Intake gms. | |
|-----------------|---------|-----------------------|---------------------|-------------------|-------------------|----------------------|------|
| Growing Stage | | | | | | | |
| 1924-25 | { | 6 | 215 | 150 | 298 | 4.3 | 0.55 |
| | | 40 | 176 | 57 | 167 | 3.0 | 1.34 |
| | | 47 | 172 | 52 | 173 | 2.9 | 1.32 |
| 1925-26 | { | 50 | 106 | 89 | 227 | 4.6 | 6.05 |
| | | 54 | 105 | 81 | 206 | 4.5 | 6.10 |
| | | 67 | 175 | 153 | 298 | 6.2 | 1.77 |
| Gestation Stage | | | | | | | |
| 1924-25 | { | 6 | 110 | 298 | 435 | 5.9 | 0.22 |
| | | 40 | 116 | 167 | 245 | 4.0 | 0.25 |
| | | 47 | 118 | 173 | 305 | 4.0 | 0.26 |
| 1925-26 | { | 50 | 116 | 227 | ---1 | 5.7 | 1.84 |
| | | 54 | 117 | 206 | ---1 | 5.7 | 1.83 |
| | | 67 | 111 | 298 | 323 | 3.2 | 2.76 |
| Lactation Stage | | | | | | | |
| 1924-25 | 47 | 32 | 255 | 264 | 4.1 | 0.10 | |
| 1925-26 | 67 | 15 | 288 | 290 | 2.9 | 1.73 | |

1. Too lame to weigh.

TABLE 6.—RECORD OF PIGS AT FARROWING AND AT WEANING
LOW CALCIUM RATION

| Year | Sow No. | Pigs farrowed | | | | Pigs Alive After 3 days | Pigs weaned | |
|---------|-----------------|---------------------|------|-------------|-----------|-------------------------|-------------|-------------|
| | | Avg. No. per litter | | Avg. Weight | | | No. | Weight lbs. |
| | | Alive | Dead | Alive lbs. | Dead lbs. | | | |
| 1924-25 | 6 ¹ | 6 | 4 | 2.3 | 2.3 | 0 | | |
| | 40 ² | 9 | 0 | 2.0 | --- | 0 | | |
| | 47 ³ | 5 | 2 | 2.3 | 2.6 | 5 | 17.2 | |
| 1925-26 | 50 ⁴ | 0 | 9 | --- | 1.9 | 0 | | |
| | 54 ⁵ | 4 | 1 | 1.3 | --- | 0 | | |
| | 67 ⁶ | 9 | 0 | 1.7 | --- | 5 | 0 | |

1. Pigs very weak at birth, one foetus, almost completely atrophied was found. Sow apparently secreted little milk.

2. Sow unable to stand at farrowing time, secretion of milk scanty. Pigs seemed to lack control of hind legs.

3. Pigs vigorous at birth, but seemed hungry at second week, and appeared to be unthrifty. In order to prevent starvation they were given cow's milk from the third week on.

4. Sow unable to stand during the 3 weeks before farrowing. Necessary to remove litter by Caesarian section. Sow died.

5. Sow unable to stand at farrowing time. Necessary to remove litter by Caesarian section and sow died. Left femur found broken. Neck of right ilium had been broken and healed in such a way that normal parturition was impossible. The pigs were transferred to another sow, but were weak and all were dead within 2 days.

6. All the pigs were dead within two weeks.

In many respects our observations are similar to those reported by Evans⁴. It is estimated that the calcium-deficient sows he described consumed daily during gestation a trifle less than 1.25 grams of calcium, an amount comparable to the quantity we had used. His animals were periodically lame, had difficulty in farrowing, secreted little milk, and very few of their pigs survived to a weaning age. Evans' data are summarized in the following table, No. 7, prepared from his report.

TABLE 7.—LITTER RECORDS OF LOW CALCIUM SOWS (EVANS)
(Weaned at 7 weeks)

| | No. of pigs in litter | No. born alive | Birth Wt. lbs. | No. Weaned | Weaning Wt. lbs. |
|------------|--------------------------|-------------------|-------------------|---------------|---------------------|
| Sow 77N8 | 10 | 3 | 1.73 | 0 | ----- |
| 2nd litter | 13 | 13 | 2.77 | 0 | ----- |
| 3rd litter | 9 | 6 | 3.02 | 4 | 18.78 |
| 4th litter | 15 | 12 | 2.89 | 0 | ----- |
| Sow 32p3 | 9 | 0 | ----- | 0 | ----- |
| 2nd litter | 8 | 8 | 2.90 | 6 | 9.62 |
| 3rd litter | 12 | 10 | 2.57 | 0 | ----- |

It was evident that the amount of calcium fed was below the level that could be relied on to carry the animals through the period from weaning to the end of lactation, with health unimpaired, so in subsequent trials, including the years 1926-27 and 1928-29, the level of calcium in the ration was increased. Distilled water was supplied constantly except for a few days when the still was unable to furnish a sufficient quantity. During the year 1926-27 it was intended to feed rations containing approximately 0.15 per cent calcium, though due to fluctuations in the calcium content of the constituents of the rations, this varied somewhat in individual mixtures. The ration was changed slightly in December, as it was thought linseed oil meal might be a better source of protein than dried blood. During this time it was evident that the pigs were receiving insufficient calcium as 5 of the 16 became lame. They were transferred for a time, 3 to 8 weeks, to a ration containing approximately 0.6 per cent calcium until they had recovered. The ration was then changed, on January 10, 1927, to Ration G, carrying a slightly larger amount of calcium, about 0.2 per cent, and little trouble was noted thereafter. The amount of dried buttermilk introduced by this change was probably of no consequence as a protein supplement, but it seemed better to increase the amount of calcium in that way rather than by adding additional calcium salts. The amount of calcium actually fed, Table 9, varied from 0.20 to 0.25 per cent of the feed consumed.

Though apparently of no consequence, it may be mentioned that the ration was changed again on June 20. So far as these animals were

concerned, there was no reason for doing so, but at that time the mortality among the litters of the high calcium sows used as controls, described later, had been 100 per cent. Their ration was changed in the hope they would be able to rear their litters, and since the rations were identical except for the mineral mixtures it seemed necessary to change them both.

During the year 1928-29 the initial calcium content of the rations was a little higher, varying from 0.20 to 0.22 per cent. So far as could be judged by external appearances this quantity was sufficient. The amount of feed consumed was satisfactory, and there was practically no lameness in the group. The slight changes made in Rations II and III were for the purpose of adjusting the calcium content. It was thought a slightly higher bran content might be beneficial during lactation so Ration IV was fed during that period. The records of the two years are summarized in Tables 8, 9, and 10.

TABLE 8.—COMPOSITION¹ OF RATIONS MODERATELY DEFICIENT IN CALCIUM

| Ration | 1926-27 | | | | 1928-29 | | | |
|-----------------------|----------------|----------------|----------------|----------------|-----------------|------------------|-------------------|------------------|
| | B ² | E ³ | G ⁴ | I ⁵ | I ⁹ | II ¹⁰ | III ¹¹ | IV ¹² |
| Corn..... | 83 | 81 | 76 | 70 | 75 | 72 | 74 | 69 |
| Dried Blood..... | 5 | | | | | | | |
| Linseed Oil Meal..... | 3 | 10 | 10 | | 8 | 10 | 10 | 10 |
| Liver Meal..... | | | | 16 | 8 | | | |
| Dried Buttermilk..... | | | 4 | 4 | | 4 | 2 | 2 |
| Wheat Bran..... | | | | | | 5 | 5 | 10 |
| Alfalfa Meal..... | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Cod Liver Oil..... | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Mineral Mixture..... | 2 ⁶ | 2 ⁶ | 3 ⁷ | 3 ⁸ | 2 ¹³ | 2 ¹⁴ | 2 ¹⁴ | 2 ¹⁴ |

1. Parts by weight.

2. Beginning Sept. 8, 1926.

3. Beginning Dec. 28, 1926.

4. Beginning Jan. 4, 1927.

5. Beginning June 21, 1927.

6. NaCl
Na₂HPO₄, 12H₂O
KH₂PO₄

2

1

1

7. NaCl
Na₂HPO₄, 12H₂O
KH₂PO₄

1

1

1

8. Na₂HPO₄, 12H₂O
KH₂PO₄
Fe(C₆H₅O₇), 3H₂O
MnSO₄, 4H₂O
KI
NaF
K₂Al₂(SO₄)₄, 24H₂O

49.46

49.46

1.00

0.01

0.01

0.03

0.03

9. Beginning July 4, 1928.

10. Beginning Sept. 6, 1928.

11. Beginning Oct. 28, 1928.

12. During lactation.

13. NaCl
Na₂HPO₄, 12H₂O
KH₂PO₄
CaCO₃

1.00

0.35

0.35

0.10

14. NaCl
Na₂HPO₄, 12H₂O
KH₂PO₄

2

1

1

TABLE 9.—AVERAGE WEIGHTS OF ANIMALS AND OF FEED CONSUMED
CAL RATION

| Year | No. of Sows | Length of Period days | Initial Weight lbs. | Final Weight lbs. | Daily Ration lbs. | Daily Ca Intake gms. | Daily P Intake gms. |
|-----------------|-------------|-----------------------|---------------------|-------------------|-------------------|----------------------|---------------------|
| Growing Stage | | | | | | | |
| 1926-27 | 9 | 157 | 91 | 219 | 4.4 | 4.5 | 13.9 |
| 1928-29 | 7 | 172 | 68 | 242 | 5.3 | 5.4 | 11.8 |
| Gestation Stage | | | | | | | |
| 1926-27 | 9 | 113 | 219 | 374 | 7.7 | 8.6 | 24.1 |
| 1928-29 | 7 | 116 | 242 | 362 | 5.8 | 4.8 | 15.5 |
| Lactation Stage | | | | | | | |
| 1926-27 | 9 | 56 | 335 | 279 | 6.7 | 7.1 | 21.0 |
| 1928-29 | 7 | 56 | 349 | 330 | 8.2 | 6.8 | 25.2 |

Additional notes, Table 9
1928-29

Sow 31. Farrowed 3-28-1929. At weaning time all the pigs were covered with a brown exudate, which extended over practically the entire body.

TABLE 10.—RECORD OF PIGS AT FARROWING AND AT WEANING (8 WEEKS)
CAL RATION

| Year | No. of litters | Pigs farrowed | | | | Pigs weaned | | |
|---------|----------------|---------------------|------|--------------|-----------|----------------|------------------------|-----------------------------|
| | | Avg. No. per litter | | Avg. Weights | | No. of litters | Average No. per litter | Average Weight per pig lbs. |
| | | Alive | Dead | Alive lbs. | Dead lbs. | | | |
| 1926-27 | 9 | 7.4 | 1.0 | 2.7 | 2.2 | 9 | 6.3 | 20.3 |
| 1928-29 | 7 | 7.4 | 0.3 | 2.6 | 2.8 | 7 | 6.0 | 20.4 |

The success of these animals in rearing their litters was quite surprising. Not a single animal that farrowed lost a litter, and the weaning weights were practically as high as we have been able to obtain on similar rations that contained an abundance of lime. The losses in weight by the sows were not excessive.

The history of the pigs during the stage of lactation was, in general, uneventful. The percentage of pigs dead at birth was somewhat high during the year 1926-27, and both years the death rate before weaning was too high. The weaning weights were subnormal, but not lower than on rations containing a higher percentage of calcium.

It is difficult to estimate with precision the minimum quantity of calcium that may safely be fed. Sows have been reared on rations that contained 0.2 per cent of that element, and later they weaned litters successfully without increasing their calcium intake. Other animals did not do so well, however, so it is estimated that a reasonable regard for safety would require that the rations of brood sows contain not less than 0.4 per cent of calcium.

III. Effect on the Skeleton of Rations Deficient in Calcium

As was mentioned in Section II, a number of animals on the low-calcium rations became lame, and many of them suffered from fractured bones. As part of another investigation⁶ a number of the animals used during the year 1924-25 were slaughtered at intervals, and advantage was taken of this opportunity to examine the skeleton. It did not seem that a chemical analysis of the entire skeleton was especially desirable, so it was decided to select a single bone for examination. The left metacarpal was chosen for this purpose, and the more important data are summarized in Table 11. Inspection shows that a ration low in calcium reduces greatly the amount of dry matter in the bones, but does not necessarily reduce the percentage of inorganic constituents. The effect of a calcium deficiency on the structure of bone is shown in Fig. 1.

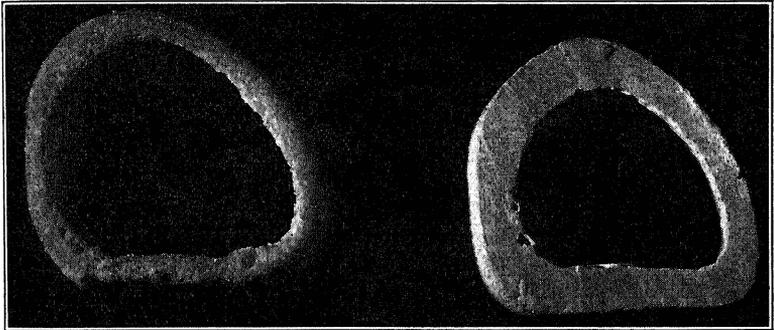


Fig. 1.—(at left) Cross-section of metacarpal bone from gilt on a low calcium ration, and (at right) cross-section from a bone of gilt on an adequate calcium ration. Note the thin walled, spongy, porous condition in the bone at the left as compared with the thick-walled almost solid specimen on the right.

TABLE 11.—EFFECT ON THE SKELETON OF RATIONS DEFICIENT IN CALCIUM

| No. of Sow | Age of Sow | | Weight of Sow | | Dry Weight of metacarpal bone gms. | Analysis of Bone | | | | |
|--------------------|--------------|------------|---------------|------------|------------------------------------|------------------|-------------|------------|-------------|--|
| | Initial days | Final days | Initial lbs. | Final lbs. | | Calcium | | Phosphorus | | |
| | | | | | | Per cent | Weight gms. | Per cent | Weight gms. | |
| Adequate Ration | | | | | | | | | | |
| 13 | 110 | 253 | 54 | 139 | 23.15 | 17.09 | 3.96 | 10.81 | 2.50 | |
| 10 | 115 | 296 | 60 | 206 | 34.05 | 16.81 | 5.72 | 10.14 | 3.45 | |
| 11 | 115 | 373 | 44 | 194 | 25.55 | 15.24 | 3.89 | 10.68 | 2.73 | |
| 14 | 110 | 500 | 63 | 250 | 35.05 | 16.42 | 5.75 | 10.45 | 3.66 | |
| 50 | 266 | 504 | 162 | 335 | 46.65 | 14.90 | 6.95 | 10.33 | 4.82 | |
| 4 | 274 | 537 | 175 | 350 | 51.25 | 16.97 | 8.70 | 10.60 | 5.43 | |
| 5 | 272 | 582 | 146 | 345 | 39.65 | 15.22 | 6.04 | 10.80 | 4.28 | |
| 31 | 269 | 711 | 183 | 484 | 49.30 | 15.37 | 7.58 | 10.94 | 5.39 | |
| 6 | 271 | 717 | 214 | 474 | 50.12 | 15.31 | 7.67 | 11.26 | 5.65 | |
| Low Calcium Ration | | | | | | | | | | |
| 44 | 110 | 239 | 55 | 123 | 13.35 | 15.02 | 2.01 | 9.91 | 1.32 | |
| 41 | 115 | 296 | 52 | 129 | 15.97 | 14.72 | 2.36 | 8.35 | 1.33 | |
| 43 | 111 | 342 | 41 | 186 | 17.30 | 15.73 | 2.72 | 9.80 | 1.69 | |
| 40 | 115 | 414 | 57 | 190 | 25.39 | 16.20 | 4.11 | 9.62 | 2.39 | |
| 40A | 267 | 508 | 139 | 351 | 32.70 | 16.59 | 5.42 | 8.57 | 2.80 | |
| 30 | 266 | 516 | 176 | 355 | 37.35 | 16.65 | 6.22 | 9.59 | 3.58 | |
| 5A | 272 | 545 | 181 | 406 | 29.50 | 16.64 | 4.91 | 10.47 | 3.09 | |
| 31A | 269 | 633 | 183 | 469 | 30.55 | 15.57 | 4.76 | 11.14 | 3.40 | |
| 47 | 105 | 658 | 52 | 369 | 36.62 | 14.99 | 5.49 | 10.75 | 3.94 | |
| 6A | 271 | 859 | 150 | 516 | 34.76 | 16.58 | 5.76 | 10.72 | 3.73 | |

IV. The Possibility that Mineral Supplements May Contain Toxic Impurities

In 1925-26 a so-called calcium high ration was used as a control for the calcium low ration. Except for the mineral mixture the two rations were identical. According to the analyses the high calcium ration contained approximately 0.5 per cent of calcium, but the amount actually fed is shown in Table 13. Few points of special interest were noted until the sows farrowed. To our surprise, however, not one of the three was able to rear a single pig. The young were exceedingly weak and helpless at birth, and without exception all were dead within a few hours. This made it necessary to consider the question of the adequacy of the ration apart from the calcium content. The ration for the following year, 1926-27, was therefore modified somewhat. Its composition was precisely the same as the low calcium ration used at that time, described in the preceding section, except for the mineral content. The most important change was probably the introduction of alfalfa meal. Blood albumin (7) is not generally regarded as a protein of high biological value, so three parts were replaced by an equal weight of linseed oil meal. This ration was originally designed as the control for the low calcium ration of the same year, so when the latter was changed, Table 8, the high calcium ration was changed also, to ration F.

It will be recalled that the low calcium ration, Table 10, gave fairly satisfactory results. Not a single litter was lost, and the average weaning weights at eight weeks were approximately 20 pounds. Although the high calcium ration was identical except in mineral content, it failed completely during the stage of lactation, and only one sow reared her litter. By June 4, two sows on the low calcium ration had farrowed, and their litters were growing nicely. In the meantime four sows on the high calcium ration had farrowed, and none of the pigs had lived over 6 days.

Since the low calcium sows were rearing their litters it did not seem probable that the ration was seriously inadequate, but nevertheless it was decided to change it, in the hope that the high calcium sows might rear their young also. We had previously obtained very rapid growth in laboratory animals when liver meal was used instead of linseed oil meal. It seemed more probable that the mineral mixture was inadequate in some respect, or was actually toxic, so it, too, was changed. This new ration, H, is described in Table 12. In order to further test the possibility that the mineral mixture might be injurious five high calcium sows were transferred to the low calcium ration, I, as described in Table 8. Ration I was identical with H, except for the mineral constituents. Three of these sows reared their litters with a considerable degree of success, and two failed.

TABLE 12.—COMPOSITION¹ OF RATIONS HIGH IN CALCIUM

| Ration | 1925-6 | 1926-27 | | | |
|-----------------------|----------------|----------------|----------------|----------------|-----------------|
| | I ² | A ³ | C ⁴ | F ⁵ | H ⁶ |
| Corn..... | 85 | 83 | 81 | 76 | 70 |
| Dried Blood..... | 10 | 5 | | | |
| Linseed Oil Meal..... | | 3 | 10 | 10 | |
| Dried Buttermilk..... | | | | 4 | 4 |
| Liver Meal..... | | | | | 16 |
| Alfalfa Meal..... | | 5 | 5 | 5 | 5 |
| Cellulose..... | 3 | | | | |
| Cod Liver Oil..... | 2 | 2 | 2 | 2 | 2 |
| Mineral Mixture..... | 4 ⁷ | 2 ⁸ | 2 ⁸ | 3 ⁹ | 3 ¹⁰ |

1. Parts by weight.

2. Beginning July 26, 1925.

3. Beginning Sept. 8, 1926.

4. Beginning Dec. 28, 1926.

5. Beginning Jan. 14, 1927.

6. Beginning June 21, 1927.

7. NaCl 869
 MgSO₄, 7H₂O 915
 Na₂HPO₄, 12H₂O 1,331
 K₂HPO₄ 2,588
 CaH PO₄, 2H₂O 2,596
 Ca(C₃H₅O₂)₂, 5H₂O 573
 Fe(C₆H₅O₇)₃, 3H₂O 6

8. NaCl 1
 Ca₃(PO₄)₂ 1

9. NaCl 1
 Ca₃(PO₄)₂ 2

10. Bone Ash 98.92
 Fe(C₆H₅O₇)₃, 6H₂O 1.00
 KI 0.01
 MNSO₄, 4H₂O 0.01
 NaF 0.03
 K₂Al₂(SO₄)₄, 24H₂O 0.03

There still remained four sows that were left on the high calcium ration. Two farrowed on June 5, and one on July 8. None of the pigs lived longer than 3 days. Another farrowed on August 4, and reared her litter. Of the eight that were continually on the high calcium ration she was the only one that succeeded in doing so.

As to the reason for failure of this CaH group no adequate explanation presents itself. That the organic constituents were not responsible is indicated by the fact that every sow that farrowed in the low calcium group, Section I, reared her litter. Our hypothesis at the time was that the tri-calcium phosphate used contained some toxic substance, possibly fluorine, though we were unable to identify that element in the material then in use. At any rate changing from a technical grade of calcium tri-phosphate to bone ash brought about no evident improvement. As a matter of fact the supply of bone ash was exhausted on July 9, and as there had been no improvement in the meantime it was decided to substitute tri-calcium phosphate for bone ash in the mineral mixture of Ration H. In this connection it is of interest that Bohstedt and associates⁷ reported that in 2 trials out of 3 "precipitated bone flour" appeared to be toxic, but the cause of the toxicity was obscure.

It might be supposed that the amount of calcium supplied was too high, but in other trials, Section I, the calcium content had purposely

been placed at a very high level, and this gave no evidence of being injurious. For example, Ration AD, Table 2, had contained a much larger quantity of calcium but had proven more satisfactory than any ration used thus far. The rations are described in Table 12, and a summary of the records of the animals is given in Tables 13 and 14.

TABLE 13.—AVERAGE WEIGHTS OF ANIMALS AND OF FEED CONSUMED
HIGH CALCIUM RATION

| Year | No. of Sows | Length of Period days | Initial Weight lbs. | Final Weight lbs. | Daily Ration lbs. | Daily Ca Intake gms. | Daily P Intake gms. |
|---|-------------|-----------------------|---------------------|-------------------|-------------------|----------------------|---------------------|
| Growing Stage | | | | | | | |
| 1925-26 | 3 | 124 | 72 | 224 | 4.7 | 10.4 | 11.5 |
| 1926-27 | 13 | 149 | 84 | 237 | 4.7 | 15.9 | 13.3 |
| Gestation Stage | | | | | | | |
| 1925-26 | 3 | 117 | 224 | 355 | 6.3 | 11.5 | 15.4 |
| 1926-27 | 13 | 114 | 237 | 415 | 8.0 | 36.8 | 22.1 |
| Lactation Stage | | | | | | | |
| 1925-26 | 0 | --- | --- | --- | --- | --- | --- |
| 1926-27 | 4 | 56 | 392 | 346 | 6.2 | 10.9 | 17.2 |
| } Three of these transferred to low calcium ration. | | | | | | | |

TABLE 14.—RECORD OF PIGS AT FARROWING AND AT WEANING
HIGH CALCIUM RATIIONS

| Year | Pigs farrowed | | | | | Pigs weaned | | |
|---------|----------------|---------------------|------|--------------|------|----------------|------------------------|-----------------------------|
| | No. of litters | Avg. No. per litter | | Avg. Weights | | No. of litters | Average No. per litter | Average Weight per pig lbs. |
| | | Alive | Dead | Alive | Dead | | | |
| 1925-26 | 3 | 5.3 | 1 | 2.2 | 0.6 | 0 | | |
| 1926-27 | 13 | 7.7 | 2.2 | 2.3 | 2.0 | 4 | 4 | 16.4 |

Additional notes, Table 14

1925-27

Sow 51. Farrowed 3-8-1926. The eyeballs of one pig were rudimentary or missing. Entire litter died within 24 hours.

Sow 44D. Farrowed 4-19-27. Pigs listless and squeal almost continuously. At post mortem examination the stomachs were filled with milk.

Sow 9D. Farrowed 4-25-1927. The pigs were weak, and some were stiff in the hind legs. None lived over 24 hours. About 48 hours after birth considerable redness was noted on the skin in flanks and on the underline. All were dead in 6 days, but those which lived longest showed the least abnormal color.

Sow 19H. Farrowed 5-21-1927. All were dead by the 3rd day. The stomachs were filled with milk.

Sow 14D. Farrowed 6-5-1927. Became weak on 2nd day, unable to walk, and cold to the touch. Before death they would kick and squeal feebly. None lived longer than 2 days. The stomachs contained milk.

Sow 1H. Farrowed 7-8-1927. Died of intestinal hemorrhage.

As shown in another publication the failures were not due directly to the amount of calcium consumed, and our hypothesis at present is that the mineral supplements contained some toxic impurity. No

difficulty of this kind appeared in subsequent feeding trials, and by that time our interest had shifted somewhat to the adequacy of the ration in other respects. The results obtained in later years with rations high in calcium are therefore reported separately⁸.

SUMMARY

1. Brood sows were maintained under rigid experimental conditions for approximately one year, and reared their litters, but the weaning weights were not entirely satisfactory.
2. The rations of brood sows should contain not less than 0.4 per cent of calcium.
3. The diameter of the metacarpal bone was not decreased by rations deficient in calcium, but the wall was thinner, and was porous instead of being dense and hard. The amount of dry matter was correspondingly reduced, but the percentage composition was unchanged.
4. The use of two different mineral mixtures ended in complete failure. This is interpreted as an indication that minerals may at times contain a toxic impurity.

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