FACTORS INFLUENCING MALFORMATION OF THE LEG BONES OF GROWING CHICKS

BY

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INTRODUCTION

A malformation of the leg bones of growing chicks known as "slipped tendon" has come to the attention of research workers only recently as a problem of importance. No doubt the abnormality had occurred for a long time before it was recognized as a distinct disorder, having been grouped with other nutritional disturbances in the past under the general term of "leg weakness". Only since the development of intensive brooding conditions has the disorder become a problem of major importance. It interferes with the motility of the chicks, thereby obscuring the results of nutritional experiments and lowering the market value or breeding worth of the chicks.

There is some confusion as to the proper terminology for the abnormality. It is variously known as "slipped tendon", "hock disease", "perosis", or "deforming leg weakness". There is also a difference of opinion as to the symptoms which are to be included in this condition, some workers feeling that the actual displacement of the tendon is only a phase in the development of the abnormality.

In view of the confusion as to the symptoms which should be included in the disorder, a brief description of the abnormalities observed in this study is presented. The joint which is affected, commonly called the hock joint, is the tibio-metatarsal joint. In the normal chick the tendons at this joint glide between two lateral condyles on the distal end of the tibia, which is perfectly straight. In chicks which become afflicted with slipped tendon the first observable symptom is usually a slight puffiness about the hock joint. At this time the tibia is usually straight, but the metatarsus may or may not be slightly bowed. In certain cases, between the ages of two and ten weeks, the tendons, particularly the gastrocnemious tendon, slip from the condyles to one side or the other. Some of the chicks recover and the hock apparently returns to normal. In other cases the hock becomes flattened laterally and the legs are bowed. Frequently the chick is no longer able to stand, but rests on the hocks with the feet extended to the front or side. Even when able to move about with little difficulty, the chicks act as though standing were painful to them. The bones of the legs become bent, particularly the tibia and metatarsus. The epiphysis at the distal end of the tibia is always bent laterally in the direction in which the tendon slips, and the extent of this bending appears to be roughly proportional to the severity of the deformity. This lateral bending of the distal end of the tibia has not been observed in chicks not afflicted with slipped tendon. It is probable, therefore, that this bending is the result, rather than the cause of the displacement of the tendon. For the purposes of this study only those chicks in which actual displacement of the tendon occurred were reported as having slipped tendon.

Some workers have stated that excess mineral matter in the ration produces slipped tendon, others that excess calcium or phosphorus is a disturbing factor. Excess protein has been blamed for aggravating the abnormality. Wire floors, or lack of exercise associated with wire floors seem to increase the number of slipped tendon. A "preventative factor" has been reported to be found in oat hulls, rice bran, wheat shorts, and other feedstuffs.

The etiology of slipped tendon has been studied by several workers. At present it appears that the abnormality is gross rather than microscopic in nature. Histological changes which have been found were not constant. The ash content of the leg bones of chicks afflicted with slipped tendon has been found to be as high as that of the leg bones of apparently normal chicks with the same nutritional history. This fact, together with the fact that the abnormality has occurred when the chicks were receiving ample vitamin D in the form of cod liver oil or ultra-violet light, has led most investigators to state that chicks having slipped tendon are not rachitic. Nevertheless, the bending of the leg bones which nearly always accompanies slipped tendon indicates that gross bone formation is disturbed in some way. The relation of slipped tendon to rickets is by no means settled.

In view of the difference of opinion which exists concerning the factors influencing the incidence of slipped tendon, this study was undertaken in an effort to clarify the relation between the calcium and phosphorus content of the ration and the incidence of slipped tendon and to determine the fundamental cause or causes of the abnormality. An attempt has also been made to determine the ash content of the leg bones of chicks afflicted with slipped tendon within a few days of the first manifestation of the disorder. Studies of the histology of the deformed bones and of the thyroid and parathyroid glands of chicks with slipped tendon were attempted, but inadequate fixation obscured any differences which might have been present. These histological studies are being continued with improved technique, but the results are not yet available.

Since the initiation of this work the results of several studies of a similar nature have been reported. The findings of this study are not entirely original, therefore, but they confirm the results of other workers and throw a new light on the apparently inexplicable results of certain experiments. Further study is needed on the "preventative factor" which appears to be found abundantly in rice bran and wheat middlings. If this factor is vitamin in nature the next logical step is its isolation in a concentrated form.

REVIEW OF LITERATURE

Studies on Slipped Tendon

A statistical treatment of the major portion of the literature on the subject of "slipped tendons" was presented in Journal Paper No. 87 of the Iowa Agricultural Experiment Station (17). The relation between the protein, ash, calcium and phosphorus in the various rations reported in the literature and the percentage of slipped tendon which these rations produced was studied. At that time the majority of the workers were agreed that excess mineral matter, chiefly calcium and phosphorus, aggravates the disorder, which does not manifest the symptoms of typical rickets, as rickets in chicks has usually been defined, the ash content of the leg bones being normal. This study showed that the amount of phosphorus in the ration was highly correlated with the percentage of slipped tendon. The other correlations were not significant. However, the author (16) found that when a simplified diet was fed the number of slipped tendons which were produced by various levels of inorganic phosphorus was much less than would be expected on the basis of the phosphorus content of the ration. When the phosphorus in the ration was increased to 2.4 per cent there were few cases of slipped tendon, but the growth was very poor and the mortality was high. A ration containing eight per cent of dried soil, a composite sample of sandy loam soils of Iowa, did not produce slipped tendon nor did it depress growth. Most of the literature cited in this paper has appeared since the above mentioned work was published.

Herner and Robinson (10) found no differences in the per cent of ash in the dry fat-free bone or in the calcium and phosphorus content of the ash of bones of normal chicks and those having slipped tendon. They added various amounts of meat meal ash to a basal ration containing 20 per cent of wheat middlings and 16 per cent of meat meal. As the phosphorus in the ration increased from 0.86 per cent to 0.98 per cent the percentage of slipped tendon rose from 9.5 to 58.7 per cent, and increased to 72.1 per cent when the phosphorus was increased to 1.1 per cent. The calcium increased with the phosphorus so that the Ca:P ratio remained practically constant.

Holmes, Pigott and Moore (11) found no significant difference in the mineral content or size of tibiae from chicks with slipped tendon and normal chicks of the same age and history. They examined the tibiae from chicks with slipped tendon at three, six and nine weeks of age, choosing typical specimens from each pen and three normal birds from the same pen for comparison.

Schaible, Moore and Conolly (21) report that "perosis" was produced by high levels of bone meal, bone ash, tricalcium phosphate, magnesium carbonate, or combinations of calcium carbonate with sodium acid phosphate or potassium acid phosphate. Pheasants placed on one of these diets succumbed to the abnormality, but other species did not. The authors do not say what other species were tested. Four per cent of oyster shell or of sodium acid phosphate did not cause perosis, and it was found that soy-bean oil meal, comprising 10 per cent of the protein of a high mineral ration, was highly protective.

Henderson (9) suggests that slipped tendon is a malformation of the leg bones which is comparable to the generally accepted definition of rickets up to 1929. He further suggests rickets as a tentative description for bone deformities until clearer cut reasons exist for new terminology, especially where bone ash determinations have not been made in connection with the studies. He reports that slipped tendon is caused by excess calcium or phosphorus, or both. The abnormality was not prevented by egg yolk or chicken fat.

Heller, Zimmerman and Thompson (8) state that skiagrams of bones of chicks with slipped tendon show that there is a faulty bone formation, which is not cured by vitamin D but by a phosphorus correction in the diet. They say that correlation of the inorganic Ca:P ratio of the blood serum of chicks and the occurrence of slipped tendon is subject to criticism because the inorganic phosphorus is only one fortieth of the total phosphorus of the blood.

Wilcke (28) found no significant difference in the plasma calcium, inorganic phosphorus and ash determinations made on chicks with slipped tendon and on apparently normal chicks from the same pen. With a limited number of chicks, Ca:P ratios in the ration of 1:1, 2:1 and 3:1 produced no difference in the incidence of slipped tendon, with the total phosphorus of the ration remaining practically constant at a level of 0.624 per cent. The percentage of slipped tendon markedly increased when the phosphorus was increased to 1.217 per cent, with a Ca:P ratio of 1.18:1.

Hunter, Dutcher and Knandel (13) were among the first to report a so-called preventative factor for slipped tendon. They found that oats and oat feed possessed beneficial properties in preventing the malady, not to be explained on the basis of its fiber content. Titus and Ginn (27), and later, Titus (26) reported that rice bran contained a substance which largely prevented slipped tendon, or as they called it, perosis. They discussed the possibility of the factor being vitamin in nature. Branion (1) reported that corn contained a factor which produced slipped tendon.

Sherwood and Couch (24) present data which greatly clarify some of the inexplicable results reported previously. They found that a basal ration containing no cereal grain except corn gave 10 to 15 per cent of slipped tendon. This basal ration contained only 0.51 per cent of phosphorus. They further found that when 12 per cent of dried buttermilk was replaced by an equal amount of meat scrap in this ration, increasing the phosphorus to a little less than one per cent, the slipped tendons were increased to over 80 per cent. Rice bran and wheat middlings, when added to this basal ration at the expense of corn, definitely prevented slipped tendon at phosphorus levels up to nearly one per cent of the ration. They say that there are two or more factors responsible for the disorder known as slipped tendon. One factor is the lack of mineral balance in the ration. Their results indicate that as the phosphorus increased the slipped tendons increased, and as the calcium increased the slipped tendons decreased. The second factor is a preventative factor found in appreciable amounts in wheat grey shorts and rice bran, and possibly present in lesser amounts in oat groats and cottonseed meal.

It is a rather general belief among poultrymen that heavy breeds are more susceptible to slipped tendon than are the lighter breeds. Payne, Hughes and Leinhardt (18) reported that in the spring of 1930 at the Kansas State college farm 14 per cent of the disorder appeared in the Rhode Island Red chicks and only 0.7 per cent in the White Leghorn chicks. This indicates that there may be an hereditary susceptibility. Serfontein and Payne (21) have recently reported a very interesting experiment in this connection. One pen consisted of a male and females which showed this abnormality as chicks and recovered sufficiently to permit of reproduction. The other pen consisted of birds which had never shown signs of the abnormality. Chicks from these two pens were reared on the same ration. Only 18.6 per cent of the chicks from the normal mating developed slipped tendon, but 50 per cent of the chicks from the former mating came down with the disorder. Since this difference is highly significant, they conclude, the results indicate that it is highly probable that the tendency toward slipped tendon is inherited.

Studies of Magnesium

Malcolm (15), in 1905, reported that the ingestion of magnesium salts ($MgCl_2$) may hinder the deposition of calcium in young animals and cause loss of calcium from the bodies of older animals. Shelling, Kramer and Orent (23) found that calcification in vitro occurred most readily in the absence of magnesium. Haag and Palmer (6) reported that a more or less balanced condition of calcium, magnesium and phosphorus of the ration was essential to normal growth and functioning. They state that a high level of magnesium is a disturbing factor in nutrition. Mussehl, Hill, Blish and Ackerson (18) found that magnesium sulfate and magnesium carbonate did not appreciably influence the growth of chicks, but the latter did produce some cases of rickets when fed at a level equivalent to 0.5 per cent of magnesium.

Buckner, Martin and Insko (3) have produced a bending of the leg bones and swelling of the joints, but no displacement of the tendon, by feeding magnesium carbonate. They state that this condition is not identical with slipped tendon, as the condyles were in proper alignment with the shaft, which was straight. The chicks receiving magnesium carbonate showed a smaller per cent of ash in the leg bones than the check lots. The author (16) did not obtain this bending of the leg bones in one lot of chicks which was fed three per cent of magnesium carbonate. Most of the chicks developed enlarged hocks and the leg bones of a few of these chicks were definitely rachitic. Two apparently normal chicks were not rachitic.

EXPERIMENTAL

The results reported herein are based on three groups of chicks which were brooded from November 10, 1932, to January 19, 1933, lots 1 to 5 inclusive; from April 12 to June 7, 1933, lots 2A to 5A, 6 and 7; and from February 3 to March 31, 1934, lots 8 to 15 inclusive.

Object

The primary object of these studies was to determine the cause or causes of the leg bone deformity of chicks known as slipped tendon. An attempt was made to determine the ash content of the leg bones of chicks having slipped tendon as nearly as possible to the time of the first manifestation of the deformity. Secondarily, it was thought desirable to study the histology of deformed bones and of various organs of chicks afflicted with the disorder, as well as the age of incidence and of spontaneous recovery on various rations.

Procedure

Experiment I

It was previously found by the author (16) that with a basal ration of ground yellow corn, wheat middlings, dry skim milk, calcium carbonate and salt, additions of phosphorus from inorganic sources did not give as many slipped tendons as one would expect if the phosphorus were the only causative factor. It was also found that addition of three per cent of magnesium carbonate to the basal diet produced many enlarged hocks, clinical symptoms of rickets and a much lowered bone ash, but no slipped tendons. In view of these results it was considered advisable to feed several other levels of phosphorus, using the same basal ration as in the previously reported experiment. The ration containing magnesium carbonate was fed again in order to study more adequately the apparently rachitic condition of the chicks on this ration.

In this experiment the basal ration previously mentioned was altered slightly. The dry skim milk was increased slightly in order to raise the protein level. A high grade of ground oyster shell was substituted for the pure calcium carbonate previously used. Lots 1 to 5, inclusive, were brooded from November 10, 1932, to January 19, 1933. Sufficient feed was mixed so that two lots of chicks could be fed from the same batch of feed. On April 12, 1933, a second group of chicks was started on the same rations, the lots being designated as 2A, 3A, 4A and 5A. Two additional lots were included, lots 6 and 7. The composition of the rations is given in table I.

Table I

Percentage of ingredients in the rations

Feeds	Lot numbers						
	1	2 2A	3 3A	4 4A	5 5A	6	7
Ground yellow corn	58	55	54	62	52	23	24
Wheat middlings	20	20	20	20	20	15	0
Wheat bran	0	0	0	0	0	15	0
Dry skim milk	20	20	20	0	20	45	10
Ground whole wheat	0	0	0	0	0	0	25
Meat and bone meal	0	0	0	14	0	0	14
Ground oats	0	0	0	0	0	0	25
Ground oyster shell	0	3	0	0	3	0	0
$Ca_3(PO_4)_2$	0	0	3	0.9	0	0	0
NaH_2PO_4	0	0	1	1.1	0	0	0
$MgCO_3$	0	0	0	0	0	0	0
Salt	1	1	1	1	1	1	1
Cod liver oil	1	1	1	1	1	1	1
Total	100	100	100	100	100	100	100

The percentage composition of the rations is given in table II. Beginning at the eighth week of the experiment, samples were taken daily from the feed which was placed in the feeders of lot 3A in order to test the extent to which the particles of the heavier ingredients settle to the bottom as the chicks bill the feed. These daily samples were then mixed and a sample taken for analysis. At the end of the tenth week of the experiment the feed remaining in the troughs of lot 3A was mixed and a sample taken for analysis. On the basis of these two analyses there appears to be some separation of the heavier, mineral ingredients of the ration. However, the chicks ate approximately 9000 grams of feed during the period, and the residue remaining was about 1000 grams. Therefore, the composition of the feed actually eaten by the chicks was as follows: protein, 15.28 per cent; calcium, 1.46 per cent; phosphorus, 1.29 per cent. It is apparent that this is practically the same as the original composition of the feed.

Table II

Percentage composition of the rations[1]

Lot No.	Moisture	Ash	Protein	Calcium	Magnesium	Phosphorus
1	5.95	4.19	14.92	0.36	0.18	0.59
2	5.89	6.44	15.26	1.64	0.18	0.57
3	6.18	7.70	15.68	1.68	0.17	1.38
4	6.51	8.55	15.73	1.69	0.19	1.59
5	5.65	7.34	15.27	1.71	0.89	0.53
6	5.36	6.57	21.79	0.80	0.25	0.90
7	7.32	7.16	17.91	1.71	0.16	1.04
*3A	6.79		15.32	1.49		1.31
**3A	6.67		15.67	1.75		1.46

*Sample for analysis collected daily before feeding.
**Sample of feed residue collected at end of two weeks time.

[1] These analyses were made by the laboratory of the Animal Chemistry and Nutrition subsection.

The chicks used throughout this and subsequent experiments were Single Comb White Leghorns from the Iowa State College general flock mating. The chicks for lots 1 to 5 were from pullets, while those for lots 2A to 5A, 6 and 7 were from hens. Since the pullet eggs were small the initial weight of the chicks in lots 1 to 5 was somewhat lower than that of the chicks in the other lots.

The chicks were removed from the incubator on the morning of the 22nd day of incubation, and 250 were selected on the basis of vigor. They were then divided at random into five lots of 50 chicks each, banded, individually weighed, and placed in the brooder. The chicks were weighed at bi-weekly intervals, and observations were made of any abnormalities at the time of weighing. The chicks were deprived of feed in the evening and were weighed early the following morning.

An electrically heated six deck brooder was used for the first six weeks. At the end of the sixth week the sexes were separated and placed in separate, unheated brooders. The room temperature was kept as near 70 degrees F. as was practicable.

In most of the studies previously reported the bones of normal chicks and those having slipped tendon were taken at the end of the experimental period, and the chicks afflicted with slipped tendon were compared with the normals from the same lot. There are two disadvantages in this method. It is entirely possible that the chick which one chooses as normal might have developed slipped tendon within a short time and is, therefore, not really a normal chick. This difficulty can be somewhat obviated by choosing a sufficiently large sample. The method of analyzing the bones of chicks with slipped tendon only after the chicks are eight or ten weeks of age is open to the criticism that a rachitic condition could have been present at the time the tendon slipped, but became healed before the end of the experiment.

All chicks which developed slipped tendon were killed at the end of each bi-weekly period, and the right femur, tibia and metatarsus removed, freed from adhering flesh, and placed in 95 per cent alcohol until it was convenient to proceed with the analysis. The bones were analyzed separately for ash according to the method of Hart, Kline and Keenan (7). Four chicks of each sex were removed from lot 2 at the same time and their leg bones were analyzed to establish the normal. By this method the leg bones were removed from the chick not more than two weeks after the tendon actually slipped, and the ash content of the leg bones of chicks from the control ration were taken as the normal, preventing any possibility of choosing as normal a chick which might have developed slipped tendon within a short time. The control ration used has consistently given practically normal calcification in the presence of adequate vitamin D, and has never produced a case of slipped tendon. The same procedure was followed with lots 2A to 5A, 6 and 7, lot 2A being the control. At the end of their respective experimental periods five chicks of each sex were removed from lots 1 and 5, and 5A, and the right femur taken for ash analysis.

Experiment II

In experiment I rations high in phosphorus consistently produced slipped tendon. All these rations had practically the same calcium content. Ration 3 gave the highest percentage of slipped tendon in these two tests, so this ration was chosen, and while the phosphorus content of the ration was held practically constant, the calcium content was varied from a low to a high level. Ration 2 was continued as the control ration. Ration 5 was altered by decreasing both its calcium and magnesium content. Rations 13, 14 and 15 were included in an attempt to confirm the results of Sherwood and Couch (24). Ration 13 is the same as ration 10, with the wheat middlings replaced with rice bran. Ration 14 is practically the same as the basal ration used by these workers. In ration 15 the phosphorus was increased to the same level as in ration 10. This is a much higher level of phosphorus than Sherwood and Couch fed. The composition of the rations is given in table III.

Table III

Percentage of ingredients in the rations

Ingredient	Lot numbers							
	8	9	10	11	12	13	14	15
Ground yellow corn	55.0	54.5	53.5	53.0	53.5	55.0	70.0	68.5
Wheat middlings	20.0	20.0	20.0	20.0		20.0		
Rice bran					20.0			
Dry skim milk	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Salt	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Ground oyster shell	3.0					1.0	3.0	
$Ca_3(PO_4)_2$			3.0	5.0	3.0			3.0
NaH_2PO_4		3.5	1.5		1.5			1.5
Alfalfa leaf meal							5.0	5.0
Cod liver oil	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

The mineral analysis of the rations is shown in table IV.

Table IV

Mineral analysis of the rations*

Lot No.	Ash	Calcium	Magnesium	Phosphorus
8	7.045	1.663	0.190	0.562
9	6.148	0.343	0.162	1.280
10	7.508	1.401	0.179	1.426
11	9.166	2.255	0.207	1.540
12	8.725	1.411	0.253	1.590
13	6.398	0.782	0.731	0.595
14	6.809	1.526	0.155	0.432
15	7.861	1.495	0.135	1.327

* These analyses were made by the laboratory of the Animal Chemistry and Nutrition subsection.

The chicks used in this experiment were Single Comb White Leghorns from the Iowa State College flock of highly inbred pullets, mated to cockerels from vigorous inbred lines. The same procedure and equipment were used as in experiment I. The results of the ash analyses in experiment I were so conclusive that it was not deemed necessary to repeat them. The right femur was removed from representative males and females of lot 12, which received magnesium carbonate, and from lot 8, the control, and analyzed for ash by the same method as in experiment I.

RESULTS AND DISCUSSION

Experiment I

<u>Growth and abnormalities</u>

The growth in lot 1 was somewhat lower than that in lot 2, but the difference was not significant. Though the calcium content of this ration is very low the effect on the growth appears to be negligible. No abnormalities of any kind appeared in this lot, but the general appearance of the chicks was not as good as that of the chicks in lot 2.

The growth in lot 2 was nearly normal for White Leghorns, approaching that reported by Buckner, Insko and Martin (2) for chicks brooded in battery brooders. The general appearance of the chicks was good at all times, and there were no crooked legs or slipped tendons. In this and in lots 3, 4 and 5 the calcium content of the ration was held practically constant.

In the ration fed lot 3 the phosphorus content was increased to 1.38 per cent. At this level of phosphorus eight males and two females, representing 32 per cent of the males and 8 per cent of the females, developed slipped tendon. These percentages are based on the number of chicks of each sex in the lot at the beginning of the experiment. The growth was somewhat less than that of lot 2, but the difference was not significant.

The phosphorus content of the ration fed lot 4 was 1.59 per cent. This slight increase in phosphorus over that fed lot 3 had practically no effect on the number of slipped tendons. Eight males, 33.3 per cent, and three females, 13.6 per cent, developed the abnormality. However, the growth of the chicks on this ration was markedly depressed, as compared to lot 2. Although the phosphorus content of the ration fed lot 4 was only 0.2 per cent more than that of the feed which lot 3 received, the weight of the males at ten weeks was only 368.9 grams, as compared with 615.7 grams for lot 3. There was a corresponding difference in the weights of the females. Evidently the tolerance limit of the chicks for phosphorus on this ration lies between 1.4 and 1.6 per cent.

Lot 5 was fed three per cent of magnesium carbonate. There were no slipped tendons in this lot and no bending of the leg bones, such as Buckner, Martin and Insko (3) obtained on a similar ration. There were several cases of enlarged hocks and many crooked breast bones. A few of the chicks showed clinical symptoms of rickets. The growth was significantly lower than that of lot 2.

As was previously mentioned, lots 2A to 5A, inclusive, were fed the same rations as lots 2 to 5, inclusive. These lots were discontinued at eight weeks. Though the chicks were fed at different times, and were from a different source, it is interesting to note that there is no significant difference in the weights of the corresponding lots of chicks at eight weeks. The growth of lot 2A was only very slightly greater than that of lot 2, the mean difference being 36 grams for the males and 22 grams for the females. There were no abnormalities of any kind in this lot.

The growth of lot 3A was not significantly different from that of lots 2A or 3. There were more cases of slipped tendon in this lot than in lot 3, the increase among the females being most marked. There were 14 males, 56 per cent, and 11 females, 47.8 per cent, which developed the abnormality. The first of these cases appeared between the ages of three and four weeks, and many were very severe. In contrast to this severity, the cases which developed in lot 3 were never so bad that the chicks were incapable of free motility.

As was the case in lot 4, the growth in lot 4A was much less than that in the control lot. The mean weight at eight weeks was practically the same in lots 4 and 4A. Again, there were more slipped tendons in lot 4A than in lot 4. Sixteen males, 69.6 per cent, and six females, 27.3 per cent, developed slipped tendon. More males and fewer females developed slipped tendon in lot 4A than in lot 3A, and the total number was greater in the latter lot.

The growth in lot 5A was significantly less than that in the control lot, but was practically the same as that in lot 5. The general condition of the chicks appeared to be better than that of the chicks in lot 5. There were fewer cases of enlarged hocks, and no chicks showed clinical symptoms of rickets. One male developed slipped tendon, this being the first and only slipped tendon produced on a ration containing 0.89 per cent of magnesium out of a total of 190 chicks reared on such a ration in this and the previously reported work of the author (16).

Lot 6 was fed a ration containing 45 per cent of dry skim milk. This ration was relatively low in calcium, containing only 0.80 per cent, but it contained sufficient for normal calcification. It contained 0.90 per cent of phosphorus, the increase over the basal ration coming in part from the wheat bran which was added, but largely from the increased milk. Though the chicks showed pronounced diarrhea throughout the experiment, the growth was practically the same as that of the check lot. Seven males and two females developed slipped tendon, representing 30.4 per cent of the males and 9.1 per cent of the females. Most of these cases developed between the ages of four and six weeks and were not severe.

Lot 7 was fed a ration similar to many practical farm rations, the base being made up of equal parts of ground yellow corn, ground whole wheat and ground whole oats. The source of the mineral content of this ration is largely the meat and bone meal. The ration has practically the same calcium content as lots 2, 3, 4 and 5, and the phosphorus is intermediate between that of lots 3 and 6. The numbers of slipped tendon were also intermediate between the numbers obtained in lots 3A and 6. There were 11 males and four females afflicted with the disorder, this being 52.4 per cent of the males and 16.7 per cent of the females. Apparently the ground oats had no beneficial effect.

From these results it is apparent that, with rations containing about the same level of calcium, there is a fairly consistent relationship between the amount of phorphorus in the ration and the number of slipped tendons which it will produce. Lots 3A and 4A gave more slipped tendons than lots 3 and 4, though the feed for the corresponding lots was mixed in one batch. This variation may be explained in several ways. It may be due to varying susceptibility of chicks from different sources. It is possible that seasonal differences or differences in the environment of the chicks may have some effect on the number of slipped tendons. It is also conceivable that the preventative factor which Sherwood and Couch (24) found in rice bran and wheat shorts was partially destroyed during storage of the feed. These explanations are purely speculative, as they can neither be proved nor disproved from the data.

Tables V to X, inclusive, summarize the weights of the chicks by bi-weekly intervals and the number of slipped tendons which developed during each period. The probable error of the mean is given only for the initial weight and for the weights at eight and ten weeks. The summary of the mean weights of the chicks in the various lots at the end of the experiment is shown in table XI, together with their standard deviations, and the number and percentage of slipped tendons. The percentage of slipped tendon is based on the number of chicks of each sex in the lot at the beginning of the experiment. The mean differences between the various lots and the check lots, lots 2 and 2A, are given, together with their standard deviations. Twice the standard deviation of the mean difference was considered as the least significant value for the difference between two means, and three times the standard deviation of the mean difference as the least highly significant value.

Table V

Summary Lot 1

Age in weeks	No. of males	Mean weight and its P.E.	No. of slipped tendons: New cases	No. of slipped tendons: Total	No. of females	Mean weight and its P.E.	No. of slipped tendons: New cases	No. of slipped tendons: Total
Initial	22	30.68±0.29			23	30.22±0.16		
2	22	68.73			23	65.91		
4	22	168.86			23	155.35		
6	22	277.14			23	252.87		
8	22	441.73±9.53			23	397.43±7.90		
10	22	613.82±15.27			23	549.44±13.50		

Table VI

Summary, Lots 2 and 2A

Age in weeks	No. of males	Mean weight and its P.E.	No. of slipped tendons: Now cases	No. of slipped tendons: Total	No. of females	Mean weight and its P.E.	No. of slipped tendons: New cases	No. of slipped tendons: Total
Lot 2								
Initial	23	31.61±0.32			24	30.75±0.30		
2	23	66.22			24	63.38		
4	23	157.65			24	147.42		
6	19	272.79			20	257.55		
8	19	459.05±9.61			20	425.15±10.97		
10	19	650.68±13.63			20	583.50±15.47		
Lot 2A								
Initial	30	37.70±0.16			16	38.31±0.42		
2	30	68.77			16	66.25		
4	30	160.60			16	152.94		
6	26	304.81			12	305.17		
8	22	495.32±14.27			8	447.12±28.59		

Table VII

Summary, Lots 3 and 3A

Age in weeks	No. of males	Mean weight and its P.E.	No. of slipped tendons: New cases	No. of slipped tendons: Total	No. of females	Mean weight and its P.E.	No. of slipped tendons: New cases	No. of slipped tendons: Total
Lot 3								
Initial	25	30.00±0.27			25	30.96±0.34		
2	25	64.60			25	66.08		
4	25	140.52	3	3	25	134.96	1	1
6	22	270.73	1	4	24	244.42	0	1
8	22	451.68±10.80	1	5	24	396.00±7.83	0	1
10	22	615.68±12.52	3	8	23	551.43±10.25	1	2
Lot 3A								
Initial	25	37.20±0.41			23	38.00±0.34		
2	25	67.08			23	70.22		
4	25	145.64	8	8	22	154.91	3	3
6	17	275.71	6	14	19	285.89	5	8
8	11	439.82±19.00	0	14	14	427.57±10.84	3	11

Table VIII

Summary, Lots 4 and 4A

Age in weeks	No. of males	Mean weight and its P.E.	No. of slipped tendons: New cases	No. of slipped tendons: Total	No. of females	Mean weight and its P.E.	No. of slipped tendons: New cases	No. of slipped tendons: Total
Lot 4								
Initial	24	30.96±0.27			22	31.32±0.42		
2	24	53.79			22	53.36		
4	23	93.78	2	2	22	94.09		
6	21	166.57	0	2	22	164.59		
8	20	261.70±6.25	1	3	22	254.77±10.29		
10	19	368.95±8.59	5	8	22	352.59±14.24	3	3
Lot 4A								
Initial	23	38.61±0.28			22	38.05±0.52		
2	23	55.65			22	53.27		
4	23	108.35	1	1	22	103.32		
6	22	193.68	8	9	22	176.32	4	4
8	14	272.29±14.51	7	16	18	256.06±11.81	2	6

Table IX

Summary, Lots 5 and 5A

Age in weeks	No. of males	Mean weight and its P.E.	No. of slipped tendons: New cases	No. of slipped tendons: Total	No. of females	Mean weight and its P.E.	No. of slipped tendons: New cases	No. of slipped tendons: Total
Lot 5								
Initial	20	31.40±0.46			20	30.95±0.43		
2	19	55.90			20	53.45		
4	19	113.89			20	101.90		
6	19	220.32			20	197.90		
8	19	363.42±11.32			20	317.70±8.92		
10	18	531.83±17.26			19	465.42±11.92		
Lot 5A								
Initial	27	36.74±0.40			21	36.62±0.42		
2	27	60.11			21	63.19		
4	26	119.19			21	128.62		
6	26	209.50			21	219.76		
8	26	337.31±11.83	1	1	21	341.05±10.35		

Table X

Summary, Lots 6 and 7

Age in weeks	No. of males	Mean weight and its P.E.	No. of slipped tendons: New cases	No. of slipped tendons: Total	No. of females	Mean weight and its P.E.	No. of slipped tendons: New cases	No. of slipped tendons: Total
Lot 6								
Initial	23	37.83±0.30			22	37.59±0.40		
2	23	75.00			22	70.32		
4	23	165.22	2	2	22	152.64	1	1
6	21	294.24	5	7	21	272.38	1	2
8	16	496.38±16.14	0	7	20	422.75±7.71	0	2
Lot 7								
Initial	21	36.43±0.40			24	36.83±0.42		
2	21	78.10			24	78.62		
4	21	186.19	5	5	24	183.50	1	1
6	16	348.50	5	10	23	332.65	3	4
8	11	535.64±28.10	1	11	20	504.65±12.96	0	4

Table XI

Summary, Experiment I

Lot	No. of chicks	Mean	Standard deviation of mean	Mean difference from Lot 2	Standard deviation of mean difference	Significance	No. of slipped tendons	Per cent of slipped tendons
♂♂								
1	22	613.82	22.642	36.86	30.348	*	0	0
2	19	650.68	20.208				0	0
3	22	615.68	18.557	35.00	27.436	*	8	32.0
4	19	368.94	12.736	281.74	23.887	***	8	33.3
5	18	531.83	25.592	118.85	32.608	***	0	0
♀♀								
1	23	549.44	20.017	34.06	30.440	*	0	0
2	20	583.50	22.933				0	0
3	23	551.43	15.196	32.07	27.511	*	2	8.0
4	22	352.59	21.106	230.91	31.167	***	3	13.6
5	19	465.42	17.669	118.08	28.950	***	0	0
♂♂								
2A	22	495.32	21.156				0	0
3A	11	439.82	28.175	55.49	35.234	*	14	56.0
4A	14	272.29	21.519	223.03	30.177	***	16	69.6
5A	26	337.31	17.534	158.01	27.478	***	1	3.7
6	16	496.38	23.925	1.06	31.937	*	7	30.4
7	11	535.64	41.666	40.32	46.729	*	11	52.4
♀♀								
2A	8	447.12	42.393				0	0
3A	14	427.57	16.074	19.55	45.338	*	11	47.8
4A	18	256.06	17.508	191.06	45.866	***	6	27.3
5A	21	341.05	15.348	106.07	45.086	**	0	0
6	20	422.75	11.436	24.37	43.908	*	2	9.1
7	20	504.65	19.207	57.53	46.541	*	4	16.7

*non-significant **significant ***highly significant

Bone ash determinations

The mean ash content of the leg bones from the chicks on the various rations is shown in table XII. The ash was determined by the method given by Hart, Kline and Keenan (7). The probable error of the mean was not calculated, since it is not the most reliable test for differences with such small numbers. All the chicks except those from lots 1, 2, 2A, 5 and 5A were afflicted with slipped tendon. For testing the significance of the observed variation Fisher's (4) method of analysis of variance was used. The value of the ratio of the larger to the smaller mean square was calculated and compared with the values which Snedecor (25) gives for the five per cent and one per cent points on the probability curve. For the purpose of analysis, all the ash analyses in each sex and age group were combined.

For the femora of the males at four weeks, comprising lots 2, 3, 4, 2A, 3A, 4A, 6 and 7, the value of F was found to be 1.72, while the five per cent value is 2.45. The variation is, therefore, not significant. For the tibiae at four weeks, comprising lots 2A, 3A, 6 and 7, F was found to be 8.65, while the one per cent value is only 5.42. The variation is highly significant, and casual observation of the means shows that the only group which is out of line is lot 6. It is apparent that the two males in lot 6 have a significantly lower bone ash than that of the chicks in the other two lots. The

Table XII

Ash content of leg bones from chicks on the various diets

Lot No.	Age in weeks	Femora No.	Femora Mean per cent ash	Tibiae No.	Tibiae Mean per cent ash	Metatarsi No.	Metatarsi Mean per cent ash
			Males				
2	4	4	44.08				
3	4	3	42.87				
4	4	2	44.48				
2A	4	4	45.28	4	47.01	4	46.48
3A	4	7	44.63	8	46.35	6	47.24
4A	4	1	45.23	1	48.09		
6	4	2	40.24	2	43.10	2	44.90
7	4	5	44.56	5	46.71	4	47.51
2A	6	4	45.62	4	46.31	4	46.48
3A	6	6	45.09	6	47.48	2	46.36
4A	6	8	46.01	8	47.71	7	48.63
6	6	5	44.61	5	46.24	4	46.43
7	6	5	45.39	5	47.72		
2A	8	4	45.91	2	48.06		
4A	8	7	45.82	6	48.24		
5A	8	6	43.79				
7	8	1	46.45				
1	10	6	41.82				
2	10	4	45.70				
3	10	5	43.56				
4	10	7	44.40				
5	10	5	41.21				
			Females				
2	4	4	43.84				
3	4	1	42.77				
2A	4	4	45.58	4	46.63	4	44.64
3A	4	3	43.53	3	45.33	2	45.14
6	4	1	44.59	1	46.77	1	48.09
7	4	1	43.21	1	44.01	1	42.73
2A	6	4	46.76	4	48.02	4	47.98
3A	6	5	45.66	5	47.39	2	47.26
4A	6	4	47.00	4	49.30	4	49.47
6	6	1	45.89	1	47.73	1	48.01
7	6	3	45.31	3	47.37	1	48.33
2A	8	4	47.66	4	49.75		
3A	8	3	46.47	3	49.92		
4A	8	1	48.89	2	49.62		
5A	8	5	43.74				
1	10	5	41.51				
2	10	4	45.90				
3	10	1	44.50				
4	10	3	46.38				
5	10	5	40.03				

femora of these chicks were also low in ash, as were the metatarsi, but the differences were non-significant in the case of these bones. This is the only case in the entire group of analyses in which the ash content of the bones of chicks with slipped tendon was significantly lower than that of the controls. The statistical analysis was not made in the case of the females, since it is obvious that the variability of the means is less than that of the means of the femora of the males at the same age, with the exception of one or two cases in which the bones of only one chick were analyzed.

It is evident that there are no significant differences in the ash content of the bones of the chicks in the various lots at six weeks of age. The means are as frequently above those of the control lot as they are below.

Lot 5A was fed a ration containing three per cent of magnesium carbonate. The ash content of the femora of these chicks at eight weeks of age is seen to be below that of the femora of the controls at the same age, while there is no marked variation from the control in the ash content of the femora of chicks afflicted with slipped tendon. In the case of the males, omitting the one chick in lot 7, F was found to be 2.89. The five per cent value of F is 3.74. The low bone ash of the femora of the males in lot 5A was not statistically significant. In the case of the females F was found to be

8.60, while the one per cent value was 8.02. The bone ash of the females is, therefore, significantly below that of the controls.

The ash analyses of the femora of chicks in lots 1 to 5, inclusive, at 10 weeks of age show that the ash of the bones of both males and females is low in lots 1 and 5. In the case of the males, for these five lots, F was 4.50, while the least highly significant value was 4.31. In the females F was found to be 4.67, while the tabular values are 3.41 for the five per cent point and 5.74 for the one per cent. It is evident that both the males and females of lots 1 and 5 have a lower bone ash than that of the chicks in lots 2, 3 and 4.

From these analyses it is clear that there is no significant difference in the ash content of the femora, tibiae or metatarsi of chicks having slipped tendon and of normal chicks on a control ration at the same age. The low ash content of the bones of the males in lot 6 at four weeks of age can be reasonably attributed to chance, since they are only two in number out of a total of 91 femora, 69 tibiae and 37 metatarsi of chicks having slipped tendon. It is also evident that in lot 1, which received a ration low in calcium, the bone ash is below normal but not definitely rachitic. The same may be said of lots 5 and 5A. The difference between lot 5 and the control was more marked than that between lot 5A and its control, since the chicks in lot 5 were two weeks older than those in lot 5A.

Experiment II

Growth and abnormalities

The growth in lot 8, the check lot, was good, being intermediate between that of lots 2 and 2A. The females were fairly uniform, but the males were quite variable in size. This high variability was due to the fact that seven of the chicks in the lot weighed less than 400 grams at the end of the experiment. It is rather unusual to find so many stunted chicks in one lot. The other chicks in the lot were quite uniform. The probable error of the mean was larger for both males and females than that of any other lot of chicks in the experiment, as shown in table XIII. No cases of abnormal leg bone development were observed. Many of the chicks developed crooked breast bones, but practically all of the breast bones were straight at the end of the experiment.

Lot 9 received a ration very low in calcium, 0.34 per cent, and a high amount of phosphorus, 1.28 per cent. This ration produced a marked diarrhea in the chicks. In spite of the high variability of the weights of the males in lot 8, the mean difference between the final weights of lots 8 and 9 is significant. There is no significant difference in the weights of the females in the two lots. Four males and six females developed slipped tendon. The chicks were never severely crippled, and all recovered with the exception of one male. Five cases of enlarged hocks were observed, and several chicks had slightly bowed metatarsi. All the chicks except three had crooked breast bones, but most of them recovered. Comparing the results with those obtained from lot 1, in the first experiment, it is readily seen that, on a ration as low in calcium as this, the increased amount of phosphorus over the previous treatment was somewhat detrimental to normal bone formation but had little influence on the growth.

Lot 10 was fed a ration similar to that fed lot 3, but containing a little more phosphorus. The results were practically the same. The growth was not significantly different from that of the check lot. Ten of the males and 13 of the females had slipped tendon. Three males and three females recovered. There were no enlarged hocks, a few crooked breast bones, and very few crooked legs except among those chicks having slipped tendon.

In lot 11 the per cent of phosphorus was only slightly higher than that in the rations fed lots 9 and 10, while the calcium content of the ration was 2.26 per cent. The growth was better than that of lot 8, the difference being significant in case of the females but not in case of the males. The difference of 50.3 grams in the mean weight of the males in the respective lots would have been significant if the variability of the males in lot 8 had been comparable to that of the males in the other lots. There were 13 males and 10 females which developed slipped tendon. Of this number, four males and six females recovered. The total number of slipped tendons in lots 10 and 11 were identical, but the percentage was slightly lower in lot 11, due to the fact that there were two more males in this lot. There were no enlarged hocks in lot 11, and about the same number of crooked breasts as in lot 10.

Lot 12 received the same mineral supplement as lot 10, but the wheat middlings were replaced by an equal amount of rice bran. In spite of the fact that the addition of rice bran increased the phosphorus content of the ration somewhat, no slipped tendons developed in this lot of chicks. Only one male and one female had crooked legs, and there were few crooked breasts. The growth was significantly greater than that of lot 8 in case of the females but not in case of the males. In the latter case the difference was rendered statistically non-significant by the high variability of the males in lot 8. The behavior of this lot of birds appears to confirm the observations of Titus (26) and Sherwood and Couch (24) with respect to the beneficial effect of rice bran in the ration, being even more conclusive than the results of the latter because of the higher phosphorus content of the ration.

Lot 13 was fed a ration containing two per cent of magnesium carbonate and one per cent of ground oyster shell. The calcium is lower than that of lot 8, and with this somewhat more favorable Ca:P ratio the added magnesium did not affect the growth unfavorably as did the three per cent of magnesium carbonate in lots 5 and 5A of experiment I. In fact the growth was significantly higher than that of lot 8 in case of the females. There were no slipped tendons, only one crooked leg, and very few crooked breasts. In no case did the level of magnesium which was fed produce the bending of the metatarsi which Buckner, Martin and Insko (3) reported on rations high in magnesium. However, they added five per cent of magnesium carbonate to their rations, which gave the ration a magnesium content of 1.4 per cent. It is apparent from the growth of lots 5, 5A and 13 in comparison with the control lots, that the tolerance limit for magnesium, above which growth is depressed, lies somewhere between 0.73 per cent and 0.9 per cent. The limit above which serious bone deformities develop appears to be between 0.9 per cent and 1.4 per cent of magnesium.

Lot 14 was fed a ration very similar to the basal ration used by Sherwood and Couch (24), except that three per cent of ground oyster shell was added instead of one per cent of bone meal. The growth was very poor on this ration. It is probably somewhat deficient in some member or members of the water soluble vitamin group. Goldberger and coworkers (5) found both white and yellow corn to be deficient in vitamin G, and Plimmer, Raymond and Lowndes (20), using pigeons, found that corn was much poorer in vitamin B than wheat middlings. The latter workers also point out that different samples of grains may vary considerably in their vitamin B content. Hunt and Krauss (12) found that cow's milk was relatively poor in vitamin B and richer in vitamin G. This ration might be deficient in either B or G, therefore, if the samples of feed which were used happened to be relatively low in their vitamin content. It is possible that this ration may be deficient in the growth-promoting factor which Keenan and coworkers (14) found in hog liver. The phosphorus content of this ration is also very low, being only 0.43 per cent. Eight males and three females developed slipped tendon, of which three males recovered. There were many crooked breast bones and only a few of them recovered.

Lot 15 was fed the same basal diet as lot 14, to which was added the same mineral supplement incorporated in the rations of lots 10 and 12. This mineral addition increased the phosphorus from 0.43 per cent to 1.33 per cent, but left the calcium almost unchanged. On this ration 26 males and 13 females became afflicted with slipped tendon, representing 78.8 per cent of the males and 76.5 per cent of the females. There were six cases of enlarged hocks, two chicks had abnormally short metatarsi, and all the chicks except two had crooked breast bones. The growth was about the same as that in lot 14.

With rations containing about the same level of phosphorus, variations in the calcium content of the ration had an interesting effect on leg bone deformities. On a ration very low in calcium, lot 9, 15 per cent of the males and 30 per cent of the females had mild cases of slipped tendon, of which all but one recovered. However, in lots 10 and 11, which received rations containing 1.40 and 2.26 per cent of calcium, respectively, the numbers of slipped tendon and the extent of the deformity increased. This is not in agreement with the work of Sherwood and Couch (24), who found that the numbers of slipped tendon decreased as the calcium in the ration increased. Their rations did not contain as much phosphorus as did these three rations.

Another interesting comparison is among lots 10, 12 and 15. These lots received the same mineral supplement, but the basal ration was varied. The basal ration fed lot 15 consisted of ground yellow corn, alfalfa leaf meal and dry skim milk. Nearly 80 per cent of the chicks were afflicted with slipped tendon. In lot 10 the alfalfa leaf meal and 15 pounds of the corn were replaced by 20 pounds of wheat middlings, and in this lot the incidence of slipped tendon was only about 45 per cent. In lot 12 the wheat middlings were replaced by an equal amount of rice bran, and on this ration none of the chicks developed slipped tendon.

In the light of these results and those of the previous experiment it appears highly probable that the relation between the amount of phosphorus in the ration and the incidence of slipped tendon is roughly quantitative, that a preventative substance is found in appreciable amounts in rice bran and wheat middlings, and that the relative amounts of phosphorus and preventative substance in the ration may largely determine the percentage of slipped tendon which the ration will produce. The incidence of slipped tendon is probably further modified by the degree of susceptibility of the chicks and by various environmental factors. This explanation, which is merely a working hypothesis and remains to be proved definitely, is simpler and therefore more logical than that of attributing special beneficial and detrimental properties to various foodstuffs.

Tables XIII to XVI, inclusive, summarize the weights by bi-weekly intervals and the number of slipped tendons which developed and recovered during each period. The probable error of the mean was calculated only for the initial and final weights. Table XVII gives the summary of the weights of the chicks in the various lots at the end of the experiment, together with their standard deviations and the number and percentage of slipped tendon. The percentage of slipped tendon is based on the number of chicks of each sex in the lot at the beginning of the experiment, since a few chicks were removed from the lots for study from time to time. The mean differences between the various lots and the check lot, lot 8, are given, together with their standard deviations. Twice the standard deviation of the mean difference was considered as the least significant value for the difference between two means, and three times the standard deviation of the mean difference as the least highly significant value.

Table XIII

Summary, Lots 8 and 9

Age in weeks	No. of males	Mean weight and its P.E.	No. of slipped tendons: New cases	No. of slipped tendons: Recovered	No. of females	Mean weight and its P.E.	No. of slipped tendons: New cases	No. of slipped tendons: Recovered
Lot 8								
Initial	21	32.71±0.44			26	32.88±0.37		
2	21	77.00			26	77.31		
4	21	166.48			26	156.04		
6	21	319.10			26	281.38		
8	20	476.45±21.02			25	412.40±13.11		
Lot 9								
Initial	26	32.12±0.50			20	32.55±0.44		
2	26	77.77			20	77.60		
4	25	150.56	1		20	152.45	3	
6	25	276.76	3		20	280.20	3	2
8	25	408.48±10.08		3	20	399.35±11.32		4

Table XIV

Summary, Lots 10 and 11

Age in weeks	No. of males	Mean weight and its P.E.	No. of slipped tendons: New cases	No. of slipped tendons: Recovered	No. of females	Mean weight and its P.E.	No. of slipped tendons: New cases	No. of slipped tendons: Recovered
Lot 10								
Initial	23	32.04±0.41			26	32.85±0.48		
2	23	95.52			26	90.08		
4	22	180.14	6		26	162.85	7	
6	22	326.55	3	2	26	277.00	4	1
8	21	506.95±13.26	1	1	25	420.40±11.16	2	2
Lot 11								
Initial	25	34.04±0.52			26	33.46±0.50		
2	25	103.56			26	99.35		
4	25	198.24	6		26	183.08	10	
6	25	355.16	4	1	26	323.77	0	2
8	25	526.76±12.05	3	3	26	480.65±9.70	0	4

Table XV

Summary, Lots 12 and 13

Age in weeks	No. of males	Mean weight and its P.E.	No. of slipped tendons		No. of females	Mean weight and its P.E.	No. of slipped tendons	
			New cases				New cases	
Lot 12								
Initial	22	33.41±0.51			26	33.23±0.47		
2	22	94.32			26	95.65		
4	22	184.27			26	182.96		
6	22	353.18			26	337.62		
8	22	544.73±13.85			26	507.65±8.84		
Lot 13								
Initial	21	33.29±0.47			28	32.46±0.45		
2	21	91.57			28	87.71		
4	21	176.71			28	164.64		
6	21	353.33			28	305.25		
8	21	542.14±10.27			28	466.36±9.89		

Table XVI

Summary, Lots 14 and 15

Age in weeks	No. of males	Mean weight and its P.E.	No. of slipped tendons: New cases	No. of slipped tendons: Recovered	No. of females	Mean weight and its P.E.	No. of slipped tendons: New cases	No. of slipped tendons: Recovered
Lot 14								
Initial	22	31.95±0.53			24	32.88±0.43		
2	22	61.77			24	64.67		
4	22	110.27	3		24	114.50	1	
6	22	205.82	4	1	24	213.62	0	
8	22	357.55±12.69	1	2	24	358.00±12.71	2	
Lot 15								
Initial	33	32.27±0.31			17	33.06±0.61		
2	33	80.06			17	80.82		
4	33	134.91	19		17	131.47	6	
6	33	227.85	6		17	213.18	4	
8	32	348.75±7.46	1	1	16	300.19±9.80	3	

Table XVII

Summary, Experiment II

Lot	No. of chicks	Mean weight	Standard deviation of mean	Mean difference from Lot 8	Standard deviation of mean difference	Significance	No. of slipped tendons	Per cent of slipped tendons
♂♂								
8	20	476.45	30.376				0	0
9	25	408.48	14.942	67.97	33.852	**	4	15.38
10	21	506.95	19.658	30.50	36.182	*	10	43.48
11	25	526.76	17.860	50.31	35.237	*	13	52.00
12	22	544.73	20.534	68.28	36.665	*	0	0
13	21	542.11	15.232	65.69	33.981	*	0	0
14	22	357.55	18.809	118.90	35.728	***	8	36.36
15	32	348.75	11.065	127.70	32.328	***	26	78.79
♀♀								
8	25	412.40	19.440				0	0
9	20	399.35	16.784	13.05	25.683	*	6	30.00
10	25	420.40	16.545	8.00	25.527	*	13	50.00
11	26	480.65	14.386	68.25	24.184	**	10	38.46
12	26	507.65	13.099	95.25	23.441	***	0	0
13	28	466.36	14.667	53.96	24.352	**	0	0
14	24	358.00	18.840	54.40	27.071	**	3	12.50
15	16	300.19	14.528	112.21	24.269	***	13	76.47

*non-significant
**significant
***highly significant

Figure I is a photograph of chick No. 1256 from lot 11. The tendons of both legs are badly slipped, being displaced to the right in both legs. The chick was photographed with the legs held over the edge of the table in as nearly a natural position as possible. The chick was unable to stand erect long enough to be photographed in the standing position. Figure IIIA is a photograph of the tibiae from this chick, which shows clearly the lateral bending of the distal end of the tibiae. Figure II is a photograph of chick No. 1265 from the same lot. In this chick the tendon of the right leg is slipped to the left, while the left leg is perfectly normal. In figure IIIB the tibiae of chick 1265 are shown. It can be clearly seen that the left tibia is perfectly straight, while the distal end of the right tibia is bent to the left. These two chicks are typical specimens of the abnormality as observed in these experiments. Some cases were not as severe as these but many were worse. The chicks were eight weeks of age when the photographs were made.

Figure I

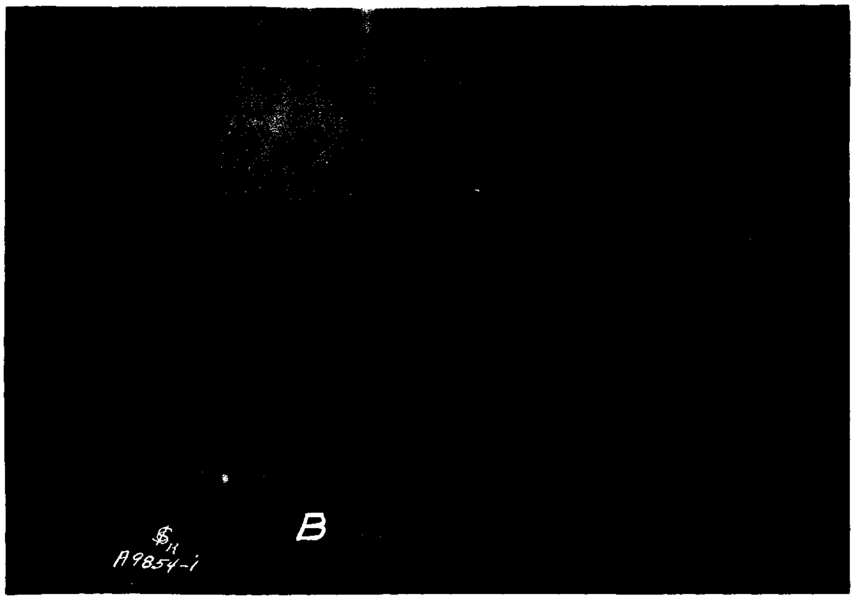

Figure II

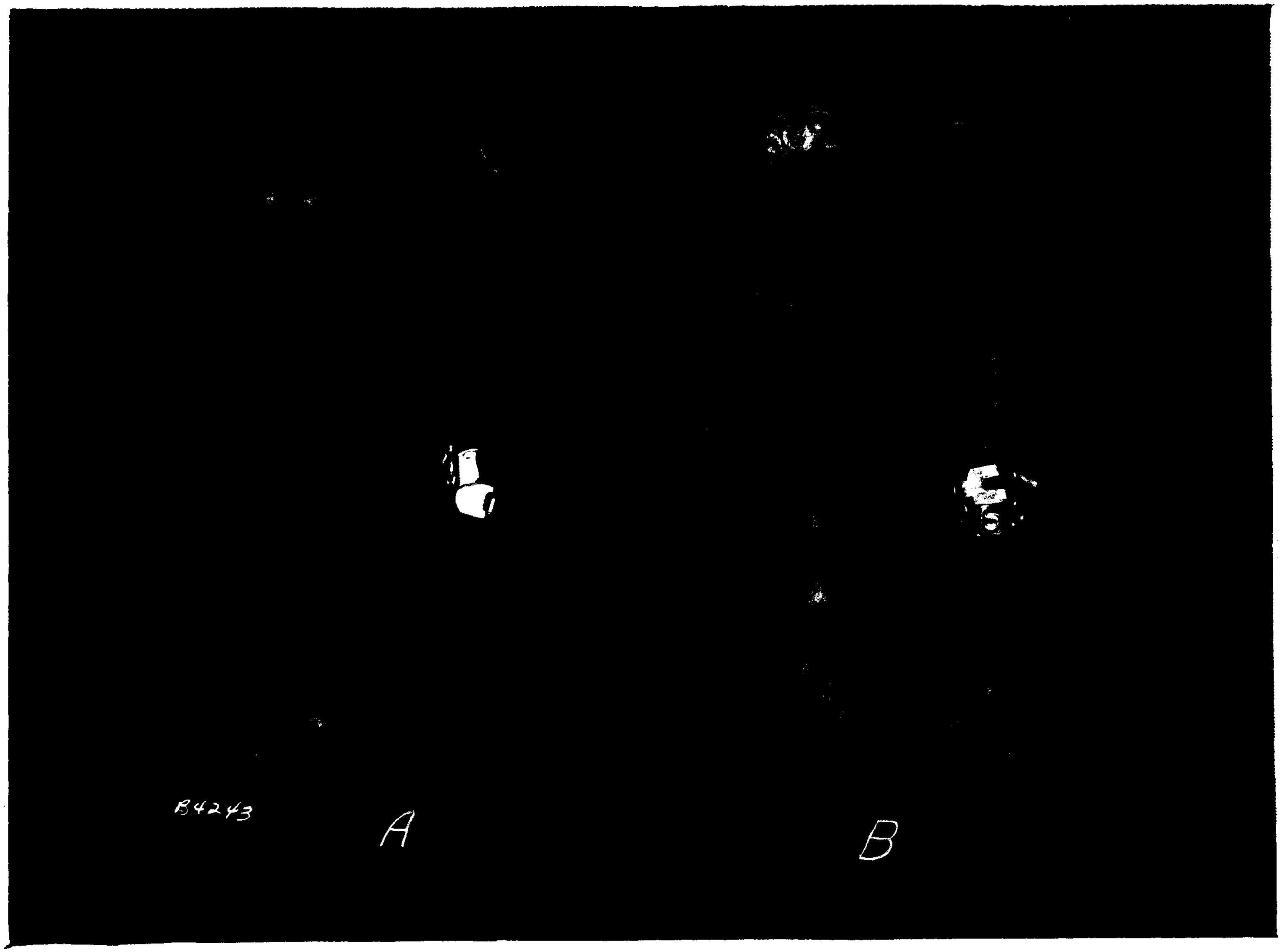

Figure III

Graphic Presentation

Figures IV and V present the data of the first experiment graphically, bringing out the essential facts about the growth of the chicks and development of abnormalities more clearly than does Table XI. It can be clearly seen that lots 4 and 4A, 5 and 5A are the only lots in which the growth differs markedly from that of the control. The practically identical rates of growth of the chicks fed at different times on the same ration is brought out clearly. Total mortality is shown on the curves of both males and females, since the sex of the chicks which died during the first two weeks was not determined.

Figures VI and VII show graphically the data of the second experiment. It is clearly shown that the growth of lots 14 and 15 was much below that of the control, lot 8. It is also shown that the males of lot 9 grew less rapidly than did those of lot 8, while this was not true in case of the females. The mortality was practically confined to the first two weeks and is shown on the curves of both sexes, since the sex was not determined of the chicks which died during the first two weeks.

The total number of chicks in the first experiment which lived long enough to have their sex determined was 505, of which 263 were males and 242 were females. There were 65 males and 28 females which developed slipped tendon. The sex ratio of chicks which developed slipped tendon was 69.9 males to 31.1 females. The total number of chicks in the second experiment was 386, of which exactly half were males. Of the chicks which developed slipped tendon, 61 were males and 45 were females, the sex ratio being 57.5 males to 42.5 females. Of the total number of chicks which developed slipped tendon in the two experiments, 63.3 per cent were males and 36.7 per cent were females. This ratio is in agreement with Payne, Hughes and Leinhardt (19), who found the sex ratio of chicks afflicted with slipped tnedon to be 63.1 males to 36.9 females in their experiments.

Form E-5

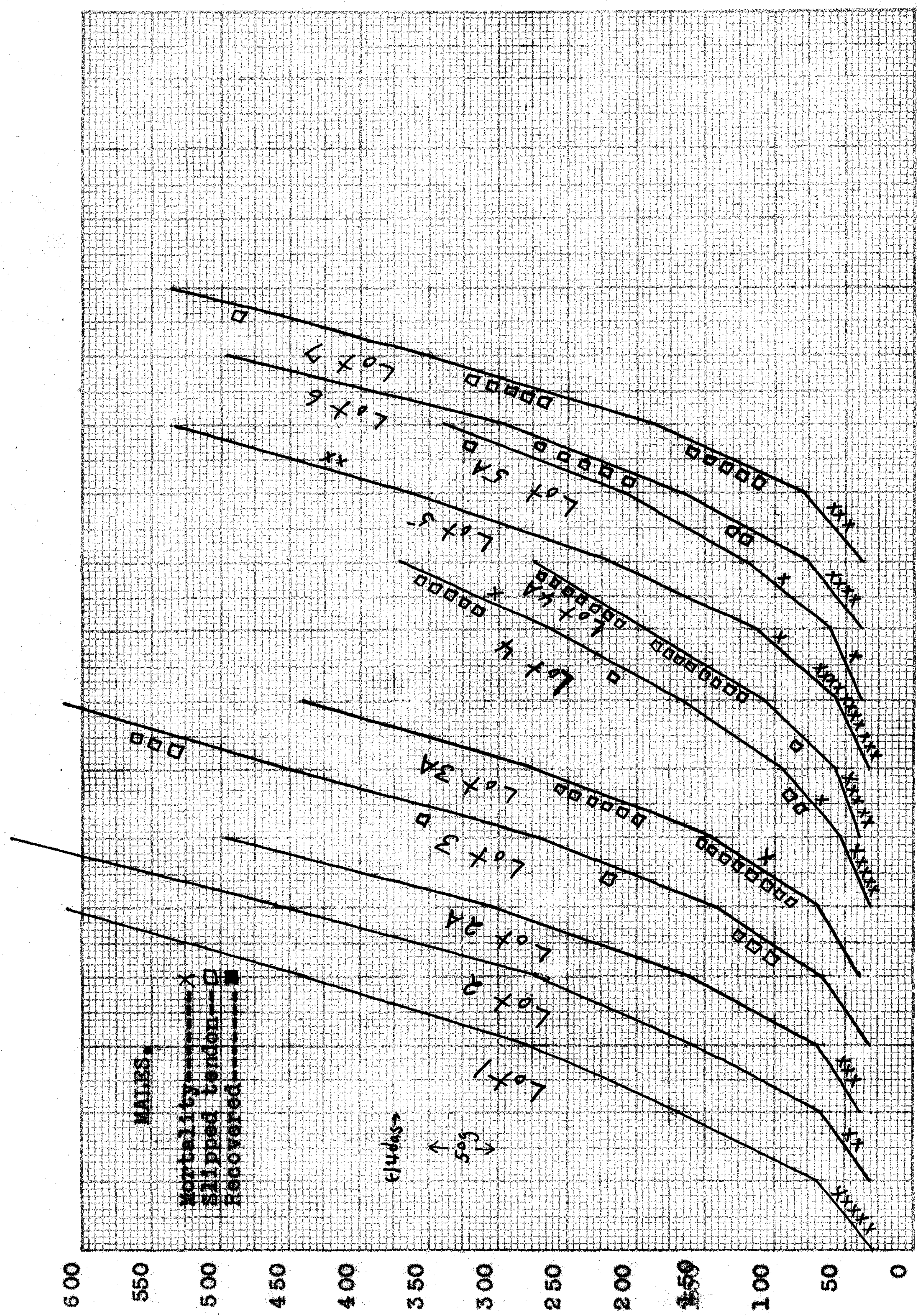

Fig. IV

Form E-6

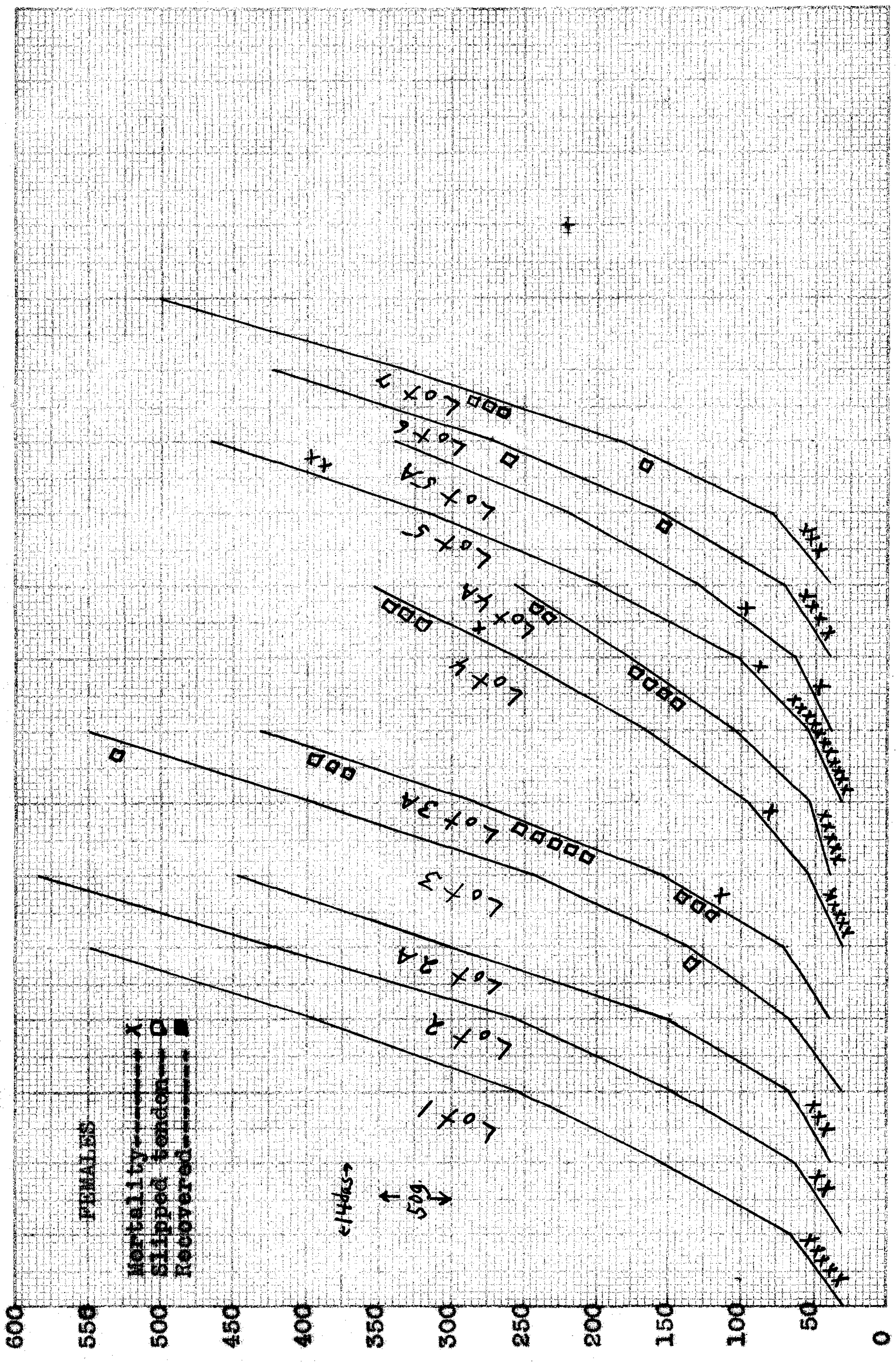
FEMALES
Mortality ——— X
Slipped tendon ——— □
Recovered ——— ■
Lot 1
Lot 2
Lot 2A
Lot 3
Lot 3A
Lot 4
Lot 4A
Lot 5
Lot 5A
Lot 6
Lot 7
600
550
500
450
400
350
300
250
200
150
100
50
0

Fig. V

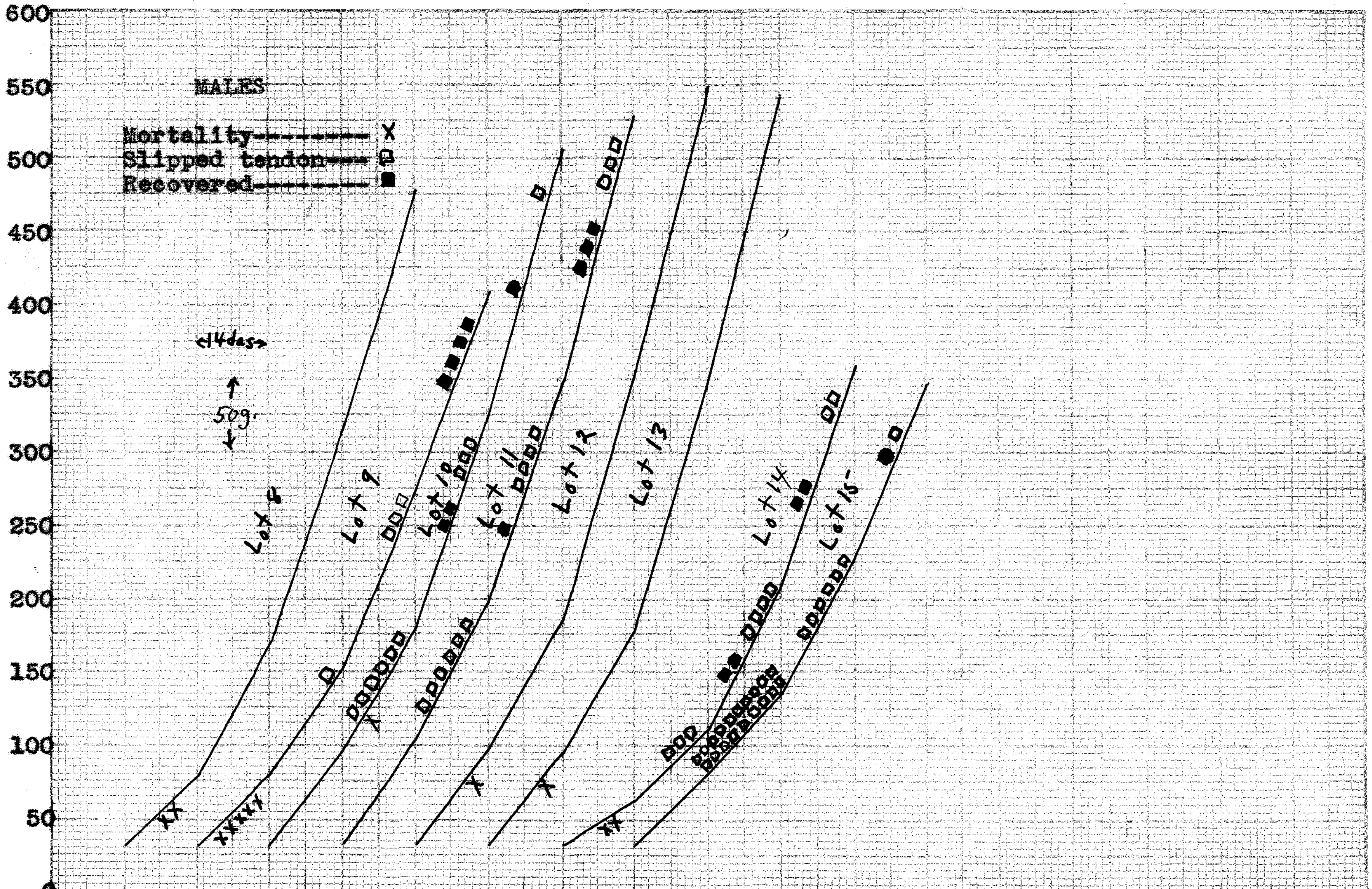
MALES
Mortality---------- X
Slipped tendon---- □
Recovered---------- ■
Lot 8
Lot 9
Lot 10
Lot 11
Lot 12
Lot 13
Lot 14
Lot 15
14 dys
50g.
600
550
500
450
400
350
300
250
200
150
100
50
0

Fig. VI

Form E-5

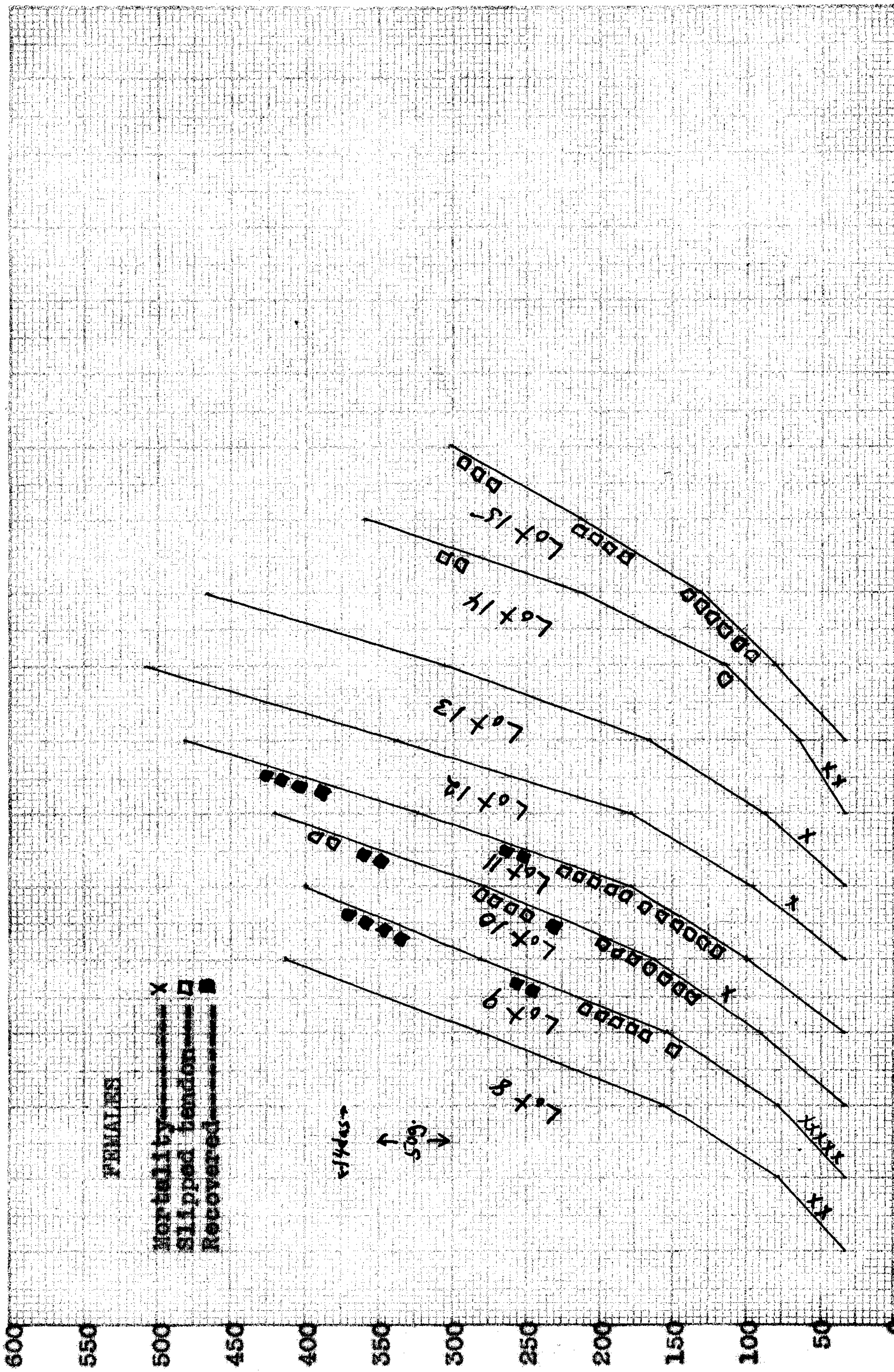

Fig. VII

SUMMARY

When varying amounts of phosphorus from inorganic sources were added to a basal ration of ground yellow corn, wheat middlings and dry skim milk, in which the amount of calcium in the various rations was held practically constant, the incidence of slipped tendon increased as the phosphorus increased. Though the trend was very definite, the relation between the amount of phosphorus in the ration and the percentage of slipped tendon was not linear, indicating that factors other than the amount of phosphorus in the ration may have been operating to influence the incidence of slipped tendon. Two groups of chicks fed on the same ration at different times gave very similar growth responses, and though the incidence of slipped tendon was not of the same magnitude the relation between the numbers of slipped tendon on the various rations remained the same. The lowest amount of phosphorus in the ration which produced slipped tendon was 0.9 per cent.

When the amount of phosphorus in the ration was held practically constant at about 1.4 per cent and the calcium was fed at levels of 0.34 per cent, 1.40 per cent and 2.26 per cent there were fewer slipped tendons on the low level of calcium than on the medium and high levels. The per cent of slipped

tendon on the medium and high levels of calcium was practically the same.

When a basal ration of ground yellow corn, alfalfa leaf meal, dry skim milk and ground oyster shell was fed about 24 per cent of the chicks developed slipped tendon, though the phosphorus content of the ration was only 0.43 per cent. With this base, when the phosphorus content of the ration was increased to 1.33 per cent by the addition of inorganic phosphorus, the incidence of slipped tendon increased to 78 per cent. With nearly the same amount of phosphorus, 1.43 per cent, a ration containing 20 per cent of wheat middlings in place of the alfalfa leaf meal and part of the corn in the above base produced only about 45 per cent of slipped tendon. A ration in which the wheat middlings were replaced by rice bran produced no slipped tendon at all.

The per cent of ash in the dry, fat-free femora, tibiae and metatarsi of chicks afflicted with slipped tendon did not differ significantly from that of the corresponding bones of chicks of the same age on a control ration. The ash of femora of chicks ten weeks of age on a ration containing only 0.36 per cent of calcium and 0.59 per cent of phosphorus was significantly lower than that of chicks of the same age on a control ration, but was not as low as the figures generally given for the ash content of the bones of rachitic chicks. The per cent of ash in the femora of chicks which received a ration containing three per cent of magnesium carbonate was significantly lower than that of chicks on the same ration without the magnesium carbonate.

CONCLUSIONS

1. With rations otherwise adequate for normal growth, excess phosphorus appears to be the chief causative factor in the production of slipped tendon.

2. The percentage of ash in the dry, fat-free leg bones of chicks afflicted with slipped tendon is not significantly different from that of the leg bones of normal chicks on a ration which produced no slipped tendon.

3. Rice bran and, to a lesser extent, wheat middlings appear to contain a substance which tends to prevent slipped tendon, the balance between the amount of the preventative factor present and the amount of phosphorus in the ration apparently determining the percentage of slipped tendon which will develop in chicks from a given source and under a given set of environmental conditions.

4. A ration containing three per cent of magnesium carbonate, the total content of magnesium (as Mg) being 0.89 per cent of the ration, produces neither slipped tendon nor marked bending of the leg bones. The growth of the chicks on this ration is significantly lower than that of chicks on a comparable ration without the added magnesium carbonate.

5. When a ration containing three per cent of magnesium carbonate is fed to chicks the ash content of the dry, fat-free femora is significantly lower than the ash content of the femora of chicks on a comparable ration without the added magnesium carbonate.

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