ABNORMAL CONDYLARTHROSIS AND ARTHROCELE OF THE TIBIAL METATARSAL JOINT IN YOUNG CHICKS

by

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INTRODUCTION

Slipped tendons, deformed legs, leg weakness, range paralysis, and perosis are names used by different authors in describing the same pathological condition in young chicks. The diversity of names does not mean a different etiological factor involved. It appears to be a disease of recent origin; and as a malady that must be reckoned with in the brooding of chicks. The responsibility for the appearance of the disease has been attributed to various factors. This condition was encountered in some of the earlier nutrition experiments but was not differentiated from rickets. Rickets is a disturbance in the metabolism of the growing organism of such nature that the salt equilibrium in the circulating fluid is disturbed, in particular as regards the calcium and phosphorus, and lime salts no longer deposit in the bones. It is prevented and cured by vitamin D supplied in the form of certain fish oils, irradiation, irradiated ergosterol, or sunshine in the presence of a well-balanced mineral mixture.

Slipped tendons is a separate and distinct disorder. There is no disturbance in the chemical composition of the blood or the histology of the bones; and furthermore, it develops in the presence of vitamin D and a well-balanced mineral mixture.

Hall and King (1931) report that this condition of partial dislocation is variable in Canada, some years reaching forty per cent in some flocks, while in other flocks this condition is practically unknown. They also state that its occurrence is most frequent in March and early April, particularly where the chicks have been reared indoors for six or eight weeks before being transferred to the range.

Payne (1931) in describing this condition states that the Department of Poultry Husbandry at Kansas State College and poultrymen in Kansas have experienced losses from this condition during the past four brooding seasons. He gave the actual per cent in the spring of 1930 as fourteen for Rhode Island Red chicks and seven tenths for the White Leghorns at the college farm. It is the general opinion among poultrymen that the heavier breeds are more susceptible to this disease than the lighter breeds.

SYMPTOMS

The first few weeks of the chick's life seems to be the critical period in the development of the slipped tendon condition. The first noticeable symptom of this condition is a tendency for the chicks to rest in a squatting position. When the chicks stand up, the metatarsal-tibia joints seem to be closer together than in the normal chick. A careful examination of the same joints reveals a slight

puffiness and an enlargement of the saphenous vein. After a few days, the joints become enlarged and sometimes the skin-covering turns a bluish-green. This color resembles that which develops following a bruise. Apparently it is caused by irritation and possibly hemorrhages of the smaller capillaries. As the condition progresses, the tarso-metatarsi and tibiae show a very slight bending. These bones become more and more curved until a partial or total deformity results. The curvature of the diaphyses of the tibae may become so great at the distal end that it causes the slipping of the gastrocnemius tendon from its normal position in the condyles. In other cases there may be a slight bowing of the legs at the hock. The joint becomes smaller and the tibia and tarsus seem to become flattened. The leg muscles sometimes lose the power of flexion and the leg becomes practically fixed in an extended position. Often the leg becomes laterally rotated, particularly from the tibia-tarsus joint downwards. One or both legs may be affected.

The disease usually makes its first appearance when the chicks are between three and eight weeks old. One case has been noticed by the writer on the eighth day and some workers claim that it may appear even after the eighth week. The third and fourth week seem to be the critical stage in the development of this condition. It frequently happens

that chicks recover from this disease starting about the sixth week. The recovery is often so complete that scarcely any deformity may be noticed.

REVIEW OF LITERATURE

According to Hunter and Funk (1930) slipped tendons are usually associated with brooding on wire, lack of exercise, or crowded conditions. It appears in chicks three to six weeks of age but has appeared in birds eight weeks of age. One or both legs may be affected. The bone ash was found to be normal and a normal calcification was revealed by the lime test. Slipped tendons were greatly increased by the addition of 1.5 per cent sodium phosphate (NaH_2PO_4) to their ration. When bone meal was omitted from the ration, the deformity did not appear and the addition of mineral in several different forms greatly increased the production of slipped tendons. They claim that the low fibre content of the ration may be a factor in the production of this abnormality.

Payne (1930) points out that this disease may be found in both slow and rapidly growing chicks, with all mash or with grain and mash rations, on wire and board bottom runways and with high and low mineral content in the ration.

Hall and King (1931) made a study of the calcium and phosphorus metabolism of chickens suffering from slipped

tendons. They determined the total ash, bone phosphorus, bone calcium, phosphatase, and made a histological and X-Ray examination of the bones. They came to the conclusion from these studies together with blood analysis of birds suffering from the disease, that there was no indication that the leg bones were abnormal. The only abnormal findings were the subluxation, bowing, and rotation as revealed in the X-Ray examination.

Payne, Hughes, and Leinhardt (1931) in studying the etiological factors involved in the malformation of bones in young chickens, claim that intensive methods of brooding may be a contributory factor in the development of slipped tendons where the mineral portion of the ration is not properly balanced. Chemically-pure calcium phosphate and calcium carbonate had the same deleterious effect as the same amount of steamed bone meal. They state that a very important etiological factor is an excessive amount of either phosphorus or calcium or of both. Like King and Hall, they could find no chemical abnormalities in the blood and the bones.

Titus (1931) found that the per cent of ash from the leg bones of afflicted chicks was essentially the same as that observed in the case of normal chicks of the same age. The calcium and inorganic phosphorus content of the blood serum were well within the normal range. In his experiments

he found that in the absence of cod liver oil, rice bran was quite effective in preventing slipped tendons but not in preventing rickets. According to his results, the addition of rice bran to the diet of growing chicks supplies something which is very effective in decreasing the percentage of cases of slipped tendons even though the calcium phosphorus ratio is relatively narrow. He suspects a factor to be present in rice bran, possibly a vitamin which is necessary for the normal development of bone, at least in the case of chickens.

Buckner and his co-workers (1931) have presented experimental results showing that rations containing five parts of magnesium carbonate, produced an abnormal condition in the leg bones of chicks. This abnormality was very marked and permanent in the presence of an equal quantity of tricalcium phosphate. This swollen condition of the joints of the leg bones of the chicks is not thought to be the condition known as slipped tendons. The reason given is that the condyles at the distal end of each tibia were in proper alignment with the shaft which was straight. The lameness was due primarily to the outward-bowing of the metatarsal bones. He further states that it is evident from his results that the addition of magnesium carbonate to the rations used disturbed the calcium and phosphorus balance necessary for the normal formation of bones during the first

six weeks.

Hunter, Dutcher and Knandel (1931) state that they were able to produce this disease experimentally, in more than ninety per cent of the birds, using White Leghorn chicks. This abnormality was produced by the addition of bone meal, sodium phosphate, and calcium carbonate to the basal ration. They found that the presence of protein concentrates rich in inorganic salts, aggravates the condition when salt or salt mixtures are fed at the same time. They also observed that oats or oat feed possess beneficial properties for the prevention of slipped tendons. They could not explain these results on the basis of their fiber content.

Before Mellanby's work in 1918, one theory of the etiology of rickets in infants attributed the condition to excessive cereal intake. Since that time, cereals have been shown to be associated in some way with a pathological phase of calcium metabolism, that is, rickets. Green and Mellanby (1928) were able by keeping other things constant, to produce more severe rickets by increasing the cereal intake -- oatmeal being most potent in its anti-calcifying influence. This ricket-producing effect is by no means limited to oatmeal, as it is also present, although to a lesser extent, in wheat and corn, and in wheat germ and corn germ. Additional amounts of calcium carbonate or calcium phosphate minimized the anti-calcifying action of the cereals and tended to

convert a rachitic into an osteoporatic condition of the bones. Green and Mellanby (1925) have destroyed the anti-calcifying action of the oats by boiling with dilute hydrochloric acid and Mirvish (1930) actually isolated, by dialyses, a potent, anti-calcifying factor from oats. King and Hall (1931) found that the addition of oatmeal to the diet induces a more severe rachitic condition of birds.

PURPOSE

The purposes of this study were: (1) to compare the grains, corn, oats, barley, and wheat in their effect on the occurrence of slipped tendons; (2) to determine whether the addition of magnesium in the form of magnesium carbonate to a ration already supplemented with calcium and phosphorus would increase this abnormality.

METHOD

One hundred and fifty Single Comb Rhode Island Red chicks were obtained from the flock maintained at Kansas State College. The chicks were hatched December 28, 1931, banded, weighed individually, and examined weekly for six weeks. All chicks were kept in battery brooders with wire bottom floors. One per cent cod liver oil was added to supply the vitamin D necessary for proper bone development. The source, per cent of protein and mineral added were the

same in each ration. Ration No. 1 is the regular ration used at the Kansas State College Poultry Farm (1931) and was supposed to give a fairly low percentage of slipped tendons. To this last mentioned ration, magnesium was added in the form of magnesium carbonate. This ration constituted No. 6 and the chicks reared on it were brooded in the bottom tray of the battery brooder. All chicks were fed an all-mash ration. Feed and water were before the chicks at all times starting from the time they were put into the battery brooder. All chicks that died during the experiment were dissected and the sex determined. Photographs were made of three representative normal chicks in each group. A photograph was also made of three chicks showing the typical condition of slipped tendons (plate 1). The rations used in the experiment are given in table 1.

CHEMICAL ANALYSIS

At the beginning of the experiment, when mixing the feed, a representative sample was taken from each lot for analysis. At the close of the experiment, five normal birds and five birds with slipped tendons were selected from those that were on the regular Kansas State College ration (lot 1); and similarly ten birds from those that were on the ration with the magnesium added (lot 6). Blood samples were obtained from each group by bleeding the birds with a

Plate 1

Typical condition of slipped tendons showing in the right legs

Table 1. Rations used in the Experiment

Ingredient	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6
Ground yellow corn	45	75	0	0	0	45
Ground oat groats	15	0	75	0	0	15
Ground wheat	0	0	0	75	0	0
Ground barley	0	0	0	0	75	0
Wheat bran	15	0	0	0	0	15
Meat cracklings *	10	10	10	10	10	10
Dried milk	5	5	5	5	5	5
Alfalfa leaf meal	8	8	8	8	8	8
Salt	1	1	1	1	1	1
Cod liver meal	1	1	1	1	1	1
Magnesium carbonate	0	0	0	0	0	3

* Meat cracklings are ground dried residue, after partially extracting the fats and oils from animal tissues, exclusive of hoof, horn, manure, and stomach content. It contains 10 to 15 per cent ash and 75 to 80 per cent crude protein.

hypodermic needle from the heart. Bones were obtained from the same groups for analysis. The following determinations were made in the Department of Chemistry:

(a) Calcium content of the plasma

(b) Inorganic phosphorus content of the blood

(c) Ash content of the bones

(d) Calcium content of the bones

(e) Phosphorus content of the bones

(f) Magnesium content of the bones.

For the bone analysis, the tibia and tarsus bones were used. The length, the diameter, and the volume of water displaced by the tibia of normal chicks and slipped tendon chicks were also obtained. The bones were freed from adhering tissue before the measurements were made.

Blood was drawn from each chick before killing and the blood from all the normal chicks on the same ration were pooled. The blood from the chicks that had the slipped tendons were handled in a similar manner. The analyses were made following the methods outlined by Clark and Collip (1925) for serum calcium and the Youngburg and Youngburg (1930) system of blood phosphorus analysis. The values obtained in the different groups are tabulated under table 7.

The tibia and tarsus were removed for bone analysis. All the bones from lot 1 were grouped. The bones from the chicks in lot 6 with the magnesium were handled in the same

manner for analysis. Bones were freed from adhering tissue, broken up and subsequently extracted with alcohol and ether for eight hours. The fat-free bone was ground up and five grams transferred to a weighed crucible. The per cent ash on the dry extracted bones was obtained in the usual way.

The ash obtained as described above, was dissolved in hydrochloric acid, transferred to a 250 cubic centimeter volumetric flask and made up to volume with distilled water. The per cent phosphorus, calcium, and magnesium were determined according to the methods described on page 15 for phosphorus, page 104 for calcium, and page 106 in the Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists (Third Edition 1930).

EXPERIMENTAL RESULTS

Ration No. 1 was used during the past brooding season (1931) at the Kansas State College Poultry Farm and produced a very low percentage of slipped tendons. This ration was taken as a standard with which the other rations could be compared. The chemical analyses of the rations used are given in table 2. It will be seen that the per cent calcium in all the rations is very low except in ration 6. This is due to the fact that meat cracklings were used which had a very low ash content. The calcium-phosphorus ratio is very narrow, that is, the rations contain nearly as much

Table 2. Chemical Analyses of the Feeds used in the Experiment

Lot No.	Per cent									Ca.-P. ratio
	Moisture	Ether Extract	N-Free Extract	Crude Protein	Fibre	Ash	Magnesium	Calcium	Phosphorus	
1	7.02	6.20	56.64	19.69	4.13	6.32	0.2093	0.737	0.777	.94:1
2	7.40	6.17	59.61	18.31	3.11	5.40	0.1552	0.730	0.615	1.18:1
3	7.32	6.77	55.19	22.50	2.79	5.43	0.1569	0.755	0.630	1.19:1
4	7.78	4.29	58.36	19.88	3.66	6.03	0.1818	0.785	0.715	1.09:1
5	7.59	4.58	56.33	19.50	5.82	7.17	0.1728	0.815	0.688	1.18:1
6	7.33	5.84	55.11	19.88	4.10	7.74	0.9149	0.932	0.794	1.17:1

phosphorus as calcium. Wilgus (1931) found the phosphorus requirements were about five-tenths per cent of the ration. He placed the calcium phosphorus ratios between 1:1 and 2.2:1 for normal growth, 2.5:1 as a border line, and 3.3:1 as disastrous. From table 2, the feeds used contain just about the lower limit of calcium as given by Wilgus.

The battery brooder had an electric heater for each compartment and the room was heated with a gas stove. Early in the experiment, the electric current was disconnected without notifying the experimenter, and the electricity was off for four hours. The weather was very cold and the temperature went down rapidly. The chicks in the bottom trays were chilled resulting in a high mortality during the first ten days. It was felt necessary to dispose of all the weak chicks in this compartment following the chilling. Replacements were made with normal chicks. The average weekly weights of the chicks are given in table 3.

Table 3. Average Weekly Weights of Chicks in Grams

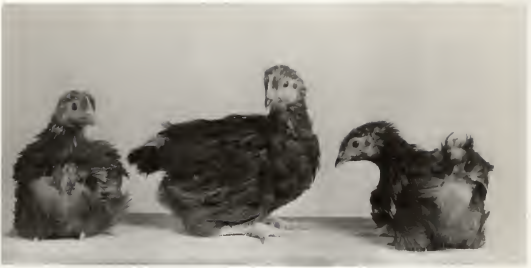
Lot No.	Age in Weeks						
	0	1	2	3	4	5	6
1	35	54	94	156	218	324	452
2	33	54	92	139	213	305	413
3	34	48	70	95	157	213	298
4	34	54	82	135	143	285	396
5	33	53	80	125	166	242	349
6	34	49	82	130	215	388	447

From table 3, it can be seen that all the chicks made a fairly normal growth, except those in lot 3 on the basal diet of oats. Most of the chicks in this lot developed necrosis of the beak resulting in a very high mortality during the first few weeks. This is a condition that usually develops in chicks fed on a finely ground or pasty feed. The feed and water were readily available under battery conditions so that the chicks after eating for a time might attempt to consume water. This results in the matting of the mash in the mouth between the mandibles and maxilla, especially in the mandibles where it is held in place under the tongue. Owing to the scant secretions in the bucal cavity, the material becomes dried out and very hard to dislodge. A repetition of these circumstances develops into an inflammatory condition known as necrosis and sloughing off of the affected parts. This condition was noticed only in lot 3. Therefore, the physical or chemical make-up of the oats must have been responsible for it. The chicks probably, as a result of this condition, did not make normal gains.

The best gains were made in lot 1, fed the Kansas State College ration. When magnesium was added to this ration (lot 6) the chicks made practically the same gains. The magnesium acted as a laxative; large quantities of water were consumed and the droppings contained a very high percentage of moisture. The chicks were normal in all respects

and in general were superior to any other lot in the experiment. Lot 2, on the basal, made slightly less gains but from table 2 it can be seen that the ration fed lot 2 had over one per cent less protein than either lot 1 or lot 6. Lots 4 and 5 made about the same gains, both rations containing nearly the same amount of protein.

Apart from variation in average gains, at the end of the experiment there was a marked difference in the feathering in the different lots. The chicks in lot 6, that had the magnesium carbonate added to the ration were the best feathered as shown in plate 4. They were not only more closely feathered, but had a distinct color and gloss. Lot 1 ranked next in quality of feathering (plate 2). The chicks on the barley and the wheat (lots 4 and 5) had a poor distribution of feathers along the different feather tracts (plates 3 and 4). Lot 2, reared on the ration containing corn, was poorly feathered (plate 2). They lacked feathers on the back, along the neck and breast. The chicks in lot 3 had feathers that were ragged and dry (plate 3). Whether the abundance and gloss of feathers in lot 6 were due to temperature, humidity or the high percentage of magnesium, cannot be stated. The lack of feathering in lot 2 on the corn ration is probably due to a shortage of cystine, one of the essentials in feather formation. Corn is deficient in cystine and lot 2 was fed such a high percentage of it



Lot 1. Chicks used as controls fed the 1931 Kansas State College ration

Lot 2. These chicks received a ration consisting of 75 per cent yellow corn

Lot 3. These chicks received a ration consisting of 75 per cent oats

Lot 4. These chicks received a ration consisting of 75 per cent wheat

Lot 5. These chicks received a ration consisting of 75 per cent barley

Lot 6. Same ration used as for lot 1 with 3 per cent magnesium carbonate added

that the deficiency was manifested in the growth of feathers.

Rapid growth does not necessarily stimulate the development of slipped tendons. As can be seen from table 3, lots 1 and 6 made the most rapid gains but the largest per cent of slipped tendons developed in lot 2. Furthermore, chick No. 416 developed this condition during the sixth week and at that time only weighed 175 grams. In general, however, it seems as if the more rapid growing chicks are more apt to develop this condition than the slower growing chicks.

The chicks that died are recorded in table 4.

Table 4. Mortality Record

Lot No.	Mortality each week						Total
	1	2	3	4	5	6	
1	0	0	0	0	0	0	0
2	1	0	0	0	0	0	1
3	1	6	2	1	0	0	10
4	1	0	3	2	0	0	6
5	1	2	1	0	0	0	4
6	0	0	1	0	0	0	1

The high mortality in lot 3 during the second week as given in table 4 was due to the development of the necrosis condition of the beaks. After the second week, the beaks were cleaned every second day. Chicks that were chilled and died during the first week are not included in table 4. Those

that became so deformed that they were not able to walk and died of starvation, or those that were killed because they were not able to reach the feed are included in table 4.

The number of slipped tendons that developed each week during the experiment are given in table 5. The source and amount of ingredients added to the different rations were the same, their calcium phosphorus ratio falling within the limits for normal growth. The amount of calcium and of phosphorus is in each case below one per cent and the highest percentage of slipped tendons showed up in lot 2 and the least in lot 3.

It would appear that each grain carries in its make-up some factor or factors that prevent or aggravate slipped tendons to a certain degree. From table 5 it appears that corn carries a large amount of those factors producing this pathological condition, or that factors preventing it are present in very small quantities. The low percentage that developed on the feed containing oats as a basal, agrees with the results obtained by Hunter and Funk (1931). The fibre content of this feed was low as oat groats were used. Since most of the oat hulls were removed from this ration, they could not have been responsible for the low percentage of slipped tendons in this lot. The inside of the oat grain must carry fairly large quantities of the factors preventing it, or oats may be entirely free from any factor that may

Table 5. Number and Age of Chicks in Each Lot which Developed Slipped Tendons

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Total	Per cent
1 week	0	0	0	0	0	0	0	.00
2 weeks	0	1	0	0	0	0	1	0.66
3 weeks	7	15	0	2	3	5	31	20.66
4 weeks	4	0	1	0	0	0	5	3.66
5 weeks	0	0	0	1	1	0	2	2.00
6 weeks	0	0	0	0	0	0	0	.00
Total	11	16	1	3	4	5	40	
Per cent	44	68	4	12	16	20	27	

Distribution of Slipped Tendons with Respect to Position

Right leg	5	2	0	2	3	3	15	37.5
Left leg	0	2	1	1	0	1	5	12.5
Both legs	6	12	0	0	1	1	20	50.0
Males	8	10	1	2	3	1	25	62.5
Females	3	6	0	1	1	4	15	37.5

bring about this condition. Barley and wheat contain these factors in a lesser degree than corn, but more than oats or they may contain larger quantities of the beneficial factors to prevent the condition.

Excessive amounts of magnesium salts introduced into ration No. 6, did not reduce the palatability and the feed intake. From table 5 it is seen that there was no increase in the production of slipped tendons when magnesium was added to this ration. Ration 1, containing 0.2093 per cent magnesium produced more than twice as many slipped tendons as ration 6, containing .9149 per cent magnesium. The chicks that developed leg trouble in lot 6 showed typical symptoms of slipped tendons. This does not agree with the findings of Buckner and his co-workers who claim that a different type of bone trouble develops when magnesium was fed in the presence of tri-calcium phosphate.

The analysis of the blood is given in table 6 and that of the leg bones in table 7.

Table 6. Analysis of the Blood at the Age of Six Weeks

Lot	Grams of Calcium in plasma	Inorganic phosphorus in blood
1 - Normal chicks	10.50	4.31
1 - Deformed chicks	11.25	4.76
6 - Normal chicks	10.75	5.15
6 - Deformed chicks	12.00	5.17

Table 7. Analysis of the Leg Bones at the Age of Six Weeks

Lot	Per cent ash in bone	Per cent calcium in ash	Per cent phosphorus in ash	Per cent magnesium in ash
1	45.25	36.42	8.34	1.038
6	42.93	35.31	8.14	1.549

The serum calcium and the inorganic phosphorus in the blood stream is slightly higher in the deformed chicks than in the normal chicks (table 6). From table 7 there is a reduction in the amount of phosphorus in the bones of the chicks in lot 6. This would suggest that magnesium replaces phosphorus to a certain limit.

The addition of three per cent of magnesium carbonate to the diet produced a clean-cut improvement in the condition of the chicks. This is directly contradictory to the findings of Park (1923) and his associates who were able to produce typical low phosphorus rickets by the addition to the diet of magnesium carbonate in quantities varying between one to four per cent. The findings described in this paper agree with those obtained by Huffman and Robinson (1930) on dairy cows since they found that magnesium added to a ration had no deleterious effects and if it had any effect, it was beneficial rather than harmful. It is evident from table 6 that there was a small reduction in the amount of calcium

and phosphorus in the leg bones of the chicks fed magnesium and it would appear if it agrees with the findings of Buckner, that magnesium carbonate added to the ration disturbs the calcium and phosphorus balance in the leg bones. However, the inorganic phosphorus and serum calcium is a little higher in lot 6, table 6, fed the extra three per cent of magnesium. The difference in the composition of the blood and bones of the chickens in lot 1 and lot 6 is so small that it is apparent that the magnesium furnished by the magnesium carbonate was not antagonistic to calcium and phosphorus utilization.

The average weight, length, diameter, and volume of 25 of the tibia are given in table 8.

Table 8. Comparison of Dimensions of the Tibia of Normal and Chicks with Slipped Tendons (age six weeks)

	Average weight (grams)	Average length (centimeters)	Average diameter (centimeters)	Volume (cubic centimeters)
Straight	5.0751	8.4495	.5622	4.5679
Crooked	6.1937	8.7792	.6109	5.7768

The volume of the bones was determined by water displacement method. From this table it is evident that the deformed bones make a more rapid growth than the normal bones. It would appear that the tendon of the leg does not keep pace

with this rapid bone development which forces it from its normal position.

The sexes were determined on 100 chicks up to ten weeks of age. Of this number, 46 were cockerels and 54 pullets. The sex ratio is therefore 1:1.17. Of this total, 15 pullets and 25 cockerels were affected with slipped tendons during the experiment. These numbers are 27.7 per cent of the pullets and 41.3 per cent of the cockerels. Of the total number of chicks affected with slipped tendons, 62.5 per cent were males and 37.5 per cent were females. These results are in agreement with those of Payne, Hughes, and Leinhardt who found a larger per cent of males than females exhibiting bone malformation. From table 5, it can be seen that this disease affects the right leg more frequently than the left, the ratio being 3:1.

DISCUSSION OF RESULTS

When one reflects on the observed difference in the slipped tendon occurrence on the different grains as given in table 5, it is evident that each grain contains in its make-up some factor or factors to prevent or aggravate this condition. Yellow corn and oats seem to be the two contrasting grains as far as the production of slipped tendons are concerned, because the highest per cent of leg trouble developed in lot 2, fed on a yellow corn basal and the

smallest numbers developed on the basal containing oats. Whether the absence or the presence of these factors is responsible for the condition cannot be stated. It has been shown by King and Hall (1931) that grains do contain factors that interfere with calcium and phosphorus assimilation in chicks. From the results discussed above, it would appear that a similar factor is responsible for the production of slipped tendons.

That low fibre content of the ration is responsible for the production of this pathological condition, as suggested by Hunter and Funk (1930) is not borne out by this experiment. The fibre content of the ration fed to lot 3 was 2.79 per cent or the lowest in the experiment. This ration containing the low fibre content produced only four per cent slipped tendons. In lot 2, which contained 3.11 per cent fibre, 68 per cent of the chicks developed this condition.

The experiments described in this paper afforded no evidence of any detrimental effects from including three per cent of magnesium in this particular ration. On the contrary, the general health of the chicks and the calcium and phosphorus retention were unaffected. This is not according to the findings of Buckner and his co-workers, who found that magnesium added to their ration increased the production of abnormal bones and disturbed the calcium and phosphorus balance for proper bone development. One

possible explanation for the increased leg trouble obtained by the above authors in using magnesium carbonate, may be the very low levels of both calcium and phosphorus used in the particular ration. Lot 1, table 5 shows that 44 per cent of the chicks were affected but when three per cent magnesium carbonate was added to the same ration in lot 6, only 20 per cent were affected. This improvement may have been brought about by the increase in calcium in ration 6, as shown in table 2, rather than the addition of magnesium carbonate. The chicks that were affected in lot 6 did not show any other symptoms than those described in this paper. The digestive tract in its selective absorptive capacity apparently represents an excellent protective mechanism for the exclusion of an excess of magnesium.

That an improper calcium phosphorus ratio is probably one of the causative factors in the production of slipped tendons has been shown by Payne et al (1931) and Titus (1932). From the results obtained by feeding different grains, it appears as if this condition is brought about by the interaction of different factors in the feed. Calcium and phosphorus undoubtedly play a primary role but there is some other factor, probably an anti-calcifying one, that has to act with the calcium and phosphorus before this pathological condition results.

CONCLUSION

1. In this experiment, corn gave the highest per cent of slipped tendons and oats the least. Barley and wheat gave less slipped tendons than corn but more than oats.

2. Three per cent magnesium carbonate added to the ration used in this experiment did not increase the production of slipped tendons and did not interfere with the proper assimilation of calcium and phosphorus in the blood stream.

3. Low fibre content is apparently not responsible for the production of slipped tendons.

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LITERATURE CITED

Buckner, Davis G., Martin, J. H., and Isko, W. M. Jr.
1932. The Effect of Magnesium Carbonate when Added to Diets of Growing Chicks. Poultry Science 11:58-62.

Clark, E. P. and Collip, J. B.
1925. Clark-Collip Modification of the Kramer-Tisdall Method. A Study of the Tisdall Method for the Determination of Blood Serum Calcium with a Suggested Modification. J. Bio. Chem. 63:461-464.

Green, H. R. and Mellanby, Edward.
1928. A Rat Technique for Demonstrating the Interferring Effect of Cereals on Bone Calcification. Biochem. Journ. 22:102-112.

Hunter, J. E. and Funk, E. M.
1930. The Production of Slipped Tendons in Chicks by Experimental Feeding. Poultry Science Proceedings of the 22nd Annual Meeting, Poultry Science Association. (Macdonald College, Ontario, Canada 45-47).

Hunter, J. H., Dutcher, R. A. and Knandel, H. C.
1931. Further Studies on the Production of Experimental Slipped Tendons or Hock Disease in Chicks. Abstracts and Notes of Papers presented at the 23rd Annual Meeting of Poultry Science Association, University of Kentucky.

Hall, G. E. and King, Earl J.
1931. Calcium and Phosphorus Metabolism in the Chicken. Poultry Science 10:259-268.

Huffman, C. F., Robinson, C. S., Winter, O. B. and Larson, R. E.
1930. The Effect of Low Calcium, High Magnesium Diets on Growth and Metabolism of Calves. Journal of Nutrition 2:471-483.

King, Earl J. and Hall, G. Edward
1931. Calcium Phosphorus Metabolism in the Chicken. Influence of Cereals and Vitamins. Poultry Science 10:332-345.

Mirvish, Louis.
1930. The Effect of Cereal Extracts on Blood-calcium. Biochem. Journ. 24:332-338.

Park, Edward H.
1923. The Etiology of Rickets. Physiological Review 3:106-163.

Payne, Loyal F.
1930. Malformed Leg Bones in Young Chickens. Science 71:664.

----------, Hughes, J. S. and Leinhardt, H. F.
1931. The Etiological Factors Involved in the Malformation of Bones in Young Chickens. Poultry Science 11:158-165.

Titus, Harry W.
1932. Perosis or Deforming Leg Weakness in the Chicken. Poultry Science 10:117-125.

Wilgus, H. S. Jr.
1931. The Quantitative Requirement of the Growing Chick for Calcium and Phosphorus. Poultry Science 10:1-117.