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TEXAS AGRICULTURAL EXPERIMENT STATION

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COLLEGE STATION, BRAZOS COUNTY, TEXAS

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DIVISION OF POULTRY HUSBANDRY

Lime and Phosphoric Acid Requirements For Chicks

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**In cooperation with U. S. Department of Agriculture.
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There has been a tendency on the part of poultrymen during the last few years to increase the amount of minerals in their chick rations and it is probable that in many cases excessive amounts of minerals are being fed. Experiments were conducted in 1930 and 1931 to determine the lime and phosphoric acid requirements for growing chicks in order that definite recommendations regarding the use of minerals might be made.

The results of these experiments show that the phosphoric acid requirement for greatest gain with chicks up to eight weeks of age is approximately 1.5 to 2.0 percent of the ration and the lime requirement is 1.5 to 3.0 percent. For chicks up to twelve weeks of age 1.1 to 1.2 percent of phosphoric acid and 1.3 to 1.9 percent of lime are required for greatest gain. These results indicate that the lime requirement for greatest gain is more exacting for the lower levels of phosphoric acid than for the higher levels studied.

The mineral requirements recommended for normal gains in live weight also resulted in satisfactory calcification of the bones.

With these amounts of phosphoric acid and lime for chicks up to twelve weeks old, there were more slipped tendons than with chicks receiving less phosphoric acid and more lime. However, later data at the Texas Station show that the basal ration selected was not satisfactory in that it did not contain the feeds necessary to prevent slipped tendons, and that the substitution of ten pounds of rice bran or twenty pounds of wheat gray shorts, or both, for an equal amount of yellow corn meal in the feed produced greater gains than the original ration. With this modification of the basal ration, and with the mineral levels recommended in these experiments the percentage of slipped tendons was reduced from 33 percent to 2 percent of the chicks. A forthcoming publication will report results of these experiments.

CONTENTS

LIME AND PHOSPHORIC ACID REQUIREMENTS FOR CHICKS

R. M. SHERWOOD

Studies on the calcium and phosphorous requirements for chicks have been conducted by numerous workers. Those working with anti-rachitic rations include Bethke (1, 2), Buckner (3, 4, 5), Halpin (6), Hart (7), Hunter (8), Massengale (9), Mussehl (10, 11), Titus (12, 13), Wilgus (14), and their associates. The Texas Agricultural Experiment Station started work on this subject in 1930. The result of these experiments conducted during the spring of 1930 and the spring of 1931 are reported in this Bulletin.

PLAN OF EXPERIMENTS

These experiments were planned to study further the mineral requirement for growing chicks. Four different series of experiments were conducted. The first consisted of five experiments carrying chicks from the day following hatching to six weeks of age and one experiment carrying the chicks from the day following hatching to eight weeks of age. The other three series of experiments started with chicks the day following hatching and carried them 12 weeks. All chicks used were Single Comb White Leghorns. All were brooded in battery brooders so arranged that all lots in each experiment had as uniform conditions as could be supplied. The chicks were weighed individually at the beginning and the end of the experiments and at two-week intervals during the experiments. They were weighed early in the forenoon after feed had been withheld since six o'clock of the preceding day.

The mixed rations used in the first series were analyzed for lime and

Table 1. Percentage of Lime and Phosphoric Acid in Feeds Used in Series 2, 3, and 4.*

Feeds	CaO	P_2O_5
Yellow corn meal	0.02	0.71
Dried buttermilk	2.20	2.19
Alfalfa leaf meal	2.36	0.53
Steamed bone meal	33.34	25.65
Oyster Shell	53.44	0.14

*Analysis made under the supervision of Dr. Fraps, State Chemist.

phosphoric acid. In the second, third, and fourth series the individual feeds were analyzed for lime and phosphoric acid; the composition of these is reported in Table 1. From these data the composition of each ration was computed.

The feed was weighed to the chicks daily; they were allowed all they would eat. Tap water was kept before them at all times.

At the close of experiment 1 of the second, third, and fourth series the tibia bones of six representative cockerels from each ration were analyzed

in the Division of Chemistry for the percent of ash in the water and fat-free bones.

Throughout this Bulletin the term "units of feed to produce a unit of gain in live weight" includes maintenance requirements as well as feed for actual gains. In the tables which give gains, feed efficiency, analysis of the tibia bones, and the percent of chicks developing slipped tendons, the rations are arranged in the order of the magnitude of the mean gain in live weight. The mean weighted gain in live weight as used in the second, third, and fourth series is one in which the pullets are weighted to cockerel weights.

EXPERIMENTAL RESULTS

Requirements Where Wheat Gray Shorts and Cottonseed Meal Were Fed Without Dried Buttermilk

Six experiments were conducted in this series using rations in which most of the protein was secured from cottonseed meal and wheat gray shorts. The rations used are shown in Table 2. Five experiments were conducted for six weeks and the sixth was continued for eight weeks.

Table 2. Percentage of Ingredients in Chick Rations for Series 1.

	Ration Numbers					
	1	2	3	4	5	6
Yellow corn meal	57	55	58	56	54	54
Wheat gray shorts	20	20	20	20	20	20
Alfalfa leaf meal	5	5	5	5	5	5
Cottonseed meal (43% protein)	13	13	13	13	13	13
Cod liver oil	2	2	2	2	2	2
Bone meal	0	0	1	1	1	3
Oyster shells	2	4	0	2	4	2
Salt	1	1	1	1	1	1

In this series of experiments, with chicks carried up to six and eight weeks of age, those which received the ration containing the largest amount of phosphoric acid, 2.01 percent, made the greatest average gains, as shown in Tables 3 and 4. Those making the next greatest average gains received the medium amount of phosphoric acid, 1.46 to 1.49 percent, while those receiving 1.14 to 1.16 percent of phosphoric acid made the poorest gains. The phosphoric acid requirement for these chicks is higher than for all other lots of chicks in this study. The data from another experiment, as presented in Table 5, show that the phosphoric acid requirement is greater during the first eight weeks than for the period from the ninth to twelfth weeks, inclusive, or for the entire period. Thus the high phosphoric acid requirement in the first series of experiments, 1.46 to 2.01 percent, was probably due partially to the age limits of the chicks and possibly in part to the phosphoric acid carriers in the rations.

The lime requirement is not as definitely shown in these experiments as is the phosphoric acid requirement. Through this limited feeding period with rations containing wheat gray shorts and cottonseed meal an intake of lime between 1.58 percent and 3.09 percent gave most rapid

Table 3. Mean Gain in Grams and Units of Feed Per Unit of Gain for the Various Rations, Series 1, six weeks. Rations arranged in order of magnitude of gains in live weight. (Cottonseed meal and wheat gray shorts.)

	Ration 6	Ration 5	Ration 4	Ration 1	Ration 3	Ration 2
	Oyster Shell 2% Bone Meal 3%	Oyster Shell 4% Bone Meal 1%	Oyster Shell 2% Bone Meal 1%	Oyster Shell 2% Bone Meal 0	Oyster Shell 0 Bone Meal 1%	Oyster Shell 4% Bone Meal 0
Percent CaO in ration	2.29	3.09	1.58	1.23	.63	2.53
Percent P_2O_5 in raton	2.01	1.49	1.46	1.16	1.47	1.14
CaO-P_2O_5 Ratio	1:.88	1:.48	1:.92	1:.94	1:2.33	1:.45
Experiment 1						
Mean gain per chick	205.5± 3.6	190.8± 4.7	178.8± 4.3	186.4± 4.9	185.2± 4.4	163.8± 3.2
Units of feed per unit of gain	3.74	3.99	4.15	4.38	4.14	4.56
Experiment 2						
Mean gain per chick	194.8± 4.1	194.1± 3.8	204.5± 4.3	178.3± 3.6	186.5± 3.8	165.9± 3.7
Units of feed per unit of gain	3.96	4.05	3.75	4.30	4.04	4.78
Experiment 3						
Mean gain per chick	229.6± 4.1	201.8± 4.1	195.1± 4.7	196.0± 4.2	188.8± 3.3	192.6± 4.4
Units of feed per unit of gain	3.67	3.76	3.52	3.67	4.01	3.85
Experiment 4						
Mean gain per chick	213.1± 5.3	221.5± 4.4	217.7± 4.0	208.6± 4.3	182.9± 2.9	202.6± 4.1
Units of feed per unit of gain	3.95	3.52	3.51	3.73	3.60	3.66
Experiment 5						
Mean gain per chick	222.8± 4.1	219.4± 4.3	204.3± 3.9	197.2± 3.6	183.9± 3.3	192.5± 3.0
Units of feed per unit of gain	3.40	3.39	3.18	3.56	3.18	3.38
Mean of Exp. 1-5						
Mean gain per chick	213.2± 2.0	205.5± 2.1	200.1± 2.0	193.3± 1.9	185.5± 1.6	183.5± 1.8
Units of feed per unit of gain	3.71	3.72	3.60	3.90	3.83	3.98

Table 4. Mean Gain in Grams and Units of Feed per Unit of Gain for the Various Rations, Series 1, eight weeks. Rations arranged in order of magnitude of gains in live weight. (Cottonseed meal and wheat gray shorts.)

	Ration 6	Ration 4	Ration 5	Ration 1	Ration 3	Ration 2
	Oyster Shell 2% Bone Meal 3%	Oyster Shell 2% Bone Meal 1%	Oyster Shell 4% Bone Meal 1%	Oyster Shell 2% Bone Meal 0	Oyster Shell 0 Bone Meal 1%	Oyster Shell 4% Bone Meal 0
Percent CaO in ration	2.29	1.58	3.09	1.23	.63	2.53
Percent P_2O_5 in ration	2.01	1.46	1.49	1.16	1.47	1.14
CaO-P_2O_5 Ratio	1:.88	1:.92	1:.48	1:.94	1:2.33	1:.45
Mean gain per chick	345.1± 6.8	326.6± 4.9	315.8± 6.3	306.2± 5.8	299.3± 5.7	269.0± 4.1
Units of feed per unit of gain	3.65	3.75	3.98	3.99	4.12	4.81

Table 5. Comparison of Gains in Live Weight in Grams at Different Periods of Growth on Different Phosphoric Acid Levels. (18 percent dried buttermilk.)

Bone meal in ration	Percent of Phosphoric Acid in Ration	Gain in Live Weight in Grams		
		First eight weeks	Nine to twelve weeks inclusive	One to twelve weeks inclusive
2	1.43	272.3	457.0	729.3
1	1.18	266.4	513.2	779.6
0	.93	203.1	440.6	643.7

gains on levels of 1.46 to 2.01 per cent of phosphoric acid. With phosphoric acid levels of only 1.14 to 1.16 percent the gains were better on a ration containing 1.23 percent of lime than on one containing 2.53 percent of lime. The lime requirement is more exacting on low phosphoric acid levels than on high phosphoric acid levels.

No slipped tendons developed in this series of experiments, and no ash analyses were made of the bones.

Requirements When Twelve Percent of the Ration Consists of Dried Buttermilk

In the second series of experiments, six rations which contained 12 percent of dried buttermilk and different percentages of lime and phosphoric acid were fed to duplicate lots of chicks for twelve weeks; the rations used are given in Table 6. In this series of experiments as well as in the third and fourth series, which were being conducted simultaneously, the results obtained indicated that the basal rations were not satisfactory in that slipped tendons developed even though excessive amounts of phosphoric acid were not fed. It was later brought out by Titus (12) and Titus and Ginn (13) that rice bran protects chicks against slipped tendons when fed rations not containing an excessive amount of phosphoric acid. Other results at the Texas Station to appear in a forthcoming publication show that wheat gray shorts, as well as rice bran, is of value in preventing slipped tendons. Hunter reports that with a basal ration consisting of corn meal 69 percent, wheat middlings 5 percent, alfalfa meal 3 percent, dried milk 15 percent, meat meal 2½ percent, fish meal 2½ percent, bone meal 2 percent, and cod liver oil 1 percent, the percentage of hock trouble in battery brooding was at least 50 percent. When 20 parts of corn meal was replaced by a like amount of oat feed the hock trouble was prevented entirely. The addition of more bone meal to the basal ration caused as much as 90 percent hock trouble, and the elimination of the bone meal from the basal ration prevented hock trouble altogether.

Table 6. Percentage of Ingredients in Chick Rations for Series 2.

	Ration numbers					
	1	2	3	4	5	6
Yellow corn meal	81	80	80	79	78	77
Dried buttermilk	12	12	12	12	12	12
Alfalfa leaf meal	5	5	5	5	5	5
Salt	¾	¾	¾	¾	¾	¾
Fortified cod liver oil	¼	¼	¼	¼	¼	¼
Bone meal	0	0	1	1	2	2
Finely ground oyster shell	1	2	1	2	2	3

It is noted from Table 7 that the rations containing 1.11 to 1.36 percent of phosphoric acid made the greatest gains, while those receiving .86 to .87 percent of phosphoric acid made the poorest gains. In this series chicks receiving a lime intake of 1.27 percent made greatest gains, followed by those receiving 2.13 percent of lime. On all levels of phosphoric acid the lower level of lime gave greatest gains.

The percentage of ash in the water and fat-free tibia bones was lower in the lots receiving the low amount of phosphoric acid than in the other lots, as shown in Table 7. There was no perceptible difference between the percentage of ash in the bones of the lots receiving the medium and the largest amounts of phosphoric acid.

Table 7. Mean Gain in Grams, Units of Feed per Unit of Gain, Percentage of Ash in Tibia Bones, and Percentage of Chicks Which Developed Slipped Tendons, Series 2, twelve weeks. Rations arranged in order of magnitude of gains in live weight. (12 percent dried buttermilk.)

	Ration 3	Ration 5	Ration 4	Ration 6	Ration 1	Ration 2
	Oyster Shell 1% Bone Meal 1%	Oyster Shell 2% Bone Meal 2%	Oyster Shell 2% Bone Meal 1%	Oyster Shell 3% Bone Meal 2%	Oyster Shell 1% Bone Meal 0	Oyster Shell 2% Bone Meal 0
Percent CaO in ration	1.27	2.13	1.80	2.67	.93	1.47
Percent P_2O_5 in ration	1.12	1.36	1.11	1.35	.87	.86
CaO-P_2O_5 Ratio	1:.88	1:.64	1:.62	1:.51	1:.93	1:.59
Experiment 1						
Mean weighted gain per chick	907.8± 19.7	900.8± 15.2	860.3± 20.4	804.9± 21.0	769.3± 21.0	580.8± 16.1
Units of feed per unit of gain	3.35	3.56	3.50	3.68	3.70	4.05
Percentage of ash in water and fat free tibia bones	47.12	48.02	48.23	48.09	46.40	42.80
Percentage of chicks which developed slipped tendons	20.8	8.7	4.2	8.0	12.0	12.0
Experiment 2						
Mean weighted gain per chick	803.1± 20.9	765.3± 22.6	803.3± 19.3	747.2± 13.2	715.0± 10.1	566.8± 11.2
Units of feed per unit of gain	3.23	3.50	3.28	3.92	3.53	3.99
Percentage of chicks which developed slipped tendons	16.7	37.5	4.0	4.8	18.2	4.2
Mean of Exp. 1 & 2						
Mean weighted gain per chick	855.5± 14.4	833.1± 13.6	831.8± 14.1	776.1± 12.4	742.2± 11.7	573.8± 9.8
Units of feed per unit of gain	3.30	3.54	3.40	3.79	3.63	4.02
Percentage of ash in water and fat-free tibia bones of Experiment 1	47.12	48.02	48.23	48.09	46.40	42.80
Percentage of chicks which developed slipped tendons	18.8	23.4	4.1	6.5	14.9	8.2

The percentage of birds developing slipped tendons was greater in the lots receiving the largest amounts of phosphoric acid than in the lots receiving the medium or smaller amounts of phosphoric acid. The percentage of chicks developing slipped tendons was lower in the lots receiving the larger amounts of lime than in those receiving the smaller amounts of lime. Other results to appear in a forthcoming publication show that the slipped tendons on the medium and the low phosphoric acid rations could have been prevented by including rice bran or wheat gray shorts in those rations.

Requirements When Eighteen Percent of the Ration Consists of Dried Buttermilk

In this third series of experiments six rations which contained 18 percent of dried buttermilk and different amounts of lime and phosphoric acid were fed to duplicate lots for 12 weeks. The rations used are shown in Table 8. The difference between the rations in the second and third series is that in the second series twelve percent of each ration consisted

of dried buttermilk, while in the third series eighteen percent of each ration consisted of this feed.

In this third series of experiments, the chicks receiving a medium amount of phosphoric acid, 1.20 percent, made the highest average gains, as shown in Table 9. The second best amount of phosphoric acid is not definite.

Table 8. Percentage of Ingredients in Chick Rations for Series 3.

	Ration numbers					
	1	2	3	4	5	6
Yellow corn meal	75	74	74	73	72	71
Dried buttermilk	18	18	18	18	18	18
Alfalfa leaf meal	5	5	5	5	5	5
Salt	¾	¾	¾	¾	¾	¾
Fortified cod liver oil	¼	¼	¼	¼	¼	¼
Bone meal	0	0	1	1	2	2
Finely ground oyster shell	1	2	1	2	2	3

Table 9. Mean Gain in Grams, Units of Feed per Unit of Gain, Percentage of Ash in Tibia Bones, and Percentage of Chicks Which Developed Slipped Tendons, Series 3, twelve weeks. Rations arranged in order of magnitude of gains in live weight. (18 percent dried buttermilk.)

	Ration 3	Ration 4	Ration 1	Ration 5	Ration 6	Ration 2
	Oyster Shell 1% Bone Meal 1%	Oyster Shell 2% Bone Meal 1%	Oyster Shell 1% Bone Meal 0	Oyster Shell 2% Bone Meal 2%	Oyster Shell 3% Bone Meal 2%	Oyster Shell 2% Bone Meal 0
Percent CaO in ration	1.40	1.93	1.06	2.26	2.80	1.60
Percent P_2O_5 in ration	1.20	1.20	.95	1.45	1.44	.95
CaO-P_2O_5 Ratio	1:.86	1:.62	1:.90	1:.64	1:.52	1:.59
Experiment 1						
Mean weighted gain per chick	979.4± 24.3	955.0± 24.3	888.3± 15.4	880.1± 32.7	834.0± 12.6	792.9± 14.8
Units of feed per unit of gain	3.22	3.16	3.35	3.36	3.71	3.85
Percentage of ash in water and fat-free tibia bones	49.26	48.17	46.44	49.05	48.46	46.31
Percentage of chicks which developed slippel tendons	16.7	4.0	12.5	33.0	25.0	8.3
Experiment 2						
Mean weighted gain per chick	893.8± 22.5	855.3± 18.9	820.1± 16.5	738.8± 21.0	764.8± 16.8	698.1± 20.3
Units of feed per unit of gain	3.10	3.22	3.26	3.23	3.32	3.81
Percentage of chicks which developed slipped tendons	19.0	12.5	27.3	45.5	57.1	8.0
Mean of Exp. 1 & 2						
Mean weighted gain per chick	936.6± 16.6	905.2± 15.4	854.2± 11.3	809.5± 19.4	799.4± 10.5	745.5± 12.6
Units of feed per unit of gain	3.17	3.19	3.31	3.31	3.54	3.83
Percentage of ash in water & fat-free tibia bones of Exp. 1	49.26	48.17	46.44	49.05	48.46	46.31
Percentage of chicks which developed slipped tendons	17.8	8.2	19.6	38.3	40.0	8.2

The rations in the third series contained more phosphoric acid than the corresponding rations in the second series. Possibly the amount of phosphoric acid in the third series, for the rations low in phosphoric acid is nearer correct than in the second series, and the other rations of the third series contain too much phosphoric acid. In other words, the rations in the third series containing the least amount of phosphoric acid may be better than the corresponding rations in the second series, and the rations in the third series containing the larger amounts of

phosphoric acid may not be as good as those in the second series. Probably the optimum amount of phosphoric acid for greatest gains is between 1.1 percent and 1.2 percent.

The lime requirement for greatest gain in this series of experiments is probably near 1.4 percent. In both experiments of the series the ration containing 1.4 percent of lime made greater gains than the ration containing 1.9 percent of lime.

In this series of experiments the calcification of bones was slightly poorer from the birds which received rations containing the least amount of phosphoric acid, .95 percent. There was no difference observed in the calcification of bones between the rations containing 1.20 percent of phosphoric acid and those containing 1.45 percent of phosphoric acid.

The percentage of birds developing slipped tendons was greater in the lots receiving the largest amount of phosphoric acid than in the lots receiving the medium or smaller amounts of phosphoric acid. The percentage of chicks developing slipped tendons was lower in the lots receiving the larger amounts of lime than in those receiving the smaller amounts of lime.

In the third series of experiments three levels of phosphoric acid were studied, each with two levels of lime. In the fourth series the same three levels of phosphoric acid were used as in the third series and each was studied with four comparable lime-phosphoric-acid ratios. These rations contained 18 percent of dried buttermilk as did those studied in the third series of experiments. The rations used in the fourth series, as given in Table 10, were fed to duplicate lots for a period of 12 weeks.

Table 10. Percentage of Ingredients in Chick Rations For Series 4.

	Ration Numbers											
	1	2	3	4	5	6	7	8	9	10	11	12
Yellow corn meal	71.25	70.25	69.25	68.25	72.20	71.38	70.57	69.76	73.15	72.51	71.89	71.26
Dried buttermilk	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
Alfalfa leaf meal	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Cod liver oil	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Salt	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
Bone meal	2.00	2.00	2.00	2.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00
Finely ground oyster shell	1.00	2.00	3.00	4.00	1.05	1.87	2.68	3.49	1.10	1.74	2.36	2.99

The chicks which received the rations containing 1.18 to 1.19 percent of phosphoric acid made the highest gains, as shown in Table 11. Rations which contained 1.42 to 1.44 percent of phosphoric acid made better gains than rations containing .93 to .94 percent of phosphoric acid, except in the case of those containing the least amount of lime. In this

Table 11. Mean Gain in Grams, Units of Feed per Unit of Gain, Percentage of Ash in Tibia Bones, and Percentage of Chicks Which Developed Slipped Tendons, Series 4, twelve weeks. Rations arranged in order of magnitude of gains in live weight. (18 percent dried buttermilk.)

	Ration 6	Ration 5	Ration 7	Ration 1	Ration 9	Ration 3	Ration 8	Ration 4	Ration 2	Ration 10	Ration 11	Ration 12
	Oyster Shell 1.87% Bone Meal 1%	Oyster Shell 1.05% Bone Meal 1%	Oyster Shell 2.68% Bone Meal 1%	Oyster Shell 1% Bone Meal 2%	Oyster Shell 1.10% Bone Meal 0	Oyster Shell 3% Bone Meal 2%	Oyster Shell 3.49% Bone Meal 1%	Oyster Shell 4% Bone Meal 2%	Oyster Shell 2% Bone Meal 2%	Oyster Shell 1.14% Bone Meal 0	Oyster Shell 2.36% Bone Meal 0	Oyster Shell 2.99% Bone Meal 0
Percent CaO in ration	1.86	1.42	2.27	1.73	1.12	2.80	2.73	3.33	2.26	1.46	1.79	2.13
Percent P_2O_5 in ration	1.19	1.19	1.18	1.44	.94	1.43	1.18	1.43	1.44	.94	.93	.93
CaO-P_2O_5 ratio	1:.64	1:.84	1:.52	1:.83	1:.84	1:.51	1:.43	1:.43	1:.64	1:.64	1:.52	1:.44
Experiment 1												
Mean weighted gain per chick	811.6± 25.3	761.4± 18.5	779.0± 16.0	728.1± 19.1	731.7± 19.0	719.9± 22.2	752.1± 15.0	741.4± 15.4	698.5± 16.6	681.9± 9.8	628.8± 11.7	600.2± 14.1
Units of feed per unit of gain	3.17	3.27	3.64	3.39	3.47	3.49	3.74	3.40	3.44	3.76	4.07	4.18
Percentage of ash in water and fat-free tibia bones	47.70	49.08	48.11	47.70	45.63	47.90	47.60	48.67	48.15	47.00	43.72	43.41
Percentage of chicks which developed slipped tendons	16.0	32.0	4.2	16.0	29.1	30.4	8.7	28.0	50.0	12.5	8.0	4.3
Experiment 2												
Mean weighted gain per chick	802.5± 16.1	824.8± 21.4	803.2± 21.8	765.2± 35.3	760.5± 19.0	757.7± 19.5	701.6± 17.0	710.7± 15.8	712.9± 25.1	643.7± 16.7	754.1± 17.1	528.4± 13.0
Units of feed per unit of gain	3.38	3.18	3.26	3.27	3.45	3.25	3.53	3.51	3.36	3.75	4.18	4.40
Percentage of chicks which developed slipped tendons	8.0	16.0	12.0	40.0	12.0	33.3	8.3	16.7	37.5	4.2	4.2	4.2
Mean of Exp. 1 & 2												
Mean weighted gain per chick	807.1± 15.0	793.1± 14.2	791.1± 13.6	746.7± 20.1	746.1± 13.4	738.8± 14.8	726.9± 11.3	726.1± 11.0	705.7± 15.0	662.8± 9.7	601.5± 10.4	564.3± 9.5
Units of feed per unit of gain	3.27	3.22	3.44	3.33	3.46	3.37	3.63	3.45	3.40	3.76	4.12	4.29
Percentage of ash in water and fat-free tibia bones of Exp. 1	47.70	49.08	48.11	47.70	45.63	47.90	47.60	48.67	48.15	47.00	43.72	43.41
Percentage of chicks which developed slipped tendons	12.0	24.0	8.2	28.0	20.4	31.9	8.5	22.5	43.8	8.3	6.1	4.3

case the birds receiving the extreme phosphoric acid levels made the same gains. The poorer growth of the other lots on the low phosphoric acid intake was partially due to the excessive amounts of lime. Here again it is noted that the lime requirement for optimum gains is more exacting on low phosphoric acid intakes than on high phosphoric acid intakes.

Rations containing 1.42 to 2.27 percent of lime made highest gains on phosphoric acid levels of 1.18 percent.

The calcification of bones was poor in the chicks on the rations low in phosphoric acid and high in lime, and satisfactory on the medium and high phosphoric acid rations regardless of the lime intake.

The percentage of chicks which developed slipped tendons was greatest in the lots receiving the rations containing the largest amount of phosphoric acid and lowest in the lots receiving the rations containing the lowest amount of phosphoric acid. The percentage of slipped tendons was lowest in the lots receiving the rations containing the largest amounts of lime.

SUMMARY AND CONCLUSIONS

The phosphoric acid requirement for the first six or eight weeks is higher than for a period of twelve weeks. With the rations studied it is shown that 1.5 to 2.0 percent of phosphoric acid, equivalent to .65 to .87 percent of phosphorus, is required for normal growth and 1.5 to 3.0 percent of lime, equivalent to 1.07 to 2.14 percent of calcium, produces greatest gains.

With chicks grown to 12 weeks of age and receiving rations containing 12 to 18 percent of dried buttermilk, the phosphoric acid requirement for satisfactory gain in weight is between 1.1 and 1.2 percent, which is equivalent to .48 to .53 percent of phosphorus.

The results of feeding twelve weeks are in close agreement with Wilgus (14) but are higher than those found by Bethke (1, 2) and his associates, and Hart (7) and his associates. As pointed out by Wilgus, however, the differences in the rate of gain in weight made by the chicks in the different experiments may explain this difference in the results.

The lime requirement under these conditions is between 1.3 and 1.9 percent, which is equivalent to .93 to 1.36 percent calcium. These requirements are higher than those reported by Wilgus (14), Bethke and associates (1, 2), and Hart and associates (7). It is not known whether or not this higher requirement of lime is the result of the inadequate basal ration. If the basal ration used in these experiments were to be used by poultrymen it would be necessary to recommend larger amounts of lime and less phosphoric acid in order to reduce the amount of slipped tendons. Other results at the Texas Station to appear in a forthcoming publication show that this basal ration may be improved by the substitution of 10 pounds of rice bran and 20 pounds of wheat gray shorts for 30 pounds of the yellow corn meal to the extent that very few

chicks develop slipped tendons with the mineral requirements as recommended above. The phosphoric acid and lime requirements mentioned above for normal gains also result in satisfactory calcification of the bones.

LITERATURE CITED

(1) Bethke, R. M., Kennard, D. C., Kick, C. H.
1929. The Availability of Calcium in Calcium Salts and Minerals for Bone Formation in the Growing Chick. Poultry Science 9: 45-50.

(2) Bethke, R. M., Kennard, D. C., Kick, C. H., and Zinzalian, G.
1929. The Calcium-Phosphorus Relationship in the Nutrition of the Growing Chick. Poultry Science 8: 257-265.

(3) Buckner, G. D. and Martin, J. H.
1929. Calcium and Phosphorus Metabolism of the Growing Chick. Poultry Science 8: 284-289.

(4) Buckner, G. D., Martin, J. H., and Insko, W. M., Jr.
1929. The Relative Utilization of Certain Calcium Compounds by the Growing Chick. Poultry Science 9: 1-5.

(5) Buckner, G. D., Martin, J. H., and Insko, W. M., Jr.
1930. The Calcium and Phosphorus Requirement of the Growing Chick. Poultry Science 9: 235-238.

(6) Halpin, J. G. and Lamb, A. R.
1932. The Effect of Ground Phosphate Rock Fed at Various Levels on the Growth of Chicks and on Egg Production. Poultry Science 11: 5-14.

(7) Hart, E. V., Scott, H. T., Kline, O. L., and Halpin, J. G.
1930. The Calcium-Phosphorus Ratio in the Nutrition of Growing Chicks. Poultry Science 9: 296-306.

(8) Hunter, J. E.
1932. Special Correspondence.

(9) Massengale, O. M. and Platt, C. S.
1930. The Effect of Calcium from Different Sources on the Growth and Egg Production of Poultry. Poultry Science 9: 240-246.

(10) Mussehl, F. E., Ackerson, C. W., and Blish, M.J.
1927. The Mineral Metabolism of the Growing Chick. Poultry Science 6: 239-242.

(11) Mussehl, F. E., Hill, R. F., Blish, M. J., and Ackerson, C. W.
1930. The Utilization of Calcium by the Growing Chick. Jour. Agr. Research 40: 191-199.

(12) Titus, H. W.
1932. Perosis, or Deforming Leg Weakness, in the Chicken. Poultry Science 11: 117-126.

(13) Titus, H. W. and Ginn, W. M.
1931. Rice Bran, a Preventative of Perosis, Deforming Leg Weakness, in Chickens. Science 74: 249-250.

(14) Wilgus, W. S., Jr.
1932. The Quantitive Requirement of the Growing Chick for Calcium and Phosphorus. Poultry Science 10: 107-118.