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PERFORMANCE OF MEAT-STRAIN CHICKS FED DIETS SUPPLEMENTED WITH VARIOUS LEVELS AND SOURCES OF CALCIUM AND PHOSPHORUS

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by

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INTRODUCTION

Raising poultry has become an industry on a commercial basis. The use of various minerals in poultry feeds has been known for some time, particularly calcium and phosphorus because of their important role in nutrition. So, in preparing feeds for poultry, special care is given to calcium and phosphorus levels in the ration according to the purpose for which the birds are fed. Calcium and phosphorus are available in both organic and inorganic form. If the contents of these two minerals in the poultry feeds are too low, or too high, the result will be a deficiency disease or malnutrition.

Many experiments have been conducted from time to time by different workers, using various levels and sources of calcium and phosphorus, for better growth in meat-strain birds, and for efficient egg production in laying birds. The results of experiments conducted in the past have not been in agreement, but they have been either controversial or inconsistent. Therefore, further studies are necessary to investigate, under modern trends, more about the use of calcium and phosphorus in the broiler rations.

In this study, the effect of diets supplemented with various levels and sources of calcium and phosphorus on the performance of broiler-strain chicks was investigated. Two experiments were conducted, in order to test the performance of broiler-strain chicks fed different sources and levels of calcium and phosphorus.

The following were determined: 1) Comparison of single source and combination of sources of calcium and phosphorus;

2) effect of calcium and phosphorus on growth of broiler-strain chicks; 3) pounds of feed required per pound of gain (feed conversion) as affected by calcium and phosphorus; 4) superiority of sources and levels of calcium and phosphorus; and 5) mortality and abnormalities with the use of high or low levels of calcium and phosphorus.

REVIEW OF LITERATURE

The calcium and phosphorus requirements of growing chicks and other animals have been a subject of much research. Mussehl, Blish, and Ackerson (1927) stated that elements concerned in the mineral metabolism may relate to the body and influence its functions in at least three ways:

1. As constituents of the bone, giving rigidity and stability to the skeletal tissues.

2. As essential elements of the organic compounds which are the chief dry matter constituents of the muscle tissue, blood cells, etc.

3. As soluble salts held in solution in the body fluids in which they serve as "buffers" or regulators of acidity, alkalinity, etc., this being of the utmost importance in maintaining the complex constituents of the body fluids in the optimum physico-chemical state. Just what happens as a result of an excess of calcium and phosphorus in the mineral organism is not yet fully understood. Excess phosphorus is generally assumed to be eliminated in the form of phosphates through the kidneys, whereas the usual assumption is that excess calcium is eliminated through the digestive system.

Mussehl, Blish, and Ackerson (1927) also reported that addition of either four or eight parts of calcium carbonate or eight parts of raw bone meal to an otherwise complete ration containing 20 percent meat and bone meal, resulted in poorer growth and increased mortality. It has been the experience and practical observation that the inclusion or addition of what might be termed large amounts of calcium or phosphorus in the ration of the growing chick generally resulted in depressed growth and increased mortality, with a greater tendency for the development of rachitic symptoms.

McCollum and associates (1920-21), as well as Sherman and Pappenheimer (1920-21), have pointed out the three dietary components: calcium, phosphorus, and vitamin D, or its equivalent, are especially concerned in normal bone formation. These investigators further pointed out the relative proportions of these three factors, particularly the quantitative relations, between calcium and phosphorus in the food supply are, within certain limits of concentration, of great significance in determining whether an animal, such as the rat, will develop bones which are normal or pathological.

Bethke _et al_. (1929) stated the optimum, or near optimum, ratio of calcium to phosphorus for the growing chick lies between 3:1 and 4:1. The requirements for the antirachitic factor are not a minimum at this relationship. Within certain limits of concentration, the ratio of calcium to phosphorus is of greater significance in calcification and growth than the amounts of these elements in the ration. Further, they stated that addition of vitamin D, or its equivalent, to the ration, or environment of a chick makes possible a greater variation in the Ca:P ratio and concentration without seriously interfering with growth and normal bone formation.

Davis et al. (1930) conducted an experiment on calcium and phosphorus requirements of the growing chick, and concluded that raw bone meal was equally good, if not better, than raw bone meal and limestone when fed in the quantities indicated, as a supplement to a yellow corn meal, wheat middlings, and skim-milk ration for growing White Leghorn chicks.

Hart et al. (1930) also conducted an experiment on the calcium-phosphorus ratio in the nutrition of growing chicks, and their work showed that 1) Optimum Ca-P ratio for chicks in respect to both growth and calcification of skeleton, lies between 1:0.50 and 1:0.25. This is in the presence of vitamin D, and with the percent of calcium in the ration varying from 0.61 to 1.13 percent and with 0.30 percent of phosphorus. 2) With a minimum amount of vitamin D supplied by the basal ration, the best calcification and growth was obtained at a Ca-P ratio of 1:0.26 to 1:0.30, with 2.49 to 2.71 percent of calcium and 0.66 to 0.83 percent of phosphorus in the ration.

With a minimum supply of vitamin D, the levels of calcium and phosphorus in the ration must be higher than in its presence, if growth and calcification are to approach that secured with a generous supply of vitamin D.

Calcium-phosphorus ratio in chick nutrition has been investigated by Bethke et al. (1929) with the conclusion that the requirement for vitamin D is at a minimum when the Ca-P ratio lies between 1:0.33 and 1:0.25; further, that the addition of vitamin D makes possible a greater variation in the Ca-P ratio. Optimum ratio for the growing chick is quite different from that proposed for the rat, namely, 1:0.65.

Massengale and Platt (1930) studied the effect of calcium from different sources on growth and egg production of poultry, and observed that:

1) Birds receiving C.P. $CaCO_3$ as a source of calcium in a diet did not grow as well or produce as many eggs as birds receiving $CaCO_3$ in the form of oyster shell or limestone.

2) From the data presented, it seems that $CaCO_3$ in the form of oyster shell or limestone is utilized better than precipitated $Ca_3(PO_4)_2$. On the other hand, evidence points to the fact the latter can be utilized by the birds better than C.P. $CaCO_3$.

3) On the basal diet used, the birds developed leg weakness; however, with the addition of calcium in the form of limestone, this disturbance disappeared.

4) The evidence presented confirms the work of other investigators that a calcium supplement is necessary for poultry rations.

Wilgus (1931), experimenting with the quantitative requirements of growing chicks for calcium and phosphorus, observed that:

1) When an optimum supply of the antirachitic factor was provided, the calcium requirement of the growing chick approached a minimum level of 0.66 percent; however, practical mashes with common protein supplements generally contained about 1.2 percent of calcium.

2) Under similar conditions, the requirement of chicks for phosphorus was 0.5 percent of the ration or less. Practical rations with common protein supplements, however, almost invariably contained a larger quantity of phosphorus than this.

3) The calcium-phosphorus ratio may vary between 1.0:1 and 2.2:1 with normal results. A ratio of 2.5:1 appears border-line while a ratio of 3.3:1 is disastrous.

Musseh1 and Ackerson (1935) experimented with calcium and phosphorus requirements of growing turkeys and observed that some factor other than the calcium-phosphorus ratio has a physiological effect on calcium and phosphorus assimilation. The calcium and phosphorus requirements probably vary according to the growth rate which is influenced by the quantity and quality of protein as well as by vitamin factors other than D.

Carver, Evans, and McGinnis (1946) conducted an experiment on calcium, phosphorus, and vitamin D interrelationships in the nutrition of the growing chick, and the results showed that amounts of calcium and phosphorus, as well as their ratios, are of importance if optimum growth and bone ash are to be obtained. When no supplementary vitamin D was added to the diets, a progressive improvement in growth and percentage of bone ash was obtained by increasing the phosphorus content of the diet from 0.5 to 0.8 percent at Ca:P ratios of 2:1 and 3:1. At all levels of phosphorus, a 4:1 Ca:P ratio caused a depression in both growth and percentage of bone ash.

Bethke *et al*. (1929) and Hart *et al*. (1930) showed the optimum Ca:P ratio to be between 3:1 and 4:1 when low levels of vitamin D were fed. When larger amounts of vitamin D were added to the diet, Hart et al. (1930) observed less difference between various Ca:P ratios, and found that lower levels of calcium and phosphorus could be used. Nowotarski and Bird (1943) found that smaller amounts of vitamin D were required when the calcium and the phosphorus levels in the diet were increased.

Lindblad et al. (1952) studied the effect of aureomycin on calcium and phosphorus requirements of chicks. The chicks were fed diets containing all combinations of 0.4, 1.0, and 1.8 percent calcium and 0.2, 0.4, and 0.6 percent inorganic phosphorus, in the presence and absence of aureomycin. In the absence of aureomycin, optimum growth and feed efficiency were obtained with the diet containing 1.0 percent calcium and 0.6 percent inorganic phosphorus, while in the presence of aureomycin, 1.0 percent calcium and 0.4 percent inorganic phosphorus proved adequate.

The phosphorus requirements for growing chickens have been studied chiefly by means of rations containing considerable amounts of cereal products. This has complicated the estimation of the requirement for phosphorus by the growing chicken due to the poor availability of phytin phosphorus, as shown by Lowe, Steenbock, and Krieger (1939) and Heuser et al. (1943). Mitchell and McClure (1937) and Mitchell (1947) have assessed the phosphorus requirements of poultry, and have shown that the requirements should decrease with increasing body size. In considering the comparative nutritional requirements of farm animals, Guilbert and Loosli (1951) observed the recommended allowances of phosphorus for growing chickens remain constant with advancing age;

whereas, other farm animals showed a decreased need for this element. They explained part of the difference in total requirement by the fact that phytin phosphorus, found in all practical rations, is less available than inorganic phosphorus to the chicken.

O'Rourke, Phillips, and Cravens (1952) experimented with phosphorus requirements of growing chickens as related to age, and concluded the phosphorus required by the chick decreases with increasing age. The minimum levels of phosphorus required were 0.43 percent to three weeks, 0.35 percent from two to five weeks, and 0.27 percent from four to ten weeks.

Almquist (1954) studied the phosphorus requirement of young chicks and poults, and stated the readily-available phosphorus requirement of the young poult was approximately 0.6 percent. Singsen (1948) concluded from his work that the available phosphorus requirement for satisfactory calcification appeared to lie between 0.38 and 0.47 percent for the four-week-old chick, and between 0.39 and 0.44 percent for the eight-week-old chick. Gillis, Norris, and Heuser (1949) stated the minimum requirements for growth and calcification were somewhat more than the suggested adequate level of 0.4 percent inorganic phosphorus. McGinnis, Norris, and Heuser (1944) showed that chick rations containing 0.58 percent phosphorus from vegetable sources could not support maximal calcification with any levels of vitamin D up to as much as 320 units. The data on bone ash values showed a linear relation to log vitamin D intake. This suggests there was a constant suboptimal level of available phosphorus, the utilization of which was increased with vitamin D. When all phosphorus was in the inorganic form, as little as 20 units of vitamin D was sufficient. Pepper, Slinger, and Motzok (1952), using practical diets, found that 0.41 percent calculated inorganic phosphorus was not sufficient for maximal calcification in chicks at five weeks, when growth was stimulated by the presence of aureomycin.

Studies by Miller and Joukovsky (1953), of various phosphate supplements for chicks, were made with a basal diet containing 0.42 percent phosphorus of which 0.10 percent probably was available. At five weeks of age, chicks fed phosphate supplements which provided 0.2 percent phosphorus (0.3% total available phosphorus) did not promote maximum growth or calcification; whereas, 0.4 percent added phosphorus (0.5% total available phosphorus) appeared to be sufficient. The data of Grau and Zweigart (1953), calculated to inorganic phosphorus levels, indicated that maximum tibia bone ash of chicks was obtained at 28 days of age with an intake of not more than 0.45 percent. Fisher, Singsen, and Matterson (1953) reported that a high- and a low-energy diet for chicks required 0.51 and 0.58 percent total phosphorus, respectively, for maximal calcification at four weeks. The diets contained a very small amount of phytin phosphorus, possibly 0.08 percent. If this is subtracted from the estimated total requirements, the available phosphorus appears to be 0.43 to 0.50 percent.

Lindblad, Slinger, and Motzok (1954) observed that female chicks showed maximal gain to six weeks with 0.4 percent inorganic phosphorus as compared to 0.6 percent in association with 1.0 percent calcium in a practical diet. With 1.8 percent calcium, the 0.6 percent level of inorganic phosphorus was best. In the case of male chicks, the 0.6 percent level of inorganic phosphorus was superior to 0.4 percent when associated with 1.0 or 1.4 percent calcium. It is evident, therefore, that in feeding a flock of mixed sexes, somewhat more than 0.4 percent inorganic phosphorus would be desirable.

Pepper, Slinger, and Motzok (1955) studied the effect of animal fat on the calcium and phosphorus requirements of chicks. In the first experiment, duplicate groups of Columbian Rock male chicks were fed a practical broiler starting diet containing 0, 5, and 10 percent stabilized animal fat. The protein level was maintained constant at 23.7 percent (N x 6.25) and each level of fat was fed in the presence of 1.0 and 1.2 percent calcium with a constant level of 0.45 percent inorganic phosphorus. This plan was repeated with diets containing 0.55 percent inorganic phosphorus. The results indicated that, in the absence of added fat, 1.0 percent calcium was just as satisfactory as 1.2 percent. In the presence of added fat, increasing the level of calcium resulted in improved feed efficiency.

O'Rourke, Phillips, and Cravens (1955) stated the levels of phosphorus required were at least 0.73 percent to three weeks, 0.60 percent from four to ten weeks, and not more than 0.42 percent from ten weeks to sexual maturity. In another experiment, they found the phosphorus requirement for the one-day to eight-week-old cockerels was 0.75 percent, while the requirements of the pullets was 0.60 percent. The requirement of the pullets decreased to 0.50 percent from eight weeks until sexual maturity.

Simco and Stephenson (1960) reestimated the calcium and phosphorus requirements for chicks. It shows from their data that the calcium requirement of the chick for optimum growth, feed conversion, and maximum bone ash development was not over 0.6 percent of the diet. The phosphorus requirement, likewise, did not exceed 0.6 percent of the formula. In all cases, growth obtained with these levels was equal or superior to that obtained with diets which contained 1 percent calcium and 0.6 percent phosphorus. When fed in the presence of an antibiotic, the 0.6 percent level of calcium often produced a significant improvement in growth when compared to weight gains of birds receiving the antibiotic plus calcium at the 1 percent level.

Formica et al. (1961) experimented with calcium and phosphorus requirements of growing turkeys and chickens and observed that broiler-strain chicks one day to four weeks of age grew well and had normally calcified bones on diets which contained 0.6 percent calcium and 0.6 percent total phosphorus. When dietary calcium and phosphorus were reduced below these levels, growth was retarded and calcification was reduced. Growth and feed conversion were essentially constant at dietary calcium and phosphorus levels between these minimums and the N.R.C. requirement figures. Under the conditions of these tests, 0.81 percent calcium and 0.65 percent phosphorus fully met the requirements of day-old poults. Similarly, 0.6 percent calcium and 0.6 percent phosphorus were adequate for day-old chicks.

Simco and Stephenson (1961) obtained optimum growth, efficiency of feed utilization, and maximum toe ash values with levels of calcium as low as 0.5 percent and a phosphorus level of 0.5 percent. When a lower level (0.42%) of phosphorus was fed, the feeding of excessive calcium (1.0%) appeared to magnify the growth depression.

Formica et al. (1962) experimented with calcium and phosphorus requirements of growing turkeys and chickens, and their data indicated that 0.6 percent calcium and 0.6 percent phosphorus were adequate for day-old broiler-strain chicks.

Lillie et al. (1961) studied the effect of calcium and phosphorus levels on growth rate and bone calcification of broilers and concluded the calcium and phosphorus levels used had little or no effect on the bone ash or the calcium content of eight-week-old chickens.

Stephenson, Rinehart, and Bragg (1962) studied the calcium-phosphorus requirement for day-old poults and observed the minimum calculated levels, above which no significant improvement in growth or toe ash was noted, were 0.61 percent calcium and 0.61 percent phosphorus. An improvement in feed conversion was, however, obtained by increasing the phosphorus level to 0.70 percent (0.45% inorganic). Further increases in the phosphorus levels were not beneficial.

Edwards et al. (1963) reported the level of calcium in the ration of broilers that gave maximum rate of growth to four weeks of age was 0.99 and 1.07 percent. Vogt and Penner (1963) recommended for broiler rations, a level of 0.8 percent calcium and 0.7 percent phosphorus. Anonymous (1963) stated the phosphorus level of broiler-finisher rations can be reduced to 0.5 percent if the ratio of Ca:P is no wider than 1:1 or 1.5:1. Peeler (1963), in discussing the mineral requirements of broilers, stated that estimates for calcium requirement by various workers varied from 0.6 to 1.0 percent. However, in a majority of cases, optimum results were obtained with calcium levels below the N.R.C. recommendation of 1.0 percent. Under practical conditions, broiler rations should contain a minimum of 0.45 percent available phosphorus (which means roughly, 0.65-0.75% total phosphorus) and about 0.8 percent calcium. Waldroup, Ammerman, and Harms (1963a) conducted four trials to determine the calcium and phosphorus requirements of broilers from four to eight weeks of age, and the results of these trials indicated that 0.5 percent total phosphorus, using highly available sources, was adequate for broilers during the period when the diet contained 0.6 percent calcium. However, better growth was obtained with a 0.6 percent total phosphorus when higher levels of calcium were used. A calcium level of 0.6 percent was adequate with 0.5 percent phosphorus, with 0.9 percent calcium giving better results with higher levels of phosphorus. Waldroup, Ammerman, and Harms (1963) confirmed with their other experiments that sex interactions indicate the mineral requirements of females are less than those of males.

MATERIALS AND METHODS

Two experiments were conducted at Kansas State University in the Leland Call Hall poultry nutrition laboratory. A total of 768 birds were used in the two experiments. Experiment I, consisting of 192 birds fed different levels and sources of calcium

(Table 1), was initiated on March 24, 1964 and ran until May 19, 1964. The second experiment, consisting of 576 birds, ran from June 1, 1964 to July 27, 1964. In this experiment, 384 birds were fed different levels and sources of phosphorus (Table 2), and 192 birds were used for part two of Experiment I. Meat-strain (White Rock) chicks were used in the two experiments.

Day-old chicks were randomized into 48 lots of 16 each. The chicks were individually wing banded and weighed. Electrically heated starting batteries were used to rear the birds to four weeks of age, at which time they were transferred to nonheated growing batteries, which were kept in rooms with a room temperature of 70° F.

The chicks (Lots) were placed in the starting batteries at random. The temperature of the batteries was controlled thermostatically at 94° F. in the beginning and to two weeks of age, then gradually reduced to 70° F. While daily feeding and watering, both morning and evening, each lot was checked for mortality. Dead chicks were examined, the sex noted, and the wing band recorded.

Grain was ground and all ingredients were mixed in the feed building located at the University Poultry Farm. A large platform balance was used to weigh all ingredients measured in pounds; whereas, gram levels were weighed on a computogram balance. Two separate premixes were made, one for minerals and the other for vitamins and feed additives. The ingredients were added to approximately 15 pounds of ground yellow corn and mixed for five minutes in a small electrically operated mixer. The calcium and

Table 1. Levels of calcium and feed composition, Experiments I and II.

Ingredients used	Ground limestone		Ground oyster shell		½ ground limestone and ½ ground oyster shell	
	1.0% Ca.	0.8% Ca.	1.0% Ca.	0.8% Ca.	1.0% Ca.	0.8% Ca.
	Pounds					
Corn, ground yellow	30.0	30.0	30.0	30.0	30.0	30.0
Sorghum grain, ground	28.5	29.0	28.5	29.0	28.5	29.0
Alfalfa meal, dehydrated, 17% protein	2.0	2.0	2.0	2.0	2.0	2.0
Soybean oil meal, 44% protein	33.8	33.8	33.8	33.8	33.8	33.8
Distiller's solubles	2.4	2.4	2.4	2.4	2.4	2.4
Salt	0.5	0.5	0.5	0.5	0.5	0.5
Limestone, ground	1.3	0.8	--	--	0.65	0.4
Oyster shell, ground	--	--	1.3	0.8	0.65	0.4
Dicalcium phosphate	1.5	1.5	1.5	1.5	1.5	1.5
Total	100.0	100.0	100.0	100.0	100.00	100.0
Added per 100 pounds	Grams					
Trace mineral mix[1]	23	23	23	23	23	23
Vitamin A (10,000 USP units/g)	10	10	10	10	10	10
Vitamin D_3 (15,000 ICU/g)	5	5	5	5	5	5
B complex[2]	46	46	46	46	46	46
Vitamin B_{12} (20 mg/lb)	10	10	10	10	10	10
Choline chloride, 25% mix	40	40	40	40	40	40
Methionine	46	46	46	46	46	46
Coccidiostat (Amprol plus)	23	23	23	23	23	23

[1] Trace mineral premix, supplying by %: Mn, 10; Fe, 10; Ca., max., 14, min., 12; Cu, 1; Zn, 5; I_2, 0.3; Co, 0.1.

[2] B-complex vitamin mix, supplying in mg/lb.: riboflavin, 8,000; pantothenic acid, 14,720; niacin, 24,000; choline chloride, 80,000.

Table 2. Levels of phosphorus and feed composition, Experiments I and II.

Ingredients used	Steamed bonemeal		Dicalcium phosphate		½ steamed bone meal and ½ dicalcium phosphate	
	0.6% P	0.45% P	0.6% P	0.45% P	0.6% P	0.45% P
	Pounds					
Corn, ground, yellow	29.0	29.6	29.2	29.7	29.0	29.6
Sorghum grain, ground	29.0	29.0	29.0	29.0	29.0	29.0
Alfalfa meal, dehydrated, 17% protein	2.0	2.0	2.0	2.0	2.0	2.0
Soybean oil meal, 44% protein	34.0	34.0	34.0	34.0	34.0	34.0
Distiller's solubles	2.5	2.5	2.5	2.5	2.5	2.5
Salt	0.5	0.5	0.5	0.5	0.5	0.5
Limestone, ground	1.4	2.0	1.8	2.0	1.7	2.0
Steamed bone meal	1.6	0.4	--	--	0.8	0.2
Dicalcium phosphate	--	--	1.0	0.3	0.5	0.2
Total	100.0	100.0	100.0	100.0	100.0	100.0
Added per 100 pounds	Grams					
Trace mineral mix[1]	23	23	23	23	23	23
Vitamin A (10,000 USP units/g)	10	10	10	10	10	10
Vitamin D_3 (15,000 ICU/g)	5	5	5	5	5	5
B complex[2]	46	46	46	46	46	46
Vitamin B_{12} (20 mg/lb)	10	10	10	10	10	10
Choline chloride, 25% mix	40	40	40	40	40	40
Methionine	46	46	46	46	46	46
Coccidiostat (Amprol plus)	23	23	23	23	23	23

[1] Trace mineral premix, supplying by %: Mn, 10; Fe, 10; Ca., max. 14, min. 12; Cu, 1; Zn, 5; I_2, 0.3; Co, 0.1.

[2] B-complex vitamin mix, supplying in mg/lb.: riboflavin, 8,000; pantothenic acid, 14,720; niacin, 24,000; choline chloride, 80,000.

phosphorus, both organic and inorganic, were added to the rest of the 15 pounds of ground yellow corn and mixed for five minutes in the same electric mixer. These two mixtures were then blended into approximately 70 pounds of the rest of the ingredients used for the purpose to form a total of 100 pounds of feed and again mixed for five minutes in a horizontal paddle mixer. Thus, each time different levels and sources of calcium and phosphorus were used in preparing the feed, varying quantities of ingredients were used to make 100 pounds of feed. All ingredients used, in varying quantities with different sources and levels of calcium and phosphorus, are shown in Tables 1 and 2. The feed was mixed as needed. All feed not immediately used was placed in burlap bags, properly labeled and stored in the feed-mixing building. Feed was added to the diet storage cans as needed, and the amount was recorded. The storage cans were labeled with the respective lot numbers, and placed in the nutrition laboratory.

On the first day, the feed was spread on egg flats and the chicks were taught to eat by dipping their beaks in water and then in the feed. The egg flats were removed after four days, and the chicks began to eat from the battery feed troughs. The feeding troughs were half filled to avoid unnecessary wastage of feed. Each time fresh feed was put in the feed trough, the old feed left in the trough was stirred up. The chicks were fed twice daily, 7:00 to 8:00 a.m. and 4:00 to 5:00 p.m.

During the first week, fresh clean water was provided in water jars in addition to water troughs. The water troughs were cleaned daily in the morning, and fresh water was added every time. The droppings also were removed from time to time, and healthy, clean conditions were maintained in the batteries. The birds were fed ad libitum and fresh water was provided at all times.

At the end of each two-week period, the feed remaining in the feed troughs was returned to its respective feed storage cans and weighed. The weights were recorded. This amount was subtracted from the total feed weighed out, and the pounds of feed consumed per lot was calculated. The chicks were weighed at the same time, and the individual weights of each chick were recorded on prescribed sheets. The chicks were sexed as male and female at eight weeks. The chicks were weighed four times during the entire experiment at two, four, six, and eight weeks of age, and also the feed cans were weighed and the pounds of feed consumed per lot during each interval of two weeks were calculated.

At the end of the experiments, weights were adjusted for sex. All female weights were adjusted to male weights. These adjusted male and female weights were totaled and an overall average for each period was determined. The average adjusted weights of males and females at two, four, six, and eight weeks of age for all lots are listed in Tables 3 and 5. The average gain in body weights of males and females were calculated. The feed utilization also was determined.

RESULTS AND DISCUSSION

An analysis of variance of the growth data and feed conversion at 1.0 percent calcium level, using ground limestone as a

Table 3. Growth data for gain and feed conversion, calcium Experiments I and II.

Calcium phase	1.0% calcium		0.8% calcium		1.0% calcium	0.8% calcium
	Ground limestone	Ground oyster shell	Ground limestone	Ground oyster shell	½ ground limestone and ½ ground oyster shell	½ ground limestone and ½ ground oyster shell
	Grams					
Experiment I	1333.19	1481.38	1389.93	1367.23	1428.71	1393.63
	1417.01	1326.40	1323.75	1374.19	1366.69	1401.63
Experiment II	1358.56	1390.44	1287.00	1363.88	1298.06	1316.63
	1353.19	1340.56	1384.80	1350.31	1393.31	1405.63
	Feed conversion					
Experiment I	2.55	2.35	2.46	2.55	2.44	2.53
	2.57	2.60	2.40	2.41	2.45	2.38
Experiment II	2.94	2.37	2.45	2.40	2.45	2.26
	2.48	2.43	2.52	2.40	2.40	2.74

source, and 1.0 percent calcium level, using ground oyster shell as a source, revealed nonsignificant differences (Table 4). However, better growth and feed conversion were obtained at the 1.0 percent calcium level, using ground oyster shell, than at 1.0 percent ground limestone (Table 3) although the results were statistically nonsignificant (Table 4). When the two sources were combined and fed as one half ground limestone and one half ground oyster shell at the 1.0 percent calcium level, the data did not reveal any significant difference on growth and/or feed conversion (Table 4) as compared with the single sources of either ground limestone or ground oyster shell at the 1.0 percent calcium level. Again, the single source as ground oyster shell gave better growth than the combined sources (Table 3). Thus, it is evident that at the 1.0 percent calcium level there was no significant difference in using two sources of calcium or by using a single source of calcium.

These results are in agreement with the work of Lindblad et al. (1952) who obtained optimum growth and feed efficiency with 1.0 percent calcium and 0.6 percent inorganic phosphorus.

Similarly, an analysis of variance of the growth data and feed conversion at the 0.8 percent calcium level, using ground limestone as a source and the 0.8 percent calcium level, using ground oyster shell as a source, revealed nonsignificant differences (Table 4). Better growth and feed utilization were obtained at the 0.8 percent calcium level, using ground oyster shell, than 0.8 percent ground limestone although the results were statistically nonsignificant (Tables 3 and 4). Feeding one half

Table 4. Analysis of variance for gain in body weight and feed conversion. Pooled data for calcium Experiments I and II.

Source of variation	DF	Ss	Ms	F-ratio
Treatments (6 diets)	5	3642.37	728.47	0.38 ns
1.0% vs 0.8% (mixed)	1	117.98	117.98	0.06 ns
Mixed vs unmixed	1	579.25	579.25	0.30 ns
1.0% vs 0.8% (unmixed)	1	1592.61	1592.61	0.83 ns
Limestone vs oyster shell	1	1349.72	1329.72	0.70 ns
Interaction	1		2.81	0.00 (15) ns
Replicates	3	12063.87	4021.29	2.10 ns
Error	15	28761.40	1917.43	
Total	23	44467.64		
N = 24 (treatments or lots)				
			Feed conversion	
Treatments	5	0.117250	0.023450	1.12 ns
1.0% vs 0.8% (mixed)	1		0.003916	0.19 ns
Mixed vs unmixed	1		0.006936	0.33 ns
1.0% vs 0.8% (unmixed)	1		0.029327	1.40 ns
Limestone vs oyster shell	1		0.045476	2.18 ns
Interaction	1		0.031595	1.51 ns
Replicates	3	0.001925	0.000642	0.03 ns
Error	15	0.313491	0.020899	
Total	23	0.432666		
N = 24				

ns Nonsignificant.

ground limestone and one half ground oyster shell at an 0.8 percent calcium level did not reveal any significant difference on growth or feed conversion, when compared with a single source of ground limestone or oyster shell at the 0.8 percent calcium level (Table 3). Although statistically nonsignificant, the combined or mixed sources of calcium at 0.8 percent gave better growth as compared to a single source at this 0.8 percent calcium level; however, feed conversion was not better (Tables 3 and 4).

An analysis of variance of growth data and feed conversion for the 1.0 percent calcium level of ground limestone or ground oyster shell did not reveal any significant difference when compared with the 0.8 percent calcium level, using ground limestone or ground oyster shell (Table 4). It was observed that ground oyster shell at the 1.0 percent calcium level gave better growth and feed utilization than ground limestone or ground oyster shell at the 0.8 percent calcium level (Table 3).

These results were confirmed by the work of Formica et al. (1962) who stated the calcium requirements of poults during the first eight weeks were not greater than 1.0 percent of the diet.

When the 1.0 percent calcium level, using one half ground limestone and one half ground oyster shell, was compared with the 0.8 percent calcium level, using either ground limestone or ground oyster shell as a source, did not show any significant difference on growth or feed conversion (Table 4). Slightly better growth was observed (Table 3).

When the 1.0 percent calcium level, using one half ground limestone and one half ground oyster shell, was compared with the 0.8 percent calcium level, using one half ground limestone and one half ground oyster shell, nonsignificant differences on growth and feed conversion were obtained (Table 4). However, both the mixed sources of calcium at the 0.8 percent level gave better growth, but not feed utilization as compared to the mixed sources of calcium at the 1.0 percent level (Table 3).

Table 5. Growth data for gain and feed conversion, phosphorus Experiments I and II.

Phosphorus phase	0.6% phosphorus		0.45% phosphorus		0.6% phosphorus	0.45% phosphorus
	Dicalcium phosphate	Steamed bone meal	Dicalcium phosphate	Steamed bone meal	½ dicalcium phosphate and ½ steamed bone meal	½ dicalcium phosphate and ½ steamed bone meal
			Grams			
Experiment I	1299.25	1021.21	1027.46	1039.46	1312.50	1020.47
	1209.56	1197.60	1056.00	1113.77	1256.75	1122.81
Experiment II	1068.93	1214.56	945.77	1099.88	1199.69	1176.69
	1248.00	1182.00	1083.44	1029.00	1357.38	1022.08
			Feed conversion			
Experiment I	2.42	2.68	2.93	2.84	2.42	2.67
	2.66	2.75	2.72	2.71	2.46	2.74
Experiment II	2.78	2.54	2.94	2.83	2.48	2.74
	2.32	2.49	2.57	2.71	2.40	2.88

On the other hand, the analysis of variance of growth and feed conversion for the two phosphorus experiments revealed highly significant differences. The 0.6 percent level of phosphorus, using dicalcium phosphate as a source, when compared with the 0.45 percent phosphorus level, using dicalcium phosphate or steamed bone meal as a source of phosphorus, revealed highly significant differences on growth and feed conversion (Table 6). Similarly, the 0.6 percent level of phosphorus, using steamed bone meal, when compared with the 0.45 percent level of phosphorus, using dicalcium phosphate or steamed bone meal, showed highly significant differences on growth and feed utilization (Table 6).

These results are in agreement with the work of Lindblad et al. (1952) who obtained optimum growth and feed efficiency at the 1.0 percent calcium level and 0.6 percent phosphorus level. The results are also in agreement with the work of Almquist (1954) who concluded that the phosphorus requirement of the young poult was approximately 0.6 percent. But the results obtained in this experiment are in contrast to the work of Miller and Joukovsky (1953) who stated that 0.4 percent phosphorus appeared to be sufficient for chicks. The results are also in contrast to those of Fisher, Singsen, and Matterson (1953) who reported that chicks required 0.51 and 0.58 percent total phosphorus.

Feeding one half dicalcium phosphate and one half steamed bone meal at the 0.6 percent phosphorus level revealed highly significant differences on growth data and feed conversion when compared with the 0.45 percent phosphorus level, using one half dicalcium phosphate and one half steamed bone meal.

Table 6. Analysis of variance for gain in body weight and feed conversion. Pooled data for phosphorus Experiments I and II.

Source of variation	DF	Ss	Ms	F-value
Treatments	5	179677.43	35935.49	5.82 **
0.6% vs 0.45% (mixed)	1		76383.55	12.45 **
Mixed vs unmixed	1		25246.43	4.09 ns
0.6% vs 0.45% (unmixed)	1		68427.11	11.08 **
Dicalcium vs steamed bone meal	1		104.69	0.02 ns
Interaction	1		9015.65	1.46 ns
Replicates	3	8650.53	2883.51	0.47 ns
Error	15	92616.82	6174.45	
Total	23	280944.78		
N = 24 (treatments or lots)				
		Feed conversion		
Treatments	5	0.385404	0.077081	4.35 *
0.6% vs 0.45% (mixed)	1		0.169653	9.58 **
Mixed vs unmixed	1		0.047062	2.66 ns
0.6% vs 0.45% (unmixed)	1		0.159800	9.03 **
Dicalcium vs steamed bone meal	1		0.001958	0.11 ns
Interaction	1		0.006931	0.39 ns
Replicates	3	0.066997	0.22332	1.26 ns
Error	15	0.265493	0.017700	
Total	23	0.717894		
N = 24				

ns Nonsignificant.

* Significant P .05.

** Highly significant P .01.

The results are in agreement with those of O'Rourke *et al.* (1955) who stated the requirement of phosphorus for pullets was 0.6 percent. The results are also in agreement with the work of Simco and Stephenson (1960) who concluded the calcium requirement of the chick for optimum growth and feed conversion was not over 0.6 percent of the diet. The phosphorus requirement, likewise, did not exceed 0.6 percent of the formula. The results obtained in this experiment with 0.6 percent phosphorus are confirmed with the work of Waldroup (1963) who obtained better growth at 0.6 percent phosphorus when higher levels of calcium were used.

These results are not in agreement with the work of Peeler (1963) who stated that under practical conditions, the broiler ration should contain a minimum of 0.45 percent available phosphorus.

When one half dicalcium phosphate and one half steamed bone meal were mixed and fed at the 0.6 percent phosphorus level, compared with the 0.45 percent phosphorus level of either dicalcium phosphate or steamed bone meal, nonsignificant differences on growth data and feed conversion were obtained (Table 6). However, better growth and feed utilization were obtained with the 0.6 percent phosphorus level mixed with one half dicalcium phosphate and one half steamed bone meal, as compared to the 0.45 percent phosphorus level of either dicalcium phosphate or steamed bone meal (Table 5).

There was no significant difference in the gain of body weight or feed conversion when dicalcium phosphate was fed at the 0.6 percent phosphorus level, as compared to 0.6 percent phosphorus, using steamed bone meal (Table 6). Better growth and feed efficiency were obtained with steamed bone meal (Table 5). Similarly, there was no significant difference in the gain of body weight or feed conversion when dicalcium phosphate was fed at the 0.45 percent phosphorus level, as compared to the 0.45 percent phosphorus level of steamed bone meal (Table 6). With steamed bone meal, slightly better growth and feed utilization were observed (Table 5).

When one half dicalcium phosphate and one half steamed bone meal were mixed and fed at the 0.6 percent phosphorus level, nonsignificant differences on growth and feed conversion were obtained as compared to the 0.6 percent phosphorus level, using either dicalcium phosphate or steamed bone meal as a single source of phosphorus (Table 6); however, better growth and feed utilization were observed (Table 5). Similarly, when one half dicalcium phosphate and one half steamed bone meal were fed at the 0.45 percent phosphorus level, they did not give any significant difference on growth or feed conversion as compared to the 0.45 percent phosphorus level, using either dicalcium phosphate or steamed bone meal as a single source of phosphorus (Table 6); however, better growth and feed utilization were observed (Table 5).

SUMMARY AND CONCLUSIONS

An analysis of variance of the growth data and feed conversion for the two calcium experiments revealed nonsignificant differences for sources, levels, and interaction when the 1.0 and 0.8 percent levels of single sources of ground limestone and/or ground oyster shell were compared, or when the two sources were fed as equal parts of each for a total of 1.0 and 0.8 percent levels of calcium in the total diet.

On the other hand, the analysis of variance of the growth data for the phosphorus experiment revealed a highly significant difference in the gain in body weight for the various treatments used. The 0.6 percent level of phosphorus resulted in better growth than did the 0.45 percent level for both the unmixed and the mixed sources of phosphorus supplied by dicalcium phosphate and/or steamed bone meal. There were significant differences found when the mixed sources were compared with the single sources. As for the feed conversion, it was found there was a significant difference in favor of the 0.6 percent level of phosphorus compared with the 0.45 percent level of phosphorus for both single sources and when the two sources were fed in combination.

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PERFORMANCE OF MEAT-STRAIN CHICKS FED DIETS SUPPLEMENTED WITH VARIOUS LEVELS AND SOURCES OF CALCIUM AND PHOSPHORUS

by

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A series of four different experiments was conducted to study the performance of broiler-strain chicks fed ground limestone and ground oyster shell, each as a source of calcium at 0.8 and 1.0 percent calcium levels or both the sources in combination at these levels and dicalcium phosphate and steamed bone meal, each as a source of phosphorus at 0.45 and 0.60 percent phosphorus levels or both sources in combination at these levels. A total of 768 meat-strain (White Rock) day-old chicks were used in these experiments. The chicks were randomized, wing banded, weighed, and reared from one day to four weeks in starter batteries and then transferred to growing batteries from four to eight weeks.

The chicks were fed the rations supplemented with ground limestone and ground oyster shell, each at 0.8 and 1.0 percent calcium levels or both in combination of these levels from one day to eight weeks. Similarly, dicalcium phosphate and steamed bone meal, each at 0.45 and 0.60 percent phosphorus levels or both in combination at these levels were fed from one day to eight weeks of age. The 16 supplemented diets were fed to two replicate lots in these experiments.

Body weights and feed consumption records were maintained for each two-week period during the entire eight-week experimental period. The eight-week adjusted weights were tested by the analysis of variance for each experiment separately as well as pooled for all combinations of two experiments to study the growth. Similarly, feed conversion data were pooled from the two experiments and were analyzed by analysis of variance.

The following conclusions were drawn from this experiment:

Ground limestone and ground oyster shell, each at 0.8 and 1.0 percent calcium levels or both in combination at these levels, showed nonsignificant differences on growth and feed conversion. Using either ground limestone or ground oyster shell and both in combination at the 1.0 percent calcium level gave better growth and feed conversion than the 0.8 percent calcium level, using the same sources.

On the other hand, dicalcium phosphate and steamed bone meal, each at the 0.60 percent level, or the two sources mixed at this level, showed highly significant differences on growth and feed conversion when compared with the 0.45 percent phosphorus level, using each of the two sources or in combination.