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Effect of Particle Size on the Utilization of Calcium Supplements by the Chick

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(Received for publication August 27, 1973)

ABSTRACT Four experiments were conducted using a total of 1480 broiler strain cockerels to determine the effect of particle size and source of calcium on chick weight and tibia ash. The particle sizes of the test calcium sources obtained from oyster shell and limestone were defined as 6-8, 16-20, 40-50, 100-140, and 270-Pan on a passed-retained basis using the U.S.B.S. sieve series. Non-screened samples of oyster shell, limestone and a mined marine source were also tested.

No consistent differences in growth rate and percent tibia ash were observed between oyster shell and limestone when the particle size of these supplements was equal. Increased weight gains were obtained with the medium and fine particle sizes (U.S.B.S. 16-Pan) as compared to the larger sizes (U.S.B.S. 6-8). Tibia ash was significantly increased when the particle size of the calcium supplement was medium (U.S.B.S. 40-50) as compared to the ash values obtained by feeding either the smallest (U.S.B.S. 270-Pan) or largest (U.S.B.S. 6-8) particle sizes.

Screen analyses of commercial limestone, oyster shell and the mined marine calcium source revealed that the commercial oyster shell was a larger sized material than either limestone or the mined marine source tested in this study. Increased tibia ash was obtained by feeding the commercial oyster shell product which verifies the need for a medium particle size (16-50) in the chick's diet.

These data indicate calcium utilization by the chick is dependent upon the particle size of the calcium supplement. It appears desirable to use a medium to fine (U.S.B.S. 16-Pan) particle size calcium supplement in chick diets when considering both chick weight and percent tibia ash.

POULTRY SCIENCE 53: 1024-1029, 1974

INTRODUCTION

THE importance of calcium and phosphorus in poultry nutrition is demonstrated by the vast number of research studies concerning these two major minerals. Interest in different calcium sources was shown as early as 1923 when Buckner *et al.* reported that limestone and oyster shell were equal calcium sources for laying hens. However, more recent data (Scott *et al.*, 1971; Miller and Sunde, 1972) suggest that the substitution of hen-size oyster shell for a portion of pulverized limestone usually present in complete laying rations results in an improvement in egg shell strength. These researchers suggest this effect to be due to constant "metering" of calcium from the gizzard into the blood stream of the laying hens. Researchers have also studied the effect of varying particle sizes of phosphorus and calcium on chick performance. Gillis *et al.* (1951) found that two deflourinated phosphate samples ground sufficiently fine to pass through a U.S.B.S. 20 sieve but which were entirely retained by a U.S.B.S 40 sieve were utilized by chicks as effectively as samples ground much finer (passing through a U.S.B.S. 200). McKnight (1963) concluded that the phosphorus availability from commercial coarse and fine grades of soft phosphate was not influenced by their particle size as measured by chick performance. Krishna (1971) found that chick performance measured by tibia ash remained essentially the same when calcium was supplied by either limestone or oyster shell. No significant differences in response occurred when large (U.S.B.S. 16 through 20), medium (U.S.B.S. 30 through 40) and small (U.S.B.S. 100 through Pan) particle sizes were fed. However, tibia ash was greatest when the medium particle sizes were fed. Further evidence that the particle size of mineral supplements can influence utilization by chicks is demonstrated by the sodium chloride work reported by Dilworth *et al.* (1970).

Insufficient evidence has been documented on the size of particles and source needed by the chick to obtain optimum performance. The purpose of this study was: (1) to compare sources of calcium and (2) to determine the optimum particle size of dietary calcium needed to maximize chick growth and tibia ash.

TABLE 1.—*Composition of the basal diet*

Ingredient	Percentage
Yellow corn	59.63
Soybean meal (50% protein)	32.86
Poultry oil	4.00
Sodium chloride	0.20
Methionine hydroxy analogue-Ca. (93%)	0.12
Zoalene (3, 5 dinitro-0-toluamide, 25%)	0.05
Premix[1]	0.25
Sucrose	2.00
Sodium phosphate monobasic	0.89
TOTAL	100.00
Calculated analysis:	
Crude protein, %	21.17
Energy, M.E. Cal./lb.	1460
Total calcium, %	.09
Total phosphorus, %	.70
Available phosphorus, %	.45
Meth. + cyst., megacal, %	.5393
Lysine, megacal., %	.8024

[1]The premix furnished the following amounts of other ingredients per kilogram of feed: Vitamin A, 5512 I.U.; vitamin D_3, 1653 I.C.U.; vitamin E, 1.1 I.U.; riboflavin, 4.4 mg.; niacin, 27.6 mg.; d-pantothenic acid, 8.8 mg.; folic acid, 137.8 mcg.; vitamin B_{12}, 8.8 mcg.; choline chloride, 496 mg.; ethoxyquin, 55 mg.; menadione sodium bisulfite, 1.4 mg.; manganese, 66.25 p.p.m.; zinc, 44 p.p.m.; iodine, 1.25 p.p.m.; iron, 20 p.p.m.; copper, 2 p.p.m. and cobalt, .2 p.p.m.

MATERIALS AND METHODS

Broiler strain cockerels obtained from a commercial hatchery were used in four experiments. In each experiment, four replicates of ten chicks each were fed the experimental diets. At one day of age the chicks were wingbanded and randomly assigned to decks in electrically heated battery brooders with raised wire floors. Test diets and tap water were furnished *ad libitum* in each experiment.

Composition of the basal diet used in all experiments is shown in Table 1. This diet contained 0.09% calcium based on average calculated analysis values. Each diet contained a constant level of calculated available phosphorus (0.45%) and vitamin D_3 (1653 I.C.U./kg.). All other nutrients other than calcium in each test diet were maintained at current recommended levels. Calcium sources were added to each basal diet at the expense of sucrose to provide the desired test levels of calcium.

Varying particle sizes of calcium sources were obtained using the United States Bureau of Standards (U.S.B.S.) sieve series and

Table 2.—*Effect of calcium sources, calcium particle size and calcium level on broiler performance, Exp. 1*

		Three week results					
		Mean body wt., g.			Tibia ash, %		
Calcium source[1]	Range in particle size, U.S.B.S. sieve series	.15% Ca	.45% Ca	Mean[2]	.15% Ca	.45% Ca	Mean[2]
Oyster shell	6-8	221	326	273[c]	26.9	33.8	30.4[c]
Oyster shell	40-50	212	408	311[a]	28.7	35.4	32.0[a]
Oyster shell	270-Pan	224	394	309[ab]	27.7	34.1	30.9[bc]
	Mean	219	376	298	27.8	34.6	31.1
Limestone	6-8	220	357	289[bc]	26.9	34.2	30.5[c]
Limestone	40-50	200	353	277[c]	28.2	35.5	31.8[ab]
Limestone	270-Pan	229	390	310[ab]	27.4	35.1	31.3[abc]
	Mean	216	367	292	27.5	34.9	31.2

[1]No significant differences due to calcium sources.
[2]Means within a column and without a common superscript are significantly different ($P < .0.05$).

commerical grade sources of the test calcium carbonates. Each sample was sized into varying particle sizes using 150 g. samples placed for ten minutes in a Ro-Tap[1] sieve shaker. Particle sizes used in this study were defined on a passed-retained basis as 6-8, 16-20, 40-50, 100-140, and 270-Pan. Each succeeding larger range in particle size was 2.83 times larger than the one immediately preceeding. The 6-8, 40-50, and 270-Pan particle sized calcium samples were fed in Experiments 1 and 2. All sizes described above were fed in Experiment 3.

Calcium sources fed in Experiments 1, 2 and 3 were oyster shell and/or limestone. Both sources of calcium were tested in Experiment 1. Limestone was the test calcium carbonate source in Experiment 2 and oyster shell the source in Experiment 3. These calcium sources were fed at added calcium levels of 0.15 and 0.45% (Experiments 1 and 3); 0.20, 0.40, and 0.80% (Experiment 2); and 0.20 and 0.60% (Experiment 4). Commercial sources tested in Experiment 4 included oyster shell, limestone and a mined marine source of calcium carbonate. In Experiments 1, 2 and 3, the commercial sources were screened to obtain a uniform size of calcium. However, in Experiment 4, the commercial sources were fed on an "as is" basis. Screen analysis of the commerical sources were obtained using the U.S.B.S. sieve series and these results are shown in Table 6.

In each experiment, the chicks were individually weighed at three weeks of age and feed consumption determined for each group of ten birds. Tibia ash and body weight were the criteria used in this study. Feed utilization data are not shown because of the inconsistency of the data. All chicks were sacrificed at the end of each experiment. A minimum of ten tibia per lot was taken. Each group of fresh tibia was boiled immediately for approximately three minutes in distilled water, cleaned with the use of a knife and cheesecloth, ether-extracted and dried for 24 hours. The fat-free, moisture-free tibia bones were then randomly pooled into lots of not less than five tibia bones and ashed at 600° C. for eight hours. For each experimental diet, there was a total of at least eight ashings (5 bones/ashing) per diet.

A factorially arranged randomized complete block design was used in each experiment conducted. Statistical examination of

1. The W. S. Tyler Company, Mentor, Ohio 44060.

the data was performed using the analysis of variance (Steel and Torrie, 1960). Duncan's new multiple range test (1955) was used to separate significant differences between means. All statements of significant differences refer to the 5% level of probability.

RESULTS AND DISCUSSION

Experiment 1. The objective of Experiment 1 was to evaluate three different particle sizes of limestone and oyster shell fed to two dietary calcium levels as shown in Table 2. No significant differences in body weight or tibia ash were observed due to the source of calcium. When oyster shell was the source of calcium a significantly larger body weight was obtained by feeding either the 40–50 or 270–Pan particle sizes and an increased tibia ash was observed due to feeding the 40–50 particle size as compared to either the 6–8 or 270–Pan particle sizes. When limestone was tested, body weight was significantly increased by feeding the 270–Pan particle size as compared to the 40–50 particle size. Tibia ash was increased by feeding the 40–50 particle size as compared to the 6–8 particle size. Broiler performance for all criteria was generally improved with the dietary level of 0.45% calcium as compared to 0.15% calcium.

The results of Experiment 1 are very similar to results obtained by Krishna (1971) who also reported that chick tibia ash essentially remained the same when the dietary calcium was supplied by the same particle size of either limestone or oyster shell. No significant differences in response were found by Krishna (1971) when large (16-40), medium (30-40) or small (100-Pan) particle sizes of calcium sources were fed. However, an increase in tibia ash occurred consistently when the medium particle size was fed. These results with the young chick can be compared to the data of Scott *et al.* (1971) and Miller and Sunde (1972) obtained with adult hens which suggest that the substitution of hen-sized oyster shell for a portion of pulverized limestone in complete laying rations results in an improvement in egg shell strength. Our results of Experiment 1 clearly indicate that limestone and oyster shell additions to the diet of broilers results in equal responses when the particle size and dietary level of these supplements are equal. These results also indicate that the medium to fine particle sizes (40-Pan) of calcium sources have greater biological availability for the chick than does the larger particle sizes.

Experiment 2. The objective of Experiment 2 was to again evaluate the effect of particle sized calcium supplements in chick performance. Since no statistical differences were found due to sources of calcium fed in Experiment 1, only limestone was used as the calcium source in Experiment 2. Results of Experiment 2 are shown in Table 3. A signifi-

TABLE 3.—*Effect of limestone particle size and calcium level on broiler performance, Exp. 2*

	Three week results							
	Mean body wt., g.				Tibia ash, %			
Range in particle size, U.S.B.S. sieve series	.20% Ca	.40% Ca	.80% Ca	Mean[1]	.20% Ca	.40% Ca	.80% Ca	Mean[1]
6-8	289	405	398	364[b]	29.0	32.9	34.3	32.1[b]
40-50	335	422	419	392[a]	30.3	33.4	35.3	33.0[a]
270-Pan	347	426	407	393[a]	29.5	32.6	34.2	32.1[b]
Level mean[1]	324[b]	418[a]	408[a]		29.6[c]	33.0[b]	34.6[a]	

[1]Means within a column or row grouping and without a common superscript are significantly different ($P < .0.05$).

Table 4.—*Effect of oyster shell particle size and calcium level on broiler performance, Exp. 3*

Range in particle size, U.S.B.S. sieve series	Three week results: Mean body wt., g. .15% Ca	.45% Ca	Mean[1]	Tibia ash, % .15% Ca	.45% Ca	Mean[1]
6-8	221	326	273[b]	26.9	33.8	30.4[b]
16-20	258	378	318[a]	28.4	34.5	31.5[ab]
40-50	212	408	311[a]	28.7	35.3	32.0[a]
100-140	226	384	305[a]	27.9	34.4	31.2[bc]
270-Pan	224	394	309[a]	27.7	34.1	30.9[cd]
Level Mean[1]	228[b]	378[a]		27.9[b]	34.4[a]	

[1] Means within a column or row grouping and without a common superscript are significantly different (P < .0.05).

cantly larger body weight was obtained by feeding either the 40-50 or 270-Pan particle sized calcium as compared to the other sizes fed. In general, the results of Experiments 1 and 2 indicate a medium to fine (40-Pan) particle sized calcium source is needed in a chick diet for optimum chick weight and tibia ash.

Experiment 3. Five particle sizes using oyster shell as the calcium source were fed in Experiment 3 to determine the optimum particle size of dietary calcium sources for the growing chick. Sizes tested were identified on a passed-retained basis as 6-8, 16-20, 40-50, 100-140, and 270-Pan. Each particle size was fed to chicks to supply 0.15 and 0.45% added dietary calcium.

An increase in chick weight was obtained by feeding particles smaller than the particle size retained on a U.S.B.S. 20 sieve (Table 4). Tibia ash was significantly increased by feeding the 40-50 particle size as compared to the 6-8, 100-140 or 270-Pan particle sizes. As expected, broiler performance, as measured by chick weight and tibia ash, was significantly improved when the diet contained 0.45% added calcium as compared to the 0.15% added level.

Experiment 4. The purpose of Experiment 4 was to determine the effect of three commercial grade calcium sources and two added calcium levels on broiler performance. The calcium sources tested were limestone,[2] oyster shell[3] and a mined marine source.[4] Each source was used to supply 0.20 and 0.60% added calcium to the diets.

2. Calcium Carbonate Co., Quincy, Ill.
3. Oyster Shell Products, Mobile, Ala.
4. Southern Materials Corp., Ocala, Fla.

Table 5.—*Effect of commercial calcium sources and calcium level on broiler performance, Exp. 4*

Calcium source	Three week results: Mean body wt., g. .20% Ca	.60% Ca	Mean[1]	Tibia ash, % .20% Ca	.60% Ca	Mean[1]
Limestone	289	431	360[a]	32.7	39.2	35.9[ab]
Oyster shell	283	405	344[a]	32.1	40.7	36.4[a]
Mined marine	272	421	346[a]	31.3	39.7	35.5[b]
Level Mean[1]	281[b]	419[a]		32.0[b]	39.8[a]	

[1] Means within a column or row grouping and without a common superscript are significantly different (P < .0.05).

TABLE 6.—*U.S.B.S. screen analysis of the commercial sources of calcium, Exp. 4*

U.S.B.S. screen	% Retained[1]		
	Fine limestone	Oyster shell meal	Fine SMC
20	0.22	37.12	0
30	0.67	14.00	0
50	0.89	20.22	0.22
100	7.78	13.33	4.67
	18.66	5.11	16.89
	36.89	6.45	37.33
	34.89	3.77	40.89
TOTAL	100.00	100.00	100.00

[1]Screen analysis of each commercial source of calcium was an average of three analyses.

Results of Experiment 4 are shown in Table 5. No significant differences in body weight were noted due to differences in the calcium sources. However, tibia ash was significantly larger for the chicks fed oyster shell as compared to the marine source. No significant differences were found between either the limestone or oyster shell sources. Broiler performance measured by body weight and tibia ash was significantly improved with the addition of 0.60% added calcium to the diets.

Screen analyses of the calcium sources were made using the U.S.B.S. sieve series (Table 6). The marine source was the smallest of the three calcium sources tested and limestone was intermediate in this respect. The largest amount of the marine source and limestone was retained on screens 140-Pan. However, the largest amount of the oyster shell was retained on screens 20-100. The data from Experiments 1, 2, and 3 in this study suggest that the chick can best utilize calcium sources ground medium to fine (40-Pan) for optimum growth, but ground medium (16-50) for maximum tibia ash. However, only suboptimum levels of calcium were employed in testing the effect of particle size. In general oyster shell produced an increased chick tibia ash in Experiment 4 which verified the need for the medium particle size in a chick diet.

ACKNOWLEDGEMENT

The authors wish to thank Calcium Carbonate Co., Oyster Shell Products and Southern Materials Corp. for their generous contributions of materials utilized in this study.

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