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IN CHICKENS**

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**OHIO AGRICULTURAL EXPERIMENT
STATION - - WOOSTER, OHIO**

The Effect of Calcium Source, Calcium Gluconate and Ascorbic Acid on Reproductive Performance and Egg Shell Quality in Chickens

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During the past few years there has been considerable interest in nutritive substances that affect egg shell quality. This interest arises because many egg producers and handlers continue to have problems with thin, misshapen and poor texture eggs shells that result in loss of product. Because the egg producer is interested in keeping loss eggs to a minimum, he has been willing to try potential remedies for the problem. Once egg shell quality problems develop, producers recognize that little can be done from a genetic or environmental standpoint. They already have the birds and the laying house, and it is seldom practical to change these to combat this immediate problem. In the absence of specific disease problems, the only hope is for a nutritive solution to the problem.

Research by Peterson, *et al.* (1960) and Titus (1958) indicated that calcium intake may be a limiting factor in egg shell thickness when hens fed a high energy ration are laying at a high rate. Thus a level of 2.5 percent calcium does not appear adequate for maximum shell thickness and many laying rations now contain 3.0, 4.0 or 5.0 percent calcium. To provide these high calcium levels requires the use of as much as 10 percent of a calcium source, such as limestone, in the laying ration. Problems of reduced egg production encountered by the egg producer have suggested that the use of high calcium levels may be questionable. On the other hand, Griminger *et al.* (1961) concluded that 3 percent dietary calcium was adequate for maximum calcium retention by the hen.

In addition to shell thickness, breakage and appearance of eggs is affected by shell texture and abnormalities. It is known that eggs of the same shell thickness may have widely different breaking strengths. Improvements in shell texture do not necessarily result from increases in shell thickness. Thus, research interest in dietary factors that might improve shell texture has been aroused. Two compounds which have been suggested for improving egg shell thickness and texture are vitamin C (ascorbic acid) and calcium gluconate.

TABLE 1.—Composition of Basal Rations.

Ingredient	Percent Composition of	
	Complete Basal Ration	Corn-Soybean Meal Basal Ration
Ground Yellow Corn	72.0	71.0
Wheat Middlings	1.5	—
Soybean Meal (44%)	12.5	25.0
Meat and Bone Scrap (50%)	2.5	—
Menhaden Fish Meal (60%)	2.5	—
Dried Whey Product (16%)	2.5	—
Alfalfa Meal (17%)	2.5	—
Deflourinated Rock Phosphate	2.0	1.8
Feeding Limestone	1.0	1.2
Iodized Salt	0.5	0.5
Vitamin-Mineral Premix 1*	0.5	—
Vitamin-Mineral Premix 2**	—	0.5
Total	100.0	100.0
Calculated Calcium Level of Ration	1.4	1.1

*Supplies vitamins A, D₃, riboflavin, pantothenic acid, B₁₂, manganese sulfate and antioxidant (BHT).

**Supplies vitamins A, D₃, K, thiamine, riboflavin, pantothenic acid, niacin, pyridoxine, biotin, folicin, B₁₂, choline, methionine and manganese sulfate.

The experiments reported here have attempted to evaluate ascorbic acid, calcium ascorbate and calcium gluconate for their effect on egg shell quality and to reinvestigate some of the problems associated with the use of high calcium laying rations.

EXPERIMENTAL PROCEDURE

Egg production-type laying hens housed in colony laying cages were used to determine the effect of calcium gluconate, calcium ascorbate and ascorbic acid after they had been in egg production for 40 weeks. During an 8 or 12 week period starting in mid-June, the hens were fed on the complete basal ration (Table 1) for 4 weeks and then switched to the experimental rations for a 4 or 8 week period. In the first and second experiment, all birds received an oyster shell supplement on a free-choice basis. Thus total calcium intake in these experiments was not determined. In the third experiment, all calcium was incorporated into the basal ration to provide total calcium levels of 2 and 4 percent and no supplementary oyster shell was fed. Observations were made on egg production, shell thickness, specific gravity, egg shell abnormalities and blood ascorbic acid levels. Egg shell abnormalities were expressed as the percentage of eggs laid that showed

cracks, checks, blind checks, rough texture or extreme porosity. Blood ascorbic acid levels were determined by the method of Roe and Keuther (1943). Shell thickness measurements were made during the first experiment using a paper thickness gauge to obtain an average thickness from measurements made on the dried shell at the middle, large and small ends of the shell. Specific gravity of eggs was measured in the second and third experiment by immersing eggs in saline solutions of known specific gravity. Five and 9 cages of hens each received each experimental ration. Experimental rations were prepared each week from the complete basal ration (Table 1) by supplementing them with small amounts of calcium gluconate, ascorbic acid or calcium ascorbate at the expense of corn.

In three other experiments, egg production-type pullets were housed in individual cages or colony cages and fed experimental rations containing high levels of calcium to determine the effect of calcium source on reproductive performance. After attaining 65 to 80 percent egg production on the complete basal ration plus a free-choice supplement of oyster shell, the pullets were switched to experimental rations prepared by adding a calcium source and/or fat to the corn-soybean meal basal at the expense of corn. The corn-soybean basal meal ration shown in Table 1 was used in the calcium source experiments to permit complete control of calcium intake. Data of feed consumption, egg production, body weight and specific gravity of eggs were obtained. Nine birds per treatment were used in Experiment 4 conducted with pullets in individual cages. Six cages of 14 pullets each were fed each ration in a colony cage experiment. Five and 12 pullets per treatment in individual cages were used in Experiment 6. Calcium sources used in these experiments were analyzed for calcium and magnesium by flame photometric methods. Particle size of the calcium supplements was determined by screening the dried material through standard sieves.

RESULTS

The results of the first experiment to determine the effects of ascorbic acid and calcium gluconate on egg shell quality are shown in Table 2. Egg production was not affected by any of the treatments. Rate of egg production was low in all cases because the hens were approaching the end of the first year of production and were not culled to remove non-layers. Egg shell thickness declined slightly on the basal ration and on the two rations containing calcium gluconate when compared to the basal period. Ascorbic acid prevented this decline in shell thickness and may have caused a slight increase over that observed in the basal period. However, this was not statistically significant.

TABLE 2.—Experiment 1—Summer, 1960. Effect of Ascorbic Acid and Calcium Gluconate on Egg Production, Shell Thickness and Shell Abnormalities. (5 cages of 15 hens each per treatment).

Supplement to Complete Basal Ration	Percent Egg Production During		Egg Shell Thickness (inches per 1000) During		Percent Eggs Showing Abnormalities During	
	Basal Period	Experimental Period	Basal Period	Experimental Period	Basal Period	Experimental Period
None	51	42* ²	14.9	14.8*	24	23 ¹
0.05% Calcium gluconate	49	38	14.8	14.6	22	8
0.5% Calcium gluconate	48	41	15.0	14.7	25	11
20 gms. per ton ascorbic acid	51	43	15.0	15.1	22	8
200 gms. per ton ascorbic acid	52	42	14.8	14.9	28	10

¹Reduction in egg shell abnormalities shown by all treatments statistically significant at 5% level.

²Symbol used in this table and the following tables to indicate that differences between basal and experimental groups were not significant ($p < .05$)

The percentage of eggs showing abnormalities such as checks, blind checks, roughness or ridges ranged from 22 to 28 during the basal period. During the period when the supplemented rations were fed both calcium gluconate and ascorbic acid caused a statistically significant reduction in abnormalities at both feeding levels. The unsupplemented group continued to show a high level of abnormal eggs.

During the summer of 1961, a second experiment shown in Table 3 was conducted. The reduction in egg shell abnormalities observed during the previous experiment was similar for both calcium gluconate and ascorbic acid. This suggested that these two compounds might be serving the same function. Because the low levels (0.05 or 0.5 percent) of calcium gluconate employed in these experiments supply only traces of calcium, it was suggested that gluconic acid might be the active portion of the compound. Since the chicken synthesizes ascorbic acid from compounds closely related to gluconic acid, it seemed possible that gluconic acid or contaminating related compounds might promote ascorbic acid synthesis in the chicken. Thus, total blood levels of ascorbic acid were measured to determine whether or not calcium gluconate would promote increased blood ascorbic acid levels. The data show that only ascorbic acid increased blood levels of this vitamin. Blood from birds fed calcium gluconate showed ascorbic

acid levels similar to those shown by the groups fed the basal ration. Therefore, no evidence that gluconic acid can be converted to ascorbic acid was obtained.

Egg production in the second experiment was not affected by the supplements. The specific gravity of eggs may have been increased slightly by calcium gluconate and ascorbic acid during the experimental period. This difference is not, however, statistically significant. When the house temperature was increased by heating to provide temperatures between 90 and 95° F the specific gravity of eggs declined to the same degree without any effect due to the dietary treatment. In contrast to the previous experiment the percent of eggs showing abnormalities was not affected by feeding of either ascorbic acid or calcium gluconate.

A third experiment conducted during the summer of 1962 was designed to determine the effect of calcium level in the experimental ration and strain of chicken on the response to calcium gluconate and calcium ascorbate. Because there were no strain effects, except for a lower incidence of egg shell abnormalities in one of the three strains, the data shown in Table 4 have been summarized to show only the effect of ration treatment. The calcium levels of the complete basal ration were adjusted to 2 and 4 percent by the addition of calcite at the expense of corn. During the basal period all birds were fed the 2 percent level of calcium without other supplements. During the experimental periods, the hens were fed the experimental rations indicated and during the second experimental period, the temperature of the house was kept between 85 and 95° F. Egg production was not significantly affected by the rations fed. Specific gravity of eggs was, however, significantly greater when the calcium level in the ration was increased from 2 to 4 percent. While heating the birds reduced the specific gravity of eggs, the relative difference between the 2 and 4 percent calcium levels was maintained. The increase in specific gravity of eggs due to calcium level was not affected by gluconate or ascorbate supplementation.

The percent of eggs showing abnormalities was unrelated to specific gravity. For example, when the specific gravity of eggs was increased by the higher level of calcium this was not accompanied by a reduction in shell abnormalities. Similarly, when specific gravity of eggs decreased due to heating of the hens, this was not accompanied by an increase in shell abnormalities. Thus, there was no relationship of abnormal eggs found in this experiment to specific gravity as a mea-

sure of shell thickness or quality. This would indicate that these egg abnormalities were not related to calcium intake or heat stress within the limits of these variables in this experiment. The percent of abnormal eggs was not significantly changed by ration or temperature treatment.

Experiment 4 was conducted over an 8-month period to provide preliminary data on the effect of high calcium levels in laying rations on reproductive performance. Previous field observations had indicated that high calcium levels might depress egg production and feed consumption. While some of these observations were traceable to the use of dolomitic limestone, others appeared to be associated with feeding grade calcium sources. Thus, three sources of feeding limestone were compared at 10 percent of the ration (about 4.6 percent calcium in ration) to a low calcium ration fed with a free-choice of crushed oyster shell. In a second series, these rations were fed with 4 percent added animal fat to increase their energy content and reduce dustiness of the ration. It can be seen from the data in Table 5 that high levels of limestone A were well tolerated. Limestones B and C produced a depression in egg production, lowered daily feed and energy intake and caused loss in body weight. Rations with added fat gave better results than comparable rations without fat. While limestones B and C also depressed egg production, daily feed and energy intake and body weight of hens on the fat containing rations when compared to limestone A, the greatest improvement from fat addition was observed with rations containing limestones B and C. Thus, fat helped to counteract the drop in laying performance caused by high levels of two calcium sources. The specific gravity of eggs was not affected by the calcium source fed, but appeared to be somewhat lower on rations with added fat.

Since the limestone products which produced lower egg production were higher in calcium (38 percent) than the sample that supported highest production (34 percent), it appeared that trace mineral balance might be adversely affected in the rations containing high levels of the purer calcium product. Also, because fat partially counteracted the depression in egg output caused by limestones B and C, it seemed possible that the physical nature of the limestone altered the palatability of the ration in addition to influencing the content of other nutrients. It has been suggested that finely ground limestone powders are less acceptable than coarse products. Experiment 5 (Table 6) was started to compare a wide variety of calcium sources and textures of grind as well as trace mineral supplementation on the effect of these

TABLE 3.—Experiment 2—Summer, 1961. Effect of Ascorbic Acid and Calcium Gluconate on Egg Production, Specific Gravity of Eggs, Shell Abnormalities and Blood Vitamin C Levels. (5 cages of 15 hens each per treatment).

Supplement to Complete Basal Ration	Blood Ascorbic Acid (mcg./ml.) of Hens During Expt'l. Period 1	Percent Egg Production During			Specific Gravity of Eggs During			Percent Eggs Showing Abnormalities		
		Basal Period	Expt'l. Period 1	Expt'l. Period (heated) 2	Basal Period	Expt'l. Period 1	Expt'l. Period (heated) 2	Basal Period	Expt'l. Period 1	Expt'l. Period (heated) 2
∞ None	14.2 ¹	61	60* ²	59* ²	1.080	1.081* ²	1.077* ²	22	29* ²	24* ²
0.05% calcium gluconate	14.5	58	54	51	1.080	1.082	1.078	25	27	29
0.5% calcium gluconate	14.7	59	55	57	1.080	1.083	1.078	17	17	28
20 gms. per ton ascorbic acid	18.0	63	65	58	1.080	1.082	1.077	13	27	18
200 gms. per ton ascorbic acid	18.3	63	60	54	1.080	1.083	1.079	31	31	21

¹Increase in blood ascorbic acid shown by groups fed ascorbic acid statistically significant at 5% level.

TABLE 4.—Experiment 3—Summer, 1962. The effect of Calcium Level, Calcium Gluconate and Calcium Ascorbate on Egg Production, Specific Gravity of Eggs and Shell Abnormalities. (9 cages of 15 hens each per treatment).

Calcium Level in Complete Basal Ration	Supplement to Complete Basal Ration	Percent Egg Production During			Specific Gravity of Eggs During			Percent Eggs Showing Abnormalities During		
		Basal Period	Expt'l. Period	Expt'l. Period (heated)	Basal Period	Expt'l. Period	Expt'l. Period (heated)	Basal Period	Expt'l. Period	Expt'l. Period (heated)
2.0%	None	60	64* ²	60* ²	1.075	1.076 ¹	1.071 ¹	22	18* ²	23* ²
2.0%	0.1 Percent Calcium Gluconate	67	67	64	1.074	1.074	1.071	23	25	24
2.0%	100 gms. per ton Calcium Ascorbate	65	63	61	1.075	1.075	1.072	23	22	14
4.0%	None	67	65	65	1.075	1.081	1.077	24	24	14
4.0%	0.1 Percent Calcium Gluconate	65	63	57	1.074	1.080	1.077	22	29	21
4.0%	100 gms. per ton Calcium Ascorbate	66	68	66	1.075	1.080	1.077	24	27	20

¹Increase in specific gravity of eggs due to higher calcium level statistically significant at 1% level.

TABLE 5.—Experiment 4 (1960-61 year). Effect of Calcium Source on Egg Production, Daily Feed and Energy Intake, Body Weight Changes and Specific Gravity of Eggs. (9 pullets per treatment).

Variable Components in Corn-Soybean Meal Basal at Expense of Corn		Animal Fat (percent)	Energy Level of Ration (productive calories per pound)	Percent Egg Production (hen-day basis)	Daily Feed Intake Per Bird (pounds)	Productive Energy Calories Consumed Per Bird Per Day	Body Weight Change Gain or Loss (pounds)	Specific Gravity of Eggs
Feeding Amount (percent)	Limestone Source							
0 ²		0	960	61 ¹	0.226	217	+0.06	1.090* ²
10	A	0	850	67	0.214	182	-0.03	1.087
10	B	0	850	50	0.194	165	-0.16	1.089
10	C	0	850	50	0.198	168	-0.10	1.087
0 ²		4	1030	66	0.208	214	+0.38	1.086
10	A	4	930	73	0.210	195	+0.02	1.086
10	B	4	930	62	0.192	178	-0.15	1.082
10	C	4	930	62	0.185	172	-0.12	1.084

¹LSD₀₅ ± 11 percent.

²These groups were fed crushed oyster shell on a free choice basis.

TABLE 6.—Experiment 5 (1961-62 year). Effect of Calcium Source on Egg Production, Feed Conversion and Body Weight. (6 cages of 14 pullets each per treatment).

Variable Components in Corn-Soybean Meal Basal at Expense of Corn				Percent Egg Production (hen-day basis)		Feed Conversion (pounds feed per dozen eggs)		Average Body Weight (pounds)		Specific Gravity of Eggs at Termination
Type	Calcium Supplement		Trace Mineral Mix (3)	Basal Period (3 months)	Expt'l. Period (7 months)	Basal Period (3 months)	Expt'l. Period (7 months)	Basal Period (3 months)	Expt'l. Period (7 months)	
	Source	Amount (Percent)								
Crushed Oyster Shell ²	G		No	66	63 ¹	4.5	4.4	4.0	4.4	1.074* ²
Feeding Grade Limestone	A	10	No	65	63	4.4	4.7	3.9	4.1	1.074
Feeding Grade Limestone	B	10	No	67	58	4.3	5.0	3.9	4.0	1.075
Feeding Grade Limestone	C	10	No	66	59	4.4	4.9	3.9	4.0	1.074
Granular Calcite	D	10	No	67	69	4.5	4.3	3.9	4.1	1.073
Oyster Shell Flour	E	10	No	66	41	4.5	6.7	3.9	3.8	1.076
Pure Calcium Carbonate	F	10	No	68	35(25)*	4.2	7.9(9.8)*	3.9	3.8(3.9)*	1.075
Pure Calcium Carbonate	F	10	Yes	67	36(38)*	4.4	7.7(6.3)*	3.9	3.8(3.9)*	1.078

¹LSD₀₅ ± 6 percent, LSD₀₁ ± 9 percent.

²Crushed Oyster Shell fed as free choice supplement.

³Trace mineral mix provided 500 mgs. Magnesium, 30 mgs. Iron, 5 mgs. Copper, 100 mgs. Zinc per pound of ration.

*During the last 3 months of the experimental period the trace mineral mix was removed from the last ration and 4 percent animal fat was added to this ration. The figures in parentheses compare the last two rations for the last 3 months only.

products on laying performance. Results from this experiment show that pure calcium carbonate (U.S.P. powder) and oyster shell flour at 10 percent levels greatly depress egg production, feed conversion and body weight. Supplementation of the pure calcium carbonate with a trace mineral supplement containing magnesium, iron, copper and zinc did not improve results. Thus, these trace minerals do not appear to be limiting in the high purity calcium containing ration. Granular calcite significantly increased egg production over that of pullets fed the control ration with a free-choice of crushed oyster shell. Limestone samples B and C reduced egg production by an amount that approached statistical significance when compared to the groups receiving the control ration or limestone A.

After the pullets in Experiment 5 had been fed the experimental rations for 4 months, the ration containing pure calcium carbonate with the trace mineral supplement was discontinued because no response from the trace minerals was noted. During the last 3 months of the experimental period, the trace mineral supplement was removed and 4 percent animal fat added to the ration containing pure calcium carbonate. From the values in parentheses it will be seen that the added fat increased egg production during the last 3 months over that obtained from the group fed only the pure calcium carbonate. Thus it would appear that physical texture and/or palatability of the ration was an important factor in the depression produced by the pure calcium carbonate and that fat helped to counteract this condition. On the other hand, no evidence of a mineral deficiency due to magnesium, iron, copper or zinc was obtained. The specific gravity of eggs was not influenced by the dietary treatments except that hens laying fewer eggs tended to have eggs of higher specific gravity.

Table 7 shows some characteristics of the calcium supplements employed in these experiments. It was not possible to relate the experimental results obtained in the feeding experiments to calcium content, magnesium content, or the particle size of the product employed. While the crushed oyster shell was of large particle size and gave good results, oyster shell flour gave poorer results and was mostly powder-like in its consistency. On the other hand, limestone A which was of smaller particle size than limestones B and C gave better results in the feeding experiments. Calcite of relatively coarse texture was best in the tests while pure calcium carbonate powder of very fine texture gave poorest results. The products which gave the best results were not those high or low in calcium or magnesium content.

TABLE 7.—Characteristics of Calcium Supplements Used in Experiments

Calcium Supplement	Calcium Content (percent)	Magnesium Content (percent)	Percent of Sample Retained on U.S.B.S. Sieve No.		
			100	200	over 200
Crushed Oyster Shell	38.0	1.5	96	3	1
Oyster Shell Flour	39.5	1.7	47	33	20
Calcite	33.5	3.0	59	30	11
U.S.P. Calcium Carbonate	40.0	0.5	0	0	100
Limestone A	33.8	5.6	14	40	46
Limestone B	37.8	1.4	66	13	21
Limestone C	38.2	1.4	66	14	20

Experiments 4 and 5 were conducted with calcium supplements fed only at the 10 percent level. Because this level is higher than would generally be used in commercial practice, it was decided that both the best and the poorest calcium sources should be tested at both 5 and 10 percent levels. In this experiment care was taken to note the effect of the calcium source in the ration upon feed consumption as a measure of palatability of the ration. Thus, the data on Experiment 6 (Table 8) have been summarized to show the effect of calcium source and level in the ration during the first two weeks after switching to the experimental rations and during the entire experimental period. The data show that egg production was good and not affected by the experimental rations during the first and second week of the experiment. Oyster shell flour and pure calcium carbonate at the 10 percent level gave 80 and 77 percent production, respectively, during the first two weeks. Feed conversion for these two treatments was extremely good because of reduced daily feed intake during this initial period. The reduction in feed intake was followed by a decline in body weight and eventually there was a reduction in egg production as shown by the percent egg production for the entire experiment. The reduction in egg production was significant only for the groups fed the 10 percent levels of oyster shell flour or pure calcium carbonate. The egg production of the group fed 5 percent calcium carbonate was not significantly lower than the groups fed either level of calcite or 5 percent oyster shell flour. However, this group of hens was very close to the "breaking point" on feed and energy intake.

TABLE 8.—Experiment 6 (1962). Effect of Calcium Level and Source on Egg Production, Feed Conversion, Daily Feed Intake, Energy Intake and Body Weight of Laying Hens. (12 pullets per treatment).

Variable Components in Corn-Soybean Meal Basal at the Expense of Corn			Percent Egg Production		Feed Conversion (lbs. feed per dozen eggs)		Daily Feed Intake (lbs.)		Energy Intake (productive calories)		Ave. Body Weight (lbs.)	
Calcium Source	Percent Calcium Source in Ration	Energy Level in Ration (P.E. Cal./lb.)	during first 2 weeks	during entire expt.	during first 2 weeks	during entire expt.	during first 2 weeks	during entire expt.	during first 2 weeks	during entire expt.	start of expt.	end of expt.
Calcite	5	924	75	70 ¹	3.78	4.07	0.241	0.234	223	216	4.1	4.1
Calcite	10	870	86	74	3.60	4.18	0.252	0.253	219	220	4.2	4.2
Oyster Shell Flour	5	924	78	74	3.65	4.06	0.241	0.249	223	230	4.2	4.0
Oyster Shell Flour	10	870	80	59	3.16	4.76	0.221	0.224	192	195	4.3	3.7
Calcium Carbonate	5	924	73	66	3.71	3.99	0.206	0.216	190	201	4.0	3.8
Calcium Carbonate	10	870	77	43	3.23	6.72	0.203	0.191	177	166	4.3	3.6

¹LSD₀₅ = ± 9 percent.

From Experiment 6 it is possible to conclude that the 10 percent levels of the oyster shell flour and pure calcium carbonate used in this study produce their undesirable effect on egg production by reducing feed intake and, as a consequence, intake of energy and other nutrients. This leads to egg production at the expense of body tissue and eventually to fewer eggs laid. Thus, reduction in feed intake on these high calcium rations is the cause of poorer egg production. Experiments 4 and 5 have shown that fat addition to the ration improves the acceptability of high calcium rations as does the use of calcium sources that reduce the dustiness of the ration.

SUMMARY AND CONCLUSIONS

Calcium gluconate and ascorbic acid at two levels of supplementation reduced egg shell abnormalities in one experiment but did not produce this effect in a second or third experiment. Only small changes in egg production, shell thickness and specific gravity of eggs were observed. Calcium gluconate does not increase blood vitamin C levels. While calcium level of the ration and increased temperature affected specific gravity of eggs as a measure of shell thickness, the incidence of egg shell abnormalities was not related to specific gravity of eggs.

Thus, egg shell quality problems encountered in these experiments were neither altered by dietary calcium levels of 2 and 4 percent nor increased by raising temperatures to 85 to 95°F. In one of three experiments, small amounts of supplementary ascorbic acid and calcium gluconate significantly reduced egg shell abnormalities.

When laying hens were fed corn-soybean meal type rations containing 10 percent of certain calcium sources, providing dietary calcium levels of 4.5 to 5.1 percent, depending upon composition of the source, lower feed intake, loss in body weight and reduced egg production were observed with several sources of calcium. Other sources of calcium did not produce this effect and normal reproductive performance was maintained. When used at the 5 percent level to provide dietary calcium levels of 2.8 to 3.1 percent, all calcium sources tested permitted normal rates of egg production. Thus, until more evidence is available it may be unwise to formulate laying rations that contain more than 3 percent calcium. While certain calcium sources can be used to provide dietary calcium levels of 4 and 5 percent without ensuing declines in egg production, it is questionable whether or not these higher calcium levels are of value in promoting better egg shell quality. Certainly, it would be unwise to use the higher calcium levels when the effect on production of the specific calcium source under consideration is unknown.

In the third experiment one strain of chickens produced fewer abnormal eggs under all dietary conditions imposed. This may indicate that the poultry breeder can influence egg shell quality to a greater extent than the dietary variables studied in these experiments.

Trace mineral balance does not appear to be a problem which would account for the behavior of the several calcium sources tested. If trace minerals had been limiting in these rations, a trace mineral supplement should have improved performance. Also, if trace mineral deficiency had been a problem, it should have been more acute in rations containing only 5 percent of the calcium source. The data show, however, that production was improved by the reduced calcium source level.

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