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THE COMPARISON OF ROCKSHELL TO OYSTERSHELL AND LIMESTONE AS A SOURCE OF CALCIUM ON THE PERFORMANCE OF LAYING HENS AND LAYING PULLETS

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# THE COMPARISON OF ROCKSHELL TO OYSTERSHELL AND LIMESTONE AS A SOURCE OF CALCIUM ON THE PERFORMANCE OF LAYING HENS AND LAYING PULLETS

By

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ABSTRACT

THE COMPARISON OF ROCKSHELL TO OYSTERSHELL AND LIMESTONE AS A SOURCE OF CALCIUM ON THE PERFORMANCE OF LAYING HENS AND LAYING PULLETS

By

Pamela Head

An experiment to compare rockshell to oystershell and limestone as a source of calcium was conducted for a period of sixteen weeks. The experiment consisted of 12 experimental treatments with four replicates in each. There were two trials conducted. The first trial consisted of 192 laying pullets with four hens assigned to each replicate. The second trial consisted of 144 laying hens with three hens assigned to each replicate. The experiment was designed to investigate the effect of varying levels and sources of calcium on body weight gains, feed conversion, egg weights, feed consumption and eggshell thickness. The different experimental groups received the same basal diet supplemented with varying levels and sources of calcium. All data collected were subjected to statistical analysis.

In respect to shell thickness, birds receiving diets containing rockshell, as a source of calcium, produced eggs with significantly thicker eggshells compared to birds receiving diets containing oystershell and limestone at the 3.5% calcium level for laying hens and 2.75% calcium level for laying pullets. There was a significant influence found for egg production favoring oystershell at the 3.5% and

2.75% calcium level for both laying hens and laying pullets. No significant differences in feed consumption, body weight gain or feed efficiency for either laying hens or laying pullets resulted from different sources of calcium.

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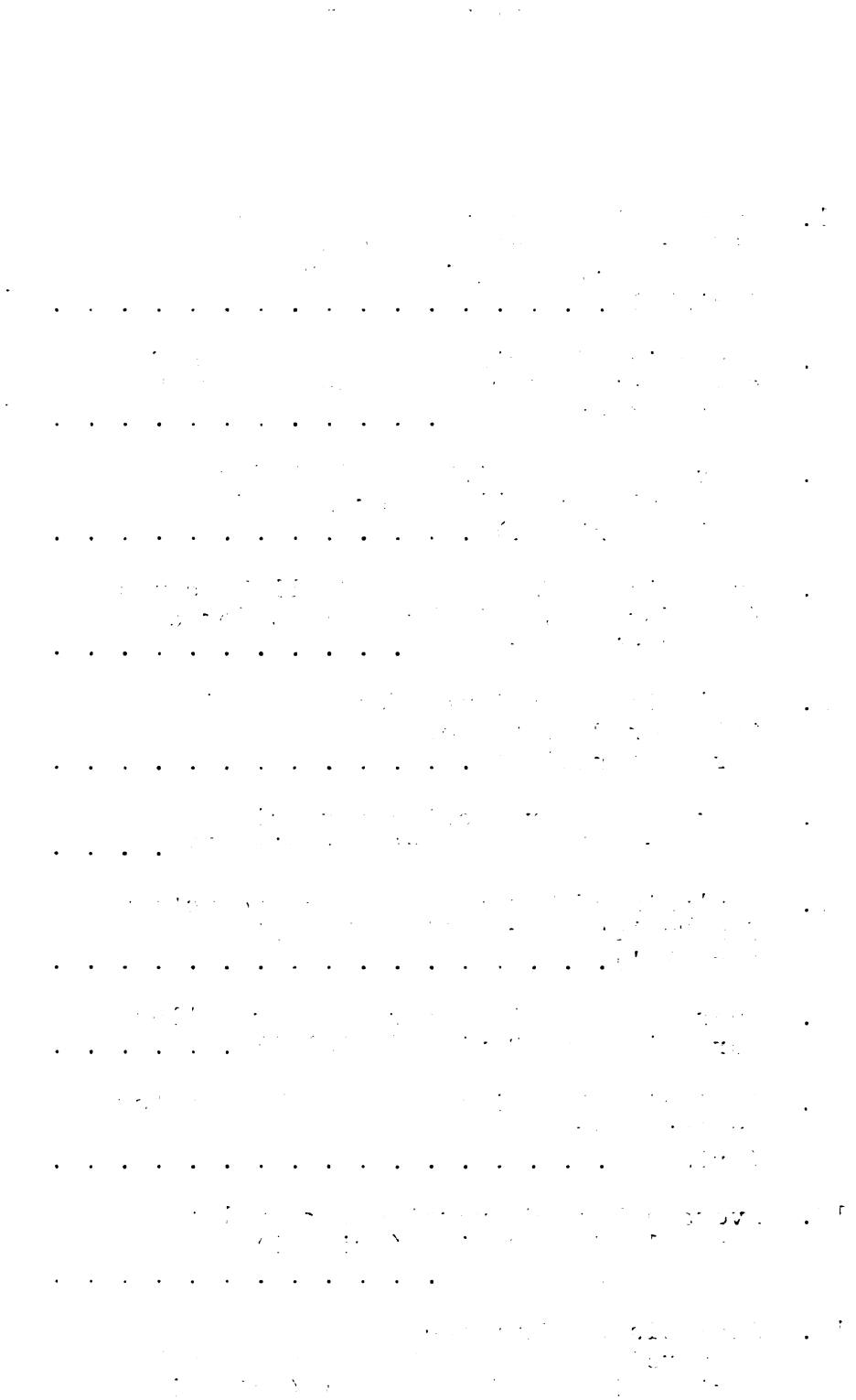

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# INTRODUCTION

It has been stated by S. Shane from the Poultry Tribune May 1981, "Losses due to defective eggshells amount to $33 million for each 1% lost at farm level." The egg industry can ill afford such tremendous cost due to shell damage. Therefore, it is imperative to find better methods of producing stronger eggshells to decrease this loss.

From a review of existing literature, it can be seen that much research regarding the effectiveness of oystershell and limestone improving eggshell quality has been carried out. A relatively new product, rockshell, is now available as a source of calcium for poultry. An experiment was designed to compare different levels of rockshell, oystershell and limestone as sources of calcium in the diet of laying hens and laying pullets.

# LITERATURE REVIEW

For many years researchers have been investigating ways to improve eggshell quality. Collier (1892) indicated that oystershell might be soluble in the gizzard of the chicken. This was the basic step leading others to investigate oystershell as a calcium source.

Scott et al (1976) stated that symptoms of calcium deficiency include: 1) retardation of growth, 2) decreased food consumption, 3) high basal metabolic rate, 4) reduced activity and sensitivity, 5) osteoporosis or low calcium rickets, 6) abnormal posture and gait, 7) susceptibility to internal hemorrhage, 8) a large increase in the volume of urine, 9) a reduced span of life, and 10) thin eggshells and reduced egg production.

There have been numerous researches conducted to determine the most effective sources of calcium for use in the diet of laying chickens. Pratt and Gutteridge (1944) found no significant differences in specific gravity of eggs from hens fed eggshell and those fed oystershell. However, a difference was found in the calcium content. Quisenberry et al (1969) found in comparing two different calcium sources, calcium carbonate and oystershell flour, that birds fed oystershell flour as a source of calcium laid larger eggs and had better livability than those fed calcium carbonate. Later, Quisenberry and Walker (1970) reported that the source of calcium had no effect upon egg production, feed efficiency and mortality. However, a significant

difference was found in the shell quality measurements due to the calcium source; oystershell resulting in superior shell weight and thickness.

Johnston and Tzyy (1973) used five different diets with calcium sources as follows: Fine calcite, hen size calcite, hen size oystershell, two-thirds hen size oystershell with one-third fine calcite, two-thirds hen-sized calcite with one-third fine calcite. Results showed no difference in eggshell thickness or in egg production between treatments.

Harris et al (1975) reported a study using five calcium sources at a level of 3% calcium. The sources were: 1) limestone, 2) aragonit, 3) oystershell, 4) mactra clam shell, and 5) eggshell. Results indicated no significant difference in shell thickness or egg weight.

Parkhurst and Garlich (1975) in their used three treatments consisting of the following sources of calcium: 1) 2/3rd hen size oystershell and 1/3rd hard shell, 2) 2/3rd hen size oystershell and 1/3rd oystershell meal, 3) 2/3rd hen size cage cal meal. The birds receiving 2/3rd hen size oystershell and 1/3rd oystershell meal consumed less feed and produced a dozen eggs with the least amount of feed. It was concluded that hens fed oystershell produced eggs with significantly thicker shells and fewer cracks.

Charles (1978) did a special study using Shell Aid at a 0.25% to 1% level in the diet of older hens. His results indicated that older hens can benefit substantially

from the use of Shell Aid.

Several problems have occurred regarding the calcium distribution in hen diets. Researchers have found that some calcium sources are distributed in the diets better than other sources. Margruder (no date) reported a study involving calcium dispersion in relation to the calcium source. He found that when at least 50% of hen size oystershell has been added to the diet as a calcium source, a better distribution of calcium in the diet may be obtained. This helps eliminate the problem of having a calcium deficiency in feed formulation.

It has been found by researchers that laying hens can receive a higher level of calcium during the night by supplementing oystershell into the diets; whereas, other sources of calcium will not provide the hens with enough dietary calcium during the night. Scott et al (1971) reported that supplying calcium in the ratio of two-thirds oystershell and one-third pulverized limestone in the diets of laying hens improved eggshell quality. They also reported that oystershell particles were retained in the gizzard after 12 hours of fasting. However, no particles were found in the gizzard of hens receiving only the pulverized limestone diet.

Roland and Harms (1973) found that the digestive system of the laying hen contained more calcium in the late afternoon compared to the early morning. They also found that it contained the smallest amount from 12 midnight to 4 am.

Wilhelm (1940) found that the rate of production and shell thickness are not dependent on each other. He also stated that there is a definite seasonal trend in eggshell thickness which is related with temperature.

Sullivan and Kuhl (1974) conducted a research project to compare oystershell and limestone as large particle calcium supplements in rations for laying chickens. Their results indicated that crushed oystershell at the 5% level in the diet of laying chickens increased hen-day egg production by 1.8%, decreased cracked and checked eggs by 3.1% and reduced the feed required per dozen eggs by 0.3 lbs.

Gleaves and Ivy (1974) reported a study using three levels of egg production which were 0, 50 and 75% along with four levels of dietary calcium which were 0.5, 2.0, 4.0 and 6.0 percent. Each of the four diets was supplied with and without supplemental oystershell. Their results indicated that hens fed oystershell continuously consumed approximately the same energy and protein content at the 50.2% and 72.5% production levels, but consumed more oystershell at the higher production level.

Sanford (1974) conducted a study using pulverized calcium carbonate and hen size oystershell as sources of supplemental calcium. His results indicated that supplying at least one-half of the supplemental calcium as hen size oystershell helped to improve egg size and shell quality as compared with the use of all pulverized calcium.

There have been several reports on the effect of

calcium level added to the diet on egg production, egg weight, shell thickness and feed consumption. Hurwitz and Grimminger (1959) fed laying hens rations containing calcium levels of 1.85% and 2.7%. Their results showed that shell thickness and shell weight were improved with higher levels of calcium.

Petersen et al (1959) conducted a study involving the calcium and phosphorus level in the diet. The experiment consisted of using calcium at 2.25%, 3.75%, 4.50% and 5.25% levels. The results indicated a significant improvement in shell quality at the 3.75% level.

Hurwitz and Bar (1966) conducted a study involving two experiments. The first experiment involved restricting the calcium in the diet to observe the changes in shell and bone calcium. The second experiment consisted of a high or low calcium diet with gypsum and limestone during a 5-day depletion diet. The calcium content of eggshells and bones was measured during this period and a subsequent 3-week repletion period. Their results proved that the dietary calcium depletion resulted in a progressive decrease in blood and eggshell calcium. They observed that following a 5-day depletion with 1.7% calcium diets, eggshell calcium returned to normal after 6-8 days on a high calcium regime.

Berg et al (1951) conducted a study to test the hypothesis that during certain seasons shell quality decline may be caused by a decrease in the ability of the birds to assimilate shell-forming material from their food. This could result in an increase of the requirement for calcium and/or Vitamin D as the laying hen ages. The experiment

consisted of feeding birds the recommended level of 2.25 percent calcium along with 450 units of vitamin D per pound of feed. The birds were given the National Research Council's recommendation for three 28-day periods. At the end of the third 28-day period the calcium level was increased to 2.625% with the vitamin D level unchanged for the first group. The second group was supplied with an increase of vitamin D to 675 units per pound of feed with the calcium level unchanged. For the third group, both the calcium and vitamin D were increased to 2.625% calcium along with 675 units of vitamin D. Their results indicated that increasing the level of calcium and/or vitamin D did not affect egg production or egg weight, nor did it prevent the seasonal decline in thickness and smoothness of eggshells.

McKinney and Gholston (1972) found that highest production and shell thickness were obtained with 3.7% calcium from oystershell followed by 4.8% calcium from limestone.

Sauveur and Mongin (1974) conducted an experiment to determine the effect that time of day oystershell was available to birds had on eggshell quality. The three time periods used were afternoon, early morning and late afternoon. Their results indicated that oystershell supplied in the morning and early afternoon resulted in a lower shell quality compared to that from oystershell distributed during the late afternoon. They also found that feed consumption was lower during the late afternoon compared to the morning and early afternoon.

Charles (1972) conducted an experiment to evaluate the effect on eggshell breaking strength of using various dietary treatments with two strains of birds. There were five dietary treatments consisting of six replicates. Each replicate consisted of five hens from strain A and strain B. The dietary treatment consisted of a basal ration with different calcium supplementation: (1) granulated calcium carbonate, (2) oystershell, (3) finely ground marble flour, (4) oystershell in combination with calcium carbonate, (5) oystershell in combination with marble flour. Calcium from oystershell did not improve shell strength in strain A, nor did marble flour seem to depress breaking strength. In strain B, breaking strength was significantly depressed with marble flour, but was significantly improved by the use of oystershell in combination with finely ground calcium carbonate.

Massengale and Platt (1930) conducted an experiment to determine the effect of calcium from different sources on the growth and egg production of poultry. Five groups of chicks were used in the experimental procedure. Treatments were as follows: (1) 1.5% calcium in the form of oystershell plus basal ration, (2) 1.5% calcium in the form of limestone plus basal ration, (3) 1.5% calcium in the form of C.P. calcium carbonate plus basal ration, (4) 1.5% calcium in the form of precipitated tri calcium phosphate and (5) basal ration with no added calcium. Their results indicated that birds receiving oystershell and limestone were larger and

had better appearance than any other groups. However, the birds receiving precipitated Ca $(PO)_2$ gained as much weight as those that received limestone and oystershell. The eggs produced by the groups receiving C.P. calcium carbonate were larger than those from the other groups. Shell percentage was the same for birds receiving oystershell, limestone and $Ca_3 (PO_4)_2$.

EGG PRODUCTION

Arvat and Hinners (1973) reported that in their experiment, egg production on a hen housed basis was not significantly affected by levels or sources of calcium in the diet. Calcium sources failed to result in significant differences in shell thickness. However, shell thickness was significantly better at the 5.7% calcium level than at the 3.7% level.

Tremere et al (1972) found that the level or sources of dietary calcium did not affect egg production, expressed on hen day basis, nor feed consumed per dozen eggs produced.

FEED CONSUMPTION AND EFFICIENCY

Scott et al (1971) found that a calcium intake of 2.8g of calcium per hen per day was inadequate and caused an increase in feed consumption and a significant decrease in eggshell quality.

Holder and Sullivan (1973) found that neither calcium level nor particle size had any consistent or great influence on percent egg production, egg weight, or feed efficiency.

Watkins et al (1976) reported that the highest level of dietary calcium (3.25%) in their diets resulted in a significant improvement in feed efficiency and egg weight; however, egg production and eggshell breaking strength for hens fed 2.5% calcium were equal to that of hens fed 3.25% calcium and significantly better than for those fed 1.75% calcium.

Charles (1975) conducted a study using 2.5% and 3.5% calcium in the diet. All diets were isonitrogenous and isocaloric. His results indicated that birds receiving 2.5% calcium consumed more feed than did birds receiving 3.5% calcium. Harms et al (1961) found that a level of 5.5 percent calcium in the diet of hens for a period of ten months did not affect feed consumption nor performance as indicated by egg production, shell thickness or mortality.

SHELL THICKNESS

In the experimental procedure of Berg et al (1947) there were three pre-laying rations given to each group of birds. Ration 1 contained 0.68 percent calcium without limestone flour. Ration 2 calcium level was increased to .93 percent and ration 3 to 3.02 percent. They determined the effect of calcium level on egg production and shell thickness with higher and lower levels of calcium in the diets. Other birds were placed on rations 4 and 5 after reaching sexual maturity and the diets contained 1.03 and 2.93 percent calcium, respectively. Their results indicated that shell thickness and egg production are not influenced

by the level of calcium during the pre-laying period, however, they are affected by the level of calcium fed during the laying period.

Bletner et al (1975) found that increasing the levels of calcium throughout the laying year had no significant effect on egg shell quality or other production parameters.

Roberson and Francis (1965) reported an experiment using two ascorbic acid levels, two calcium levels and three levels of reserpine to observe the affect on egg production, egg weight and shell thickness. They indicated that there was no significant difference found in egg production or egg weight measurements due to the calcium level. However, their data did indicate a significant difference in shell thickness due to the level of calcium in the diet.

## OBJECTIVES

1. To compare rockshell (a form of calcium containing 38% calcium, .17% magnesium and .10% phosphorous) with limestone and oystershell as a source of calcium in rations for laying hens and laying pullets.

2. To determine the response of laying hens and laying pullets to increasing levels of rockshell compared to limestone and oystershell.

The parameters studied were:

a. Shell quality
b. Egg Production
c. Feed conversion
d. Body weight
e. Egg weight

## PROCEDURES AND METHODS

The experiment was carried out at the Poultry Science Research and Teaching Center, Michigan State University. Data were collected during four 28-day periods from September 22, 1980 to January 12, 1981.

The experiment consisted of two trials. Trial one involved 192 laying pullets 18 weeks of age. There were twelve treatments consisting of four birds assigned to each replicate. Trial two consisted of 164 laying hens between 48-56 weeks of age. There were twelve treatments consisting of four replicates with three birds assigned to each replicate. Prior to the start of the experiment, the birds used in trial two had been housed on the floor and had been receiving approximately fourteen hours of light. On June 24, 1980 the birds were moved from floor pens to cages. Birds were given the same amount of light (14 hours) they had formerly received. After the sudden change of environment the birds started molting. The experimental procedure started after all birds had gone through a complete molt.

All diets were mixed prior to the start of the experiment. Feed cans were provided individually for each replicate for each treatment. All birds were placed in individual cages with replicates from all treatments distributed evenly throughout the house. Water and feed troughs were connected to the front of all cages. Water and feed were provided ad libitum. Birds were fed their

dietary treatment carefully and accurately throughout the entire experiment. Temperature was recorded daily for the house during the coldest months of the experiment.

The initial weights of all birds were obtained on August 22, 1980. Birds were assigned to each dietary treatment according to their initial weight. All cages were labeled to designate each replicate treatment for every group.

The experimental treatment consisted of the following levels and sources of calcium:

1) 2.75% calcium from oystershell and Basal Ration
2) 2.75% calcium from limestone and Basal Ration
3) 2.75% calcium from rockshell and Basal Ration
4) 3.0% calcium from oystershell and Basal Ration
5) 3.0% calcium from limestone and Basal Ration
6) 3.0% calcium from rockshell and Basal Ration
7) 3.25% calcium from oystershell and Basal Ration
8) 3.25% calcium from limestone and Basal Ration
9) 3.25% calcium from rockshell and Basal Ration
10) 3.5% calcium from oystershell and Basal Ration
11) 3.5% calcium from limestone and Basal Ration
12) 3.5% calcium from rockshell and Basal Ration

During this study the following traits were measured:

1. Egg Production

Egg production was recorded daily for four 28-day periods beginning September 22, 1980. A record was posted to account for all eggs produced daily and was summarized every 28-day period.

2. Egg Weights

All eggs were marked and collected from each group on a four-day basis during the four 28-day periods. Eggs were weighed to the nearest .5 gram using a Toledo weighing scale.

3. Shell Thickness

Shell thickness was measured with a micrometer (Ames Thickness Gauge Model 25 ME, B.C. Ames Co., 131 Lexington St., Waltham, Ma. 02154). A specific portion was measured on the egg approximately ¼" away from the apex. There was a four month average used to determine shell thickness. All shells were washed and air dried for a period of 48 hours. There was a three-day period used for egg collection for every 28-day period.

4. Feed Consumption

At the start of each four 28-day periods, the feed given to each treatment replicate group was weighed to the nearest 0.01 kg. Feed consumption was summarized at the end of every 28-day period. All feed cans were labeled. The remaining feed in troughs and

storage can of each replicate was weighed back at the end of each 28-day period to determine the amount of feed consumed.

5. Mortality

A record for mortality was kept for every treatment group and was summarized at the end of every 28-day period.

6. Body Weight Gain

The initial weight and final weight were obtained to determine the weight gain for all experimental treatments.

7. Feed Conversion

Feed conversion was calculated by the amount of feed consumed per dozen of eggs produced.

Data obtained were subjected to statistical analysis, and two statistical tests (F-test and Dunnet's test) were employed to compare the effects of the sources of calcium on shell quality, egg production, feed conversion, body weight gain, feed consumption and egg weight.

## RESULTS AND DISCUSSION

### Experiment 1 (Pullets)

(A) Feed Consumption

It appears that as the level of calcium was increased, feed consumption tended to decrease (Tables 1 and 2). The birds receiving 2.75% and 3.0% calcium consumed significantly ($P < .05$) more feed compared to the birds that were receiving 3.25% and 3.5% calcium. This agrees with Charles (1975) who reported that birds receiving 2.5% calcium consumed more feed than birds receiving 3.5% calcium. In the present experiment there were no interactions found for source by level. Period was highly significant and caused an interaction for source by period to be significant ($P < .01$).

(B) Shell Thickness

From observing the data it can be seen that birds receiving the diets containing rockshell as a source of calcium produced eggs with the highest value for shell thickness (Tables 3 and 4). This was probably due to the shell measurement at the 2.75% calcium level. Oystershell and rockshell values were similar. However, eggs from birds receiving diets containing rockshell showed a decline in shell thickness at the 3.5% calcium level, whereas, eggs from birds fed oystershell showed an increase in shell thickness. Eggs from birds fed limestone showed a decline in shell thickness at the 3.25% and 3.5% calcium levels. The data from this experiment indicated a highly significant

Table 1 - Average Feed Consumption of the Different Experimental Groups (kilograms) for a 16 week period (Trial 1)

| Calcium Source | Level of Calcium in Diet 2.75% | 3.0% | 3.25% | 3.5% | Mean |
|---|---|---|---|---|---|
| Oystershell | 11.94 | 12.60 | 10.57 | 11.25 | 11.55 |
| Limestone | 12.05 | 11.52 | 10.31 | 11.06 | 11.23 |
| Rockshell | 12.79 | 12.34 | 11.06 | 11.66 | 11.81 |
| Mean | 12.26Aa | 12.15Aa | 10.6Bc | 11.32Ab | |

+ Any two means having the same letter are not significantly different: means not having the same letter are significantly different. Small letters indicate significance at the .05 level: large letters at the .01 level.

Table 2 - Analysis of Variance of Final Average Feed Consumption of Pullets for a 16 week period (Trial 1)

| Source of Variation | D.F. | S.S. | M.S. | F |
|---|---|---|---|---|
| Source | 2 | 10.7837 | 5.39189 | 3.3447* |
| Level | 3 | 73.69172 | 24.56391 | 15.25768** |
| (S/L) | 6 | 14.32546 | 2.38758 | 1.48100 |
| Rep/(S/L)$E_1$ | 36 | 58.03391 | 1.61205 | |
| Period | 3 | 787.40859 | 262.46933 | 55.1479** |
| P/S | 6 | 73.94812 | 12.32469 | 25.8956** |
| P/L | 9 | 105.19184 | 11.69798 | 2.4585* |
| P/SL | 18 | 214.82136 | 11.93452 | 2.5075** |
| (Rep/P)$E_2$ | 108 | 514.0124 | 4.759 | |

* Significant.05 level

** Significant .01 level

Table 3 - Average Shell Thickness (mm) for Eggs Laid by Pullets for a 16 week period (Trial 1)

| | Level of Calcium in Diet | | | | |
|---|---|---|---|---|---|
| Calcium Source | 2.75% | 3.0% | 3.25% | 3.5% | Mean |
| Oystershell | .46 | .45 | .46 | .47 | .46Yzz |
| Limestone | .48 | .47 | .37 | .35 | .42Yy |
| Rockshell | .55 | .47 | .47 | .44 | .48Zw |
| Mean | .50Bc | .46Ab | .43Aa | .42Aa | |

+ Any two means having the same letter are not significantly different: means not having the same letter are significantly different. Small letters indicate significance at the .05 level: large letters at the .01 level.

Table 4 - Analysis of Variance of shell thickness for Pullets for a period of 16 weeks (Trial 1)

| Source of Variation | D.F. | S.S. | M.S. | F |
|---|---|---|---|---|
| Source | 2 | .0425 | .021125 | 1.847 |
| Level | 3 | .008 | .00267 | .232 |
| S/L | 6 | .4177 | .06962 | 6.054** |
| Rep/(SL)$E_1$ | 36 | .4144 | .0115 | |
| Period | 3 | .01595 | .00532 | 1.004 |
| P/S | 6 | .0624 | .0104 | 2.08 |
| P/L | 9 | .07287 | .0081 | 1.62 |
| S/L/P | 18 | 0.378 | .021 | 4.2** |
| (Rep/P)$E_2$ | 108 | .53818 | .0050 | |

** Significant at .01 level

difference ($P<.01$) for the interaction source by level. There was also a significant difference found for the interaction source by level by period ($P<.01$). For shell thickness this report disagrees with Roberson and Francis (1965) and Hurwitz and Grimminger (1959); however, this report agrees with Bletner et al (1975) that increasing the levels of calcium throughout the laying year had no significant effect on eggshell quality for laying pullets. The data of Roberson and Francis (1965) indicated a significant difference in shell thickness due to the level of calcium in the diet. Hurwitz and Grimminger (1959) reported that shell thickness was improved with higher levels of calcium distributed in the diet.

(C) Body Weight Gain or Loss

There were no significant differences found between treatments for body weight gain or loss over the 16 week period (Table 5).

(D) Egg Production

The highest production rate occurred at the 2.75% calcium level with the lowest occurring at the 3.0% calcium level (Table 6). These data disagree with Arvat and Hinners (1973) and Holder and Sullivan (1973) who reported that egg production was not significantly affected by sources or levels of calcium in the diet. Holder and Sullivan (1973) suggested that calcium level had no great influence on egg production. Charles' (1978) results indicated that clamshell was superior to or equal to oystershell in its effect on egg

Table 5 - Analysis of Variance for Body Weight Gain for Pullets for a 16 week period (Trial 1)

| Source of Variation | D.F. | S.S. | M.S. | F |
|---|---|---|---|---|
| Source | 2 | 2986.87 | 14793.44 | .4456 |
| Level | 3 | 97915.55 | 32638.52 | .1605 |
| S/L | 6 | 613953.36 | 102325.56 | .0031 |
| Error | 35 | 625780.60 | 17879.45 | |

Table 6 - Average Production for Pullets (%) for a 16 week period (Trial 1)

| Calcium Sources | 2.75% | 3.0% | 3.25% | 3.5% | Mean |
|---|---|---|---|---|---|
| Oystershell | 81.18 | 73.21 | 74.29 | 78.32 | 76.75Zz |
| Limestone | 81.86 | 62.36 | 81.5 | 69.53 | 73.81Yz |
| Rockshell | 72.92 | 59.54 | 70.39 | 72.82 | 68.92Yy |
| Mean | 78.65Bb | 65.04Aa | 73.39Bb | 73.56Bb | |

+ Any two means having the same letter are not significantly different: means not having the same letter are significantly different. Small letters indicate significance at the .05 level; large letters at the .01 level.

production. There was a significant difference found for source by level interaction ($P < .05$) (Table 7).

(E) Egg Weight

In this study, egg weights showed a highly significant difference due to sources of calcium in the diet (Tables 8 and 9). Differences due to calcium level were also highly significant ($P < .01$). The 3.0% and 2.75% levels resulted in eggs that were significantly ($P < .01$) heavier than those from hens receiving the 3.25% and 3.5% levels of calcium. This does not agree with Holder and Sullivan (1973) who suggested that calcium level had no great influence on egg weight.

(F) Feed Conversion

There was no significant difference in feed conversion between birds fed diets containing calcium from different sources (Tables 10 and 11). However, there was a significant difference found for levels and the interaction source by level ($P < .01$). This report agrees with Parkhust and Garlich (1975) that birds fed oystershell consumed less feed compared to other treatments, and produced a dozen eggs by utilizing the least amount of feed. This report agrees with Holder and Sullivan (1973) that calcium level did not have any great influence on feed efficiency.

Experiment 2 (layers)

(A) Feed Consumption

In this experiment no significant differences were found in feed consumption that could be attributed to source or level of calcium in the diet (Table 12 and 13). There was a significant difference found for the interaction source

Table 7 - Analysis of Variance of Production for Pullets for a 16 week period (Trial 1)

| Source of Variation | D.F. | S.S. | M.S. | F |
|---|---|---|---|---|
| Source | 2 | 27.79 | 13.9 | .716 |
| Level | 3 | 287.47 | 95.8 | 4.94** |
| S/L | 6 | 387.93 | 64.66 | 3.33* |
| Rep/(SL)$E_1$ | 36 | 698.92 | 19.41 | |
| Period | 3 | 513.313 | 171.10 | 15.18** |
| P/S | 6 | 37.61 | 6.27 | .556 |
| P/L | 9 | 94.12 | 10.46 | .928 |
| P/S/L | 18 | 173.4 | 9.63 | .854 |
| (P/Rep)$E_2$ | 108 | 1217.57 | 11.27 | |

* Significant at the .05 level

** Significant at .01 level

Table 8 - Average Egg Weight (grams) for Pullets for a 16 week period (Trial 1)

| | Level of Calcium in Diet | | | | |
|---|---|---|---|---|---|
| Calcium Source | 2.75% | 3.0% | 3.25% | 3.5% | Mean |
| Oystershell | 54.13 | 54.13 | 54.81 | 55 | 54.51Zz |
| Limestone | 54.44 | 55.68 | 47.87 | 53.56 | 52.89Yy |
| Rockshell | 51.63 | 54.13 | 54.38 | 47.13 | 51.83Yy |
| Mean | 53.43Bb | 54.65Bb | 52.35Aa | 51.90Aa | |

+ Any two means having the same letter are not significantly different: means not having the same letter are significantly different. Small letters indicate significance at the .05 level; large letters at the .01 level.

Table 9 - Analysis of Variance of Egg Weight for Pullets for a 16 week period (Trial 1)

| Source of Variation | D.F. | S.S. | M.S. | F |
|---|---|---|---|---|
| Source | 2 | 1266 | 633 | 111.56** |
| Level | 3 | 101.76 | 33.92 | 5.978** |
| S/L | 6 | 75.75 | 12.63 | 2.25 |
| Rep/(SL)$E_1$ | 36 | 204.278 | 5.674 | |
| Period | 3 | 1643.94 | 547.98 | .6363 |
| P/S | 6 | 387.10 | 64.52 | .0434 |
| P/L | 9 | 2952.17 | 328.02 | .2208 |
| P/L/S | 18 | 2733.48 | 1485.59 | 1.73* |
| (Rep/P)$E_2$ | 108 | 775.07 | 861.12 | |

*Significant at .05 level

**Significant at .01 level

Table 10 - Average Feed Conversion for Pullets for a 16 week period (Trial 1) ( $\frac{\text{Pounds feed}}{\text{Doz. eggs}}$ )

| Calcium Source | Level of Calcium in Diet 2.75% | 3.0% | 3.25% | 3.5% | Mean |
|---|---|---|---|---|---|
| Oystershell | 1.576 | 2.208 | 1.875 | 2.0298 | 1.92 |
| Limestone | 2.001 | 1.672 | 1.989 | 2.442 | 2.00 |
| Rockshell | 1.84 | 2.208 | 1.973 | 1.97 | 2.00 |
| Mean | 1.803Aa | 2.027Ab | 1.70Aa | 2.147Ab | |

+ Any two means having the same letter are not significantly different: means not having the same letter are significantly different. Small letters indicate significance at the .05 level; large letters at the .01 level.

Table 11 - Analysis of Variance Feed Conversion for Pullets for a 16 week period (Trial 1) ( $\frac{\text{Pounds Feed}}{\text{Doz. eggs}}$ )

| Source of Variation | D.F. | S.S. | M.S. | F |
|---|---|---|---|---|
| Source | 2 | .08625 | .04312 | .6455 |
| Level | 3 | .8375 | .2792 | 4.180** |
| S/L | 6 | 2.435 | .4058 | 6.0748** |
| Error | 36 | 2.403 | .0668 | |

** Significant at .01 level

Table 12 - Average Feed Consumption of the Different Experimental Groups (kilograms) (Trial 2)

| Calcium Sources | Level of Calcium in Diet 2.75% | 3.0% | 3.25% | 3.5% | Mean |
|---|---|---|---|---|---|
| Oystershell | 9.74 | 9.83 | 11.42 | 9.60 | 10.15 |
| Limestone | 10.37 | 10.73 | 8.78 | 9.50 | 9.84 |
| Rockshell | 10.08 | 8.80 | 9.11 | 11.32 | 9.83 |
| Mean | 10.06 | 9.78 | 9.77 | 10.14 | |

+ Any two means having the same letter are not significantly different: means not having the same letter are significantly different. Small letters indicate significance at the .05 level; large letters at the .01 level.

Table 13 - Analysis of Variance of Feed Consumption of Layers for a 16 week period (Trial 2)

| Source of Variance | D.F. | S.S. | M.S. | F |
|---|---|---|---|---|
| Source | 2 | 4.1211257 | 2.06078 | 1 |
| Level | 3 | 5.11818 | 1.70606 | 1 |
| S/L | 6 | 128.74123 | 21.45687 | 5.6635** |
| Rep/(SL)$E_1$ | 36 | 136.39058 | 3.78863 | |
| Period | 3 | 496.85862 | 165.61954 | 56.086** |
| P/S | 6 | 21.0993 | 3.51665 | 1.19088 |
| P/L | 9 | 125.2514 | 13.91680 | 4.7128** |
| P/SL | 18 | 152.50484 | 8.47249 | 2.86914 |
| (P/Rep)$E_2$ | 108 | 318.9211 | 2.952973 | |

** Significant at the .01 level

by level ($P < .01$). Period was highly significant ($P < .01$).

(B) Shell Thickness

In the present experiment a highly significant difference in shell thickness was found for both source of calcium and the diet and level ($P < .01$) (Tables 14 and 15). Eggshells from hens receiving limestone had the lowest mean average thickness and those from hens fed rockshell had the highest average thickness. This increase in shell thickness for rockshell was due to the J0 value at the 3.5% calcium level. No significant difference was found between oystershell and limestone. No significant difference was found for level with the exception of the 3.5% calcium level which resulted in significantly thicker eggshells. This report agrees with Petersen et al (1959) who reported a significant improvement in shell quality at the 3.75% calcium level. Quinsenberry and Walker (1970) found a significant difference in shell quality measurements due to the calcium source with oystershell producing superior shell thickness. Berg et al (1974) indicated that shell thickness is not influenced by the level of calcium during the pre-laying period; however, they reported that shell thickness is affected by level during the laying period.

(C) Body Weight Gain

No significant differences were found between treatments for body weight gain over the 16 week period (Table 16).

(D) Egg Weight

There were no significant differences in average weights of eggs produced by hens on the different treatments.

Table 14 - Average Shell Thickness for Layers (mm) for a 16 week period (Trial 2)

| | Level of Calcium in Diet | | | | |
|---|---|---|---|---|---|
| Calcium Source | 2.75% | 3.0% | 3.25% | 3.5% | Mean |
| Oystershell | .47 | .49 | .49 | .51 | .49Yy |
| Limestone | .49 | .49 | .48 | .46 | .48Yy |
| Rockshell | .48 | .50 | .49 | .70 | .542Zz |
| Mean | .48Aa | .49Aa | .49Aa | .56Bb | |

+Any two means having the same letter are not significantly different: means not having the same letter are significantly different. Small letters indicate significance at the .05 level; large letters at the .01 level.

Table 15 - Analysis of variance of Shell Thickness for Layers for a 16 week period (Trial 2)

| Source of Variation | D.F. | S.S. | M.S. | F |
|---|---|---|---|---|
| Source | 2 | 0.944 | .472 | 48.16** |
| Level | 3 | .4836 | .1612 | 16.44** |
| $SS_E$ | 86 | 0.084 | .00098 | |

** Significant at the .01 level

Table 16 - Analysis of Variance Body Weight Gain for Layers for a 16 week period (Trial 2)

| Source of Variation | D.F. | S.S. | M.S. | f |
|---|---|---|---|---|
| Source | 2 | 85288.80 | 42644.40 | .49011 |
| Level | 3 | 17801.58 | 5933.86 | .95875 |
| S/L | 6 | 346028.48 | 57671.41 | .45064 |
| $SS_E$ | 35 | 2050618.43 | 58589.10 | |

(E) Egg Production

There was a significant difference in egg production of birds receiving different levels of calcium with those on the 3.5% level favored (Tables 17 and 18). This report agrees with Quisenberry and Walker (1970) who reported that the source of calcium had no effect upon egg production. This report disagrees with Tremere et al (1972) who found that the level or sources of dietary calcium did not affect egg production, expressed on a hen day basis.

(F) Feed Conversion

There were no significant differences found for source. However, a significant difference was found for level and the interaction source by level ($P < .01$) (Tables 19 and 20).

Table 17 - Average Egg Production per Layer for a 16 week period (%) (Trial 2)

| Calcium Source | Level of Calcium in Diet 2.75% | 3.0% | 3.25% | 3.5% | Mean |
|---|---|---|---|---|---|
| Oystershell | 44.78 | 36.18 | 31.12 | 52.14 | 41.06Zz |
| Limestone | 29.12 | 36.46 | 44.79 | 28.12 | 34.62Yy |
| Rockshell | 33.68 | 37.64 | 28.46 | 48.43 | 37.05Yy |
| Mean | 35.86Aa | 36.76Aa | 34.79Aa | 42.90Bb | |

+ Any two means having the same letter are not significantly different: means not having the same letter are significantly different. Small letters indicate significance at the .05 level; large letters at the .01 level.

Table 18 - Analysis of Variance Layers Production 16 week period (Trial 2)

| Source of Variation | Degrees of Freedom | Sum of Square | Mean Square | F Stastic |
|---|---|---|---|---|
| Source | 2 | 9.398 | 4.70 | .2016 |
| Level | 3 | 2622 | 874 | 37.49** |
| $SS_E$ | 469 | 10934.16 | 23.31 | |

** Significant at the .01 level

Table 19 - Average Feed Conversion 16 week period

(Trial 2)

| | Level of Calcium in Diet | | | | |
|---|---|---|---|---|---|
| Calcium Source | 2.75% | 3.0% | 3.25% | 3.5% | Mean |
| Oystershell | 3.968 | 5.208 | 7.961 | 3.864 | 5.25 |
| Limestone | 3.732 | 6.492 | 5.764 | 6.89 | 5.72 |
| Rockshell | 7.057 | 4.246 | 6.259 | 3.791 | 5.34 |
| Mean | 4.919Aa | 5.31Aa | 6.661Bb | 4.848Aa | |

+ Any two means having the same letter are not significantly different: means having the same letter are significantly different. Small letters indicate significance at the .05 level; large letters at the .01 level.

Table 20 - Analysis of Variance of Feed Conversion for Layers for a 16 week period (Trial 2)

| Source of Variation | Degrees of Freedom | Sum of Square | Mean Square | F Stastic |
|---|---|---|---|---|
| Source | 2 | 2.394 | 1.197 | .345 |
| Level | 3 | 26.025 | 8.675 | 2.51 |
| S/L | 6 | 99.32 | 16.55 | 4.78** |
| $SS_E$ | 36 | 124.731 | 3.46 | |

** Significant at the .01 level

# SUMMARY

This Report has indicated that:

(1) At the 3.5% calcium level for laying hens and the 2.75% calcium level for laying pullets, rockshell is superior to oystershell and limestone in its effects on eggshell thickness.

(2) Calcium sources and levels have a significant influence on egg production. At the 3.5% and 2.75% calcium level,.. for both laying hens and laying pullets, birds receiving the diet containing oystershell produced more eggs than did birds receiving either limestone or rockshell as a source of calcium.

(3) Calcium sources have no significant influence on feed consumption, body weight gain or loss, or feed efficiency for either laying hens or laying pullets.

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(E) Egg Production

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| $SS_E$ | 469 | 10934.16 | 23.31 | |

** Significant at the .01 level

APPENDIX TABLE 1 - Composition of the 2.75% calcium level diet used in the experiments

| Ingredient | % |
|---|---|
| Corn, ground yellow | 69.7 |
| Soybean Meal, 45% protein | 18.1 |
| Alfalfa | .1784 |
| Dical | .60152 |
| *Calcium Carbonate | 5.536 |
| Salt | .2992 |
| Methionine DL | .03485 |
| M& B Meal | 5.124 |
| Premix | .4 |

* Indicates the source of calcium used in the experimental diets. Source was oystershell, calcium carbonate or rockshell.

APPENDIX TABLE 4 - Composition of the diet 3.5% calcium level used in the experiments

| Ingredient | % |
|---|---|
| Corn, ground yellow | 68.98 |
| Soybean Meal, 45% protein | 17.85 |
| Alfalfa | .175 |
| Dical | .60512 |
| *Calcium Carbonate | 6.76 |
| Salt | .294 |
| Methionine DL | .03429 |
| M&B Meal | 5.044 |
| Premix | .400 |

* Indicates the source of calcium used in the experimental diets. Source was oystershell, calcium carbonate or rockshell.