

To the Graduate Council:

I am submitting herewith a thesis written by Larry Glenn McCraney entitled "The Effects of Incremental Calcium Levels Throughout the Laying Period on Egg Shell Quality." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

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THE EFFECTS OF INCREMENTAL CALCIUM LEVELS THROUGHOUT THE
LAYING PERIOD ON EGG SHELL QUALITY

A Thesis
Presented for the
Master of Science
Degree
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ABSTRACT

The purpose of this experiment was to determine the effect of constant levels of calcium in the diet and the effects of increasing the calcium level in the diet at three different constant rates throughout the laying year on shell quality; egg production, egg weight, and feed consumption.

This study was conducted for 10-28 day periods, using three constant and three variable levels of calcium with three replicate lots per treatment. Five orthogonal contrasts were developed, and a multivariate analysis of variance was used where the response variables were expressed as regression coefficients to show the relationship of the parameters measured over time.

The results show no statistically significant relationship among calcium treatments for average egg weight, feed consumption, body weight and exterior quality. There was no consistent or significant effect of calcium level upon average specific gravity of the eggs. The possibility of further research into incremental calcium feeding is suggested in that the dietary calcium levels of 3.11 to 4.00 percent and 3.15 to 4.25 percent had the highest average specific gravity. Egg production was not statistically significantly affected by dietary calcium level, except that hens fed the 3.00 and 4.00 percent constant calcium levels laid at a higher rate than hens fed the 3.50 percent constant calcium level diet ($P < 0.05$). No logical explanation for this difference can be offered at this time.

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CHAPTER I

INTRODUCTION

The production of quality eggs has been a challenge to poultry men for many years. The reduction in loss due to breakage or poor shell quality has received much attention in recent times.

Estimates have been made that as many as 10 percent of all eggs produced never reach the consumer because of losses due to smashed or cracked eggs resulting from poor shell quality. Commercial egg producers now use mechanical egg gathering and grading equipment which tends to increase the number of cracked and smashed eggs. This makes it imperative that egg shell quality be maintained at as high a level as possible.

Shell quality is a term used by researchers and layment to denote several factors about egg shells such as shell thickness, shape, smoothness, color, breaking strength and texture of the egg shell. Although the nutrition of the bird plays a tremendous role in producing eggs of suitable shell quality, several other factors may also be involved. These include temperature, medicinals, air flow, light, heridity, disease, age of hen and time of oviposition.

Calcium has been the nutrient investigated most extensively by researchers in efforts to improve egg shell quality. The literature on the subject is voluminous but often conflicting. Various sources of calcium, particle sizes and levels of feeding have received wide attention in the scientific and commerical areas.

Wolford and Tanaka (1970) reviewed 57 articles concerning the effects of calcium on egg shell quality. The results of these studies could support any thesis that one would like to propose on the shell quality problem.

In unpublished work at the University of Tennessee Station, Bletner and McCraney (1972) noted that increasing dietary calcium levels or changing the management or feeding regimen designed to improve calcium utilization frequently resulted in an apparent immediate response which disappeared within a matter of two to three weeks.

It is well known that shell quality as measured by such procedures as breaking strength, egg specific gravity, and deformation deteriorates as the layer becomes older. One approach to improve this is to systematically increase the calcium content of the diet in an attempt to retard or eliminate the degradation with time.

Therefore an experiment was designed to determine the effect of increasing the calcium level of the layer diet at three different rates per unit of time on egg shell quality.

Other production parameters such as egg production, egg weight, feed efficiency and mortality were studied to assure that dietary calcium levels had no detrimental affects on these parameters and that the bird's performance was normal.

CHAPTER II

LITERATURE REVIEW

I. NATIONAL RESEARCH COUNCIL RECOMMENDATIONS

FOR CALCIUM AND PHOSPHORUS

The National Research Council (NRC) recommendations of today reflects the importance of continued research in the area of nutrition of farm animals. In the decade of the 1950's, the NRC (1954, 1960) recommended a level of 2.25 percent dietary calcium for laying birds. Peterson et al. (1960) reported that a level of 2.25 percent calcium was not adequate for the production of eggs with maximum shell quality. This prompted a decade of extensive research into the minimal requirement for calcium and phosphorus in laying birds.

Although the NRC (1966) gives the calcium requirement for laying diets as 2.75 percent, this is usually the minimum amount recommended by poultry nutritionists. Many poultry feeds provide about 3.00 percent calcium during cool weather and 3.50 percent calcium during hot weather. A larger amount of calcium is needed at the end of the laying year than at the onset of the laying year according to Scott, Nesheim and Young (1969).

The NRC recommendation for total phosphorus has been at the 0.6 percent level for laying birds since 1954. All the phosphorus of nonplant feed ingredients is considered to be inorganic. Approximately

30 percent of the phosphorus of plant products is nonphytin phosphorus and may be considered part of the inorganic phosphorus required. NRC (1971) also indicates that a portion of the phosphorus requirement of laying hens must be supplied in inorganic form.

II. EFFECTS OF CALCIUM ON SHELL QUALITY

Low Dietary Calcium

In a review Wolford and Tanaka (1970) referred to 17 published papers in which it was indicated that less than 2.00 percent calcium in the diet significantly decreased egg shell quality. Deobald, Lease and Hart (1936) found that sudden removal of free choice oyster shell brought about a gradual diminution of the total amount of mineral present in egg shells. Very thin egg shells, containing only 24 percent of the normal ash content, were obtained when the calcium deficient diet was used. Evans, Carver and Brant (1944b) reported that shell quality was considerably decreased when the dietary calcium level was reduced to 1.00 percent. Many hens receiving this level of calcium withdrew calcium from the bones until the bones were so soft that they would not support the weight of the birds.

Peterson et al. (1960) found that a dietary level of 2.25 percent calcium was not adequate for maximum shell quality. At the time Peterson et al. (1960) completed their study, the NRC (1954, 1960) requirement for calcium was at the 2.25 percent level. Work by Reddy and Sandord (1963) is in agreement with Peterson et al. (1960). MacIntyre, Chancey and Gardiner (1963) found that egg shell quality as

measured by specific gravity was the lowest at the lower dietary calcium levels, but increased significantly ($P < 0.01$) as the level of dietary calcium increased from 1.00 to 3.00 percent.

Mehring and Titus (1964) fed diets containing 0.20, 1.24 and 2.43 percent calcium. Birds which had been fed the lower calcium diet and then changed to the 2.43 percent calcium control diet at intermittent times outperformed the control birds in production and egg shell strength during the time they were fed the 2.43 percent calcium diet.

High Dietary Calcium

Wolford and Tanaka (1970) reviewed 30 papers published on the effects of high dietary calcium on egg shell quality and indicated that 21 papers reported a response to dietary calcium levels in excess of 3.00 percent and nine papers to dietary calcium levels in excess of 4.00 percent as measured by increased egg shell thickness and egg specific gravity.

The feeding of a control diet containing 15 percent protein and 3.00 percent calcium for 8 hours followed by access to free-choice oyster shell for the remaining 6 hours of the 14 hour day, was compared to the feeding of 15 percent protein basal diet plus the addition of 1.00, 2.00 or 3.00 percent calcium with birds that had been in production for five months (Pepper, Summers and McConchie, 1968). The specific gravity of the eggs of hens receiving free-choice oyster shell and those receiving the diets with additional calcium was higher than that of eggs from hens receiving the control ration. However, only the response to the 1.00 and 3.00 percent additional calcium treatments proved to be significantly higher than the controls.

Extra dietary calcium supplementation has received wide attention. Moran, Eyal and Summers (1970) conducted three studies using 72-week old hens, with birds in study 1 receiving 3.00 percent dietary calcium and oyster shell supplementation along with dicalcium phosphate and bone meal, with birds in study 2 being fed a 1.00 percent dietary calcium level and oyster shell, and with the birds in study 3 being fed either a 1.00 or 3.00 percent calcium diet in conjunction with the respective supplements. The authors concluded, that egg shell deterioration with age is not a nutritional inadequacy per se but a geneological consequence that cannot be rectified short of a forced molt rest.

Hinners, Golson and Ritchason (1963) using hens that had been in production for six months, varied the dietary calcium content from 2.27 to 6.27 percent and obtained results indicating an increase in shell thickness as the percent of calcium in the diet increased up to 5.50 percent. Kienholz, McPherron and Orme (1964) increased the calcium content of the diet from 2.50 percent to 4.00 percent after hens had been in production for eight months and obtained eggs with a significantly thicker shell when compared to the hens on the 15 percent protein layer diet containing 2.25 percent calcium.

As the level of dietary calcium becomes an important factor in good shell quality researchers have studied in depth various levels of dietary calcium. Gutowska and Parkhurst (1942) conducted a study for 2 six-month periods with Rhode Island Red Pullets, feeding levels of 2.35, 2.77 and 3.95 percent calcium using calcite as a source of

supplemental calcium. They found no significant differences in the egg shell breaking strength at levels of 2.35, 2.77 and 3.95 percent calcium. Harms and Waldroup (1961) in using a 2 by 2 by 2 factorial design in the first experiment, composed of two levels of ascorbic acid and two levels of diestrol diacetate obtained a significant improvement ($P < 0.05$) in egg shell thickness with the diet containing 4.60 percent calcium as compared with a diet containing 2.50 percent calcium. This difference was due to the calcium content and not the other factors involved. Experiment 2 was conducted to measure the effects of two levels of ascorbic acid, using the 2.50 and 4.60 percent calcium. The ascorbic acid x calcium interaction was nonsignificant. The calcium level of 4.60 percent calcium approached the 0.05 percent level of significance in shell thickness observations. These results are in agreement with the findings of Peterson et al. (1960).

Sullivan and Kingan (1962) using four calcium levels (1.80, 2.80, 3.80 and 4.80 percent), obtained a significant difference ($P < 0.01$) in both shell thickness and specific gravity when the dietary calcium content was increased from 1.80 to 2.80 percent calcium. The higher levels of calcium further increased these parameters, but with less magnitude. Reddy, Sanford and Clegg (1968) reported the results of two experiments that were conducted for 40 weeks each. Experiment 1 utilized calcium levels of 2.25, 2.65, 3.05, 3.45, 3.85, 4.24, 4.65, and 5.05 percent. Experiment 2 included levels of 2.25, 3.05, 3.85 and 4.65 percent. They reported that maximum shell quality as measured by percent shell, was obtained with 5.05 and 3.85 percent calcium in experiments 1 and 2

respectively. Increasing the calcium levels from 2.25 to 3.05 percent showed a greater response in shell quality than that observed when levels were increased above 3.05 percent.

Arvat and Hinnners (1973), using calcium levels of 3.70 and 5.70 percent, found that shell thickness was significantly better at the 5.70 percent calcium level than at the 3.70 percent level. This is in agreement with Hinnners, Gholson and Ritchason (1963). Roland, Sloan and Harms (1973) fed dietary calcium levels of 2.00 and 3.00 percent. They reported improved shell quality in all birds fed the higher calcium levels.

Noneffects of High Dietary Calcium

Stuart and Hart (1939) compared diets containing 1.00, 5.00 and 8.00 percent calcium carbonate added to the basal diet which contained 2.30 percent calcium carbonate, to the standard diet plus ad libitum feeding of oyster shell. They concluded, that feeding of excessive amounts of calcium showed little advantage over the 2.30 percent calcium carbonate basal diet and ad libitum oyster shell feeding.

Hull and Scott (1969) fed levels of 2.50, 3.00, 3.50, 4.00, 4.50 and 5.00 percent calcium to White Leghorn pullets after they had reached peak production and attained mature body weight. Their results indicated that egg shell thickness was as good with 3.50 percent dietary calcium as with any of the higher calcium levels. Wolford and Tanaka (1970) reviewed 10 papers in which high levels of calcium had no effect in which they failed to improve shell quality.

III. EFFECT OF CALCIUM ON EGG PRODUCTION

Dietary calcium levels and their effects on rate of egg production must also be considered when feeding calcium for maximum shell quality. The dietary calcium requirement is related to the percentage retained by the bird, egg size and rate of production. Although, subject to some variation according to environmental temperature and the period during which eggs are laid, the daily calcium intake requirement increases as the rate of production increases.

The minimum and maximum levels of calcium needed to support maximum egg production have been studied extensively. Peterson et al. (1960) fed calcium levels up to 5.25 percent without noting any effects on egg production. Harms and Waldroup (1961) using calcium levels of 2.50 and 4.60 percent, found no significant influence of calcium level on rate of production. Elevation of calcium level after eight months of lay, was studied by Kienholz, McPherron and Orme (1964) by elevating calcium levels from 2.25 to 4.00 percent calcium in the diet. No significant differences were observed in egg production.

Durham et al. (1960) studied the effects of calcium level on egg production. They concluded that the higher calcium level of 4.75 percent produced a small decrease in the rate of egg production. This work is in agreement with the work by Naber, Mackay and Touchburn (1963) and Hurwitz and Bornstein (1966). Reddy, Sanford and Clegg (1968) reported

that calcium levels of 3.05 and 3.85 percent resulted in higher egg production than diets containing lower calcium levels. Levels above 3.85 percent appeared to be detrimental to egg production.

When dietary calcium level was increased from 2.25 percent to 3.95 percent a significant increase in egg production with the higher calcium level was reported by MacIntyre, Chancey and Gardiner (1963). Calcium source and level of calcium in the diet was studied by Quisenberry and Walker (1970). The data indicated that dietary calcium level was positively correlated with egg production, feed efficiency and survival, however the calcium source had no effect on egg production.

Although the optimum calcium level to support egg production is still very much controversial, it is evident from research findings, that calcium levels below 2.25 percent may cause decreases in rate of production.

IV. EFFECT OF CALCIUM ON EGG WEIGHT

Researchers have been able to produce significant results showing that calcium levels above 2.25 percent have improved egg shell quality. However, studies on the effects of calcium on egg weight have been inconclusive.

Calcium levels in the diet may become detrimental to average egg weight when the calcium level is much less than the 2.25 percent level.

MacIntyre, Chancey and Gardiner (1963) fed calcium levels of 1, 2, 3, 4, 5 and 6 percent. Average egg weight was significantly ($P < 0.01$) lower on the low calcium ration.

Hinners, Gholson and Ritchason (1963) used dietary calcium levels from 2.27 to 6.27 percent and obtained results showing improvement in shell thickness as calcium level increased up to 5.50 percent, but no significant difference in egg weight. Gerry and Bird (1967) reported that calcium levels of 2.25, 3.00 and 3.75 percent had no significant effect on egg weight. The influence of level and particle size of the calcium supplement was shown by Holder and Sullivan (1973) to have no consistent effect or great influence on egg weight. This is in agreement with the work by Gerry on egg weight. This is in agreement with the work by Gerry and Bird (1967) and Roland, Sloan and Harms (1973).

Calcium levels in excess of 2.25 percent have been also shown to negatively affect egg weight. Reddy and Sanford (1963) reported that calcium levels above 2.25 percent resulted in poorer egg weight. These results are in contradiction to those of Gerry and Bird (1967).

V. EFFECT OF PHOSPHORUS ON EGG SHELL QUALITY

Researchers have long recognized the importance of phosphorus in the diet of laying birds. Phosphorus, a major constituent of the blood and bone, has several other functions in the bird. It functions in cells, enzymes, and egg shell formation. A considerable amount of attention has been given to calcium: phosphorus ratios. Not all of the phosphorus in feed is available to the chicken. Normally, the phosphorus content

of the ration is expressed in two ways, one being total phosphorus and the other being available phosphorus (Scott, Nesheim and Young, (1969). Normally, laying birds can utilize between 70-75 percent of the plant phosphorus in the diet (North, 1972). The older the bird, the better it can utilize plant phytin phosphorus.

Arscott et al. (1962) increased the phosphorus level up to 0.9 percent total phosphorus in trials utilizing 2.25 and 3.00 percent calcium. The increased phosphorus level reduced the shell thickness of the eggs laid by both normal Single Comb Leghorn pullets and dwarf Leghorn pullets.

Evans, Carver and Brant (1944a) have shown that a total phosphorus level of 0.8 percent with calcium at the 2.50 percent level to be superior to phosphorus levels of 0.6, 1.0 and 1.2 percent during the first four months of production. No significant differences were observed between 0.8, 1.0 and 1.2 percent dietary phosphorus during the last six months of the experimental trial. These results are in agreement with Peterson et al. (1959). The feeding of supplemental phosphorus in the form of soft phosphates and dicalcium phosphate have also been proven to not significantly improve egg shell quality. Crowley et al. (1961) fed a basal diet containing 0.41 percent total phosphorus supplemented with either soft phosphate, dicalcium phosphate or combinations of these to bring the diet up to 0.71 percent total phosphorus. The addition of phosphorus to the basal ration did not consistently affect any of the criteria measured. Increasing phosphorus levels from 0.705 to 1.018 percent by the addition of steamed bone meal to the basal ration failed

to show any significant changes in shell thickness, according to Hinners, Gholson and Ritchason, (1963).

It may be concluded from the literature that phosphorus is not usually a problem with respect to egg shell thickness. The NRC recommendation of 0.6 percent still seems to be appropriate for laying birds under most management conditions.

VI. JUSTIFICATION FOR USING SPECIFIC GRAVITY AS A TOOL IN MEASURING EGG SHELL QUALITY

Egg shell strength is an important factor in the production of quality eggs particularly in its relation to handling of eggs from the site of production until they are utilized by the consumer. The strength of egg shells may be influenced by numerous environmental and physiological factors such as diet, age of hens, rate of production, length of production, strain, clutch position, disease and climatic conditions.

Researchers in the area of shell strength must decide from several methods available which method best lends itself to their research objectives. Most measurements for strength or thickness of shell usually involve a physical or chemical measurement which require the egg to be broken. Novikoff and Gutteridge (1949) stated, "that most methods have been too cumbersome and complex for practical use and have shown too great variation to warrant their general application." They reported that Romanoff (1929), Almquist and Burmester (1934), and Stewart (1936) applied either a downward or a sideways force or pressure as a means of

measuring shell strength and correlated their results with shell thickness. Correlation coefficients ranged from .509 (Stewart, 1936) to .761 (Almquist and Burmester, 1934).

Morgan (1932), using a force method, reported a correlation coefficient of .493 between percent shell and breaking strength. Lund, Heiman, and Wilhelm (1937) devised an apparatus for measuring the resistance of an egg to crushing and its shell to puncturing. Correlation coefficients of .633 were obtained between shell thickness and crushing resistance. Cheney and MacIntyre (1947) according to Novikoff and Gutteridge (1949) used a modified puncturing method involving a pentrometer, and reported a high correlation between shell thickness and puncture resistance. Quinn, Gordon and Godfrey, (1945) showed that egg shell quality can be measured in terms of egg weight loss.

The specific gravity method which according to Novikoff and Gutteridge (1949), by Olsson (1934) provides a measure of percentage shell without injury to the intact egg whether it be used for hatching or goes into market channels. The specific gravity method is simply a flotation procedure and is an indication of percent shell. Eggs are dipped into sodium chloride solutions having a range of specific gravity such as 1.068 to 1.100 in intervals of 0.004, the end point being the lowest specific gravity in which the egg floats. Novikoff and Gutteridge (1949) after comparing several methods of measuring shell strength, concluded that the specific gravity method, as an index of percent shell was slightly more sensitive as a measure of resistance to breakage. They further concluded that specific gravity was found to be least variable

having a net coefficient of variation of approximately 8 percent. Other advantages of the specific gravity method over other methods, are that you still have an intact egg after measurements are taken and larger numbers of eggs can be measured at the same time.

A new apparatus has been designed to evaluate the egg shell quality by measuring the change in shape (deformation) of an egg shell by applying a certain weight on the egg shell (Schoorl and Boersma, 1962). The advantages of the deformation instrument are that it is reproducible and it leaves the egg and its contents intact. The deformation of the egg shell was compared with other methods of evaluating the shell quality. Wells (1966) reported a correlation of 0.8 to 0.9 between deformation and specific gravity. As specific gravity increases the deformation score decreases.

CHAPTER III

EXPERIMENTAL PROCEDURES

I. EXPERIMENTAL ANIMALS

Four-hundred thirty-two Single Comb White Leghorn-type pullets used in this research were housed and maintained at the Poultry Unit of the University of Tennessee Agricultural Experiment Station, Knoxville.

Birds 24 weeks of age were housed and randomly assigned to cages 25.4 by 45.7 cm. at the rate of two birds per cage with 12 cages comprising a lot. Six treatment groups with three replicate lots were used. Treatments were assigned to lots according to a randomized block design. This experiment was conducted for 10-28 day periods beginning in December, 1972, and terminating in October, 1973.

II. EXPERIMENTAL DESIGN

The experimental design chosen to test the effect of increasing the calcium level of the layer diet with time on egg shell quality involved the use of increasing calcium levels at three constant rates with time. It was considered most practical to increase calcium levels at the end of each eight weeks during the experimental period. It was arbitrarily decided to use calcium levels of 3.75, 4.00 and 4.24 during the terminal eight weeks of the trial. Since the birds had been fed a 3.00 percent calcium diet prior to being placed on the experiment. A graph was constructed with the lines beginning at zero time and 3.00 percent calcium

and extending to the desired calcium levels at the 9th four weeks experimental period. The exact level of calcium to be fed during each eight week period was determined from this graph using the values for calcium where each line intersected a time line midway through the eight weeks period. These lines are described in Figure 1. For comparative purposes calcium levels of 3.00, 3.50 and 4.00 percent were included. Table I shows the constant and increasing constant levels of calcium used in the experimental diets.

III. COMPOSITION OF DIETS

The diets were designed to be isocaloric and isonitrogenous. The diets were made up of 85 percent nonvariable ingredients and 15 percent of variables. This type of diet has been used for several years at the Tennessee Agricultural Experiment Station in studying egg shell quality. The composition of the nonvariables and variable portion of the diet is shown in Table II.

IV. METHOD OF DATA COLLECTION

Specific gravity was used as a measure of egg shell quality to determine the effect of dietary differences on egg shells. Specific gravity data were collected weekly throughout the entire period of the study. The data were collected by submerging eggs produced from one-day's collection into sodium chloride solutions of known concentration. The specific gravity score is the number of the solution in which the egg floats. Table III shows the relative concentrations and specific

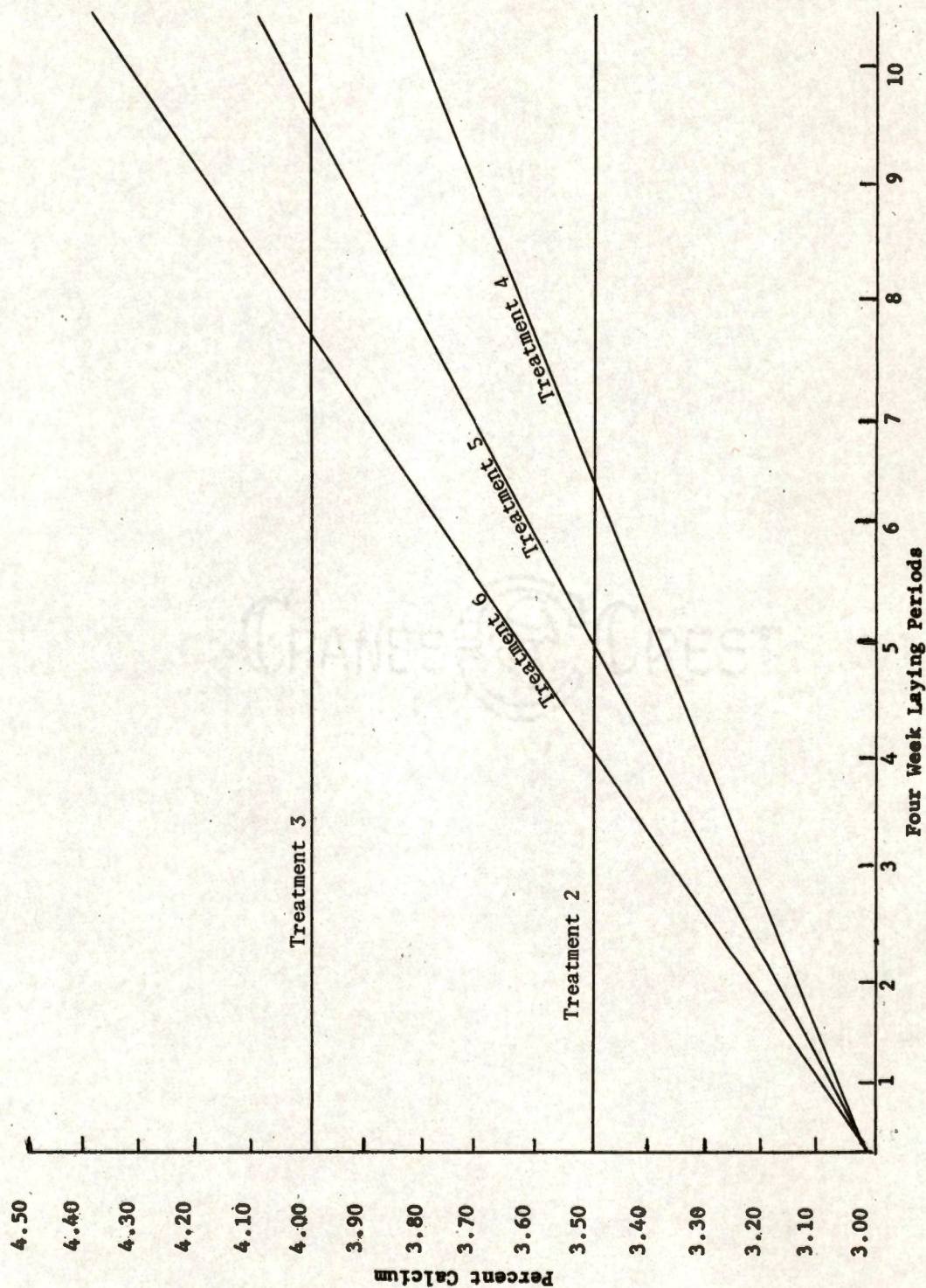


Figure 1. Determination of calcium levels fed during the laying period.

TABLE I
SCHEDULE OF CONSTANT AND INCREASING CONSTANT
RATE OF CALCIUM LEVELS BY LAYING PERIODS

Laying Period	Level of Calcium—Percent					
	<u>Constant</u>		Treatment Number	<u>Increasing</u>	<u>Constant</u>	<u>Rate</u>
	1	2		4	5	6
1-2	3.00	3.50	4.00	3.09	3.11	3.15
3-4	3.00	3.50	4.00	3.25	3.33	3.42
5-6	3.00	3.50	4.00	3.42	3.58	3.70
7-8	3.00	3.50	4.00	3.58	3.78	3.97
9-10	3.00	3.50	4.00	3.75	4.00	4.25

TABLE II
VARIABLES AND NONVARIABLES USED
IN EXPERIMENTAL DIETS

Feedstuff	Percent
<u>Nonvariables</u>	
Yellow corn	52.00
Fish meal	2.50
Alfalfa meal, 17% protein	5.00
Soybean meal, 50% protein	19.76
Vitamin mix ^a	.50
Salt	.50
Manganese sulfate	.03
Animal fat	4.71
Total nonvariables	85.00
<u>Variables</u>	
Dicalcium phosphate ^b 22% Ca, 18% P	1.3834
Ground limestone 39% Ca	6.34-9.54
Sand	4.07-7.28

^aVitamin mix supplied the following amounts per kilogram of diet: 2453 I.U. of Vit. A; 2956 I.C.U. of Vit. D₃; 4.43 mg. of riboflavin; 6.50 mg. of Vit. B₁₂; 440 mg. of choline; 24.2 mg. of niacin; and 4.76 mg. of pantothenic acid.

^bAll diets were calculated to contain 0.60% total phosphorus. Phosphorus was included as variable because the nonvariable portion has been calculated to be 85 kilograms.

TABLE III
SPECIFIC GRAVITY OF SALT WATER SOLUTIONS FOR EGG
SPECIFIC GRAVITY DETERMINATIONS

Specific Gravity	Score ^a
1.068	0
1.072	1
1.076	2
1.080	3
1.084	4
1.088	5
1.092	6
1.096	7
1.100	8
(sink in 1.100 solution)	9

^aScores used in the Sixteenth Tennessee Random Sample Laying Test, 1973. Eggs floating in the various specific gravity solutions are given the corresponding score except that eggs which sink in the 1.100 specific gravity solution are scored 9.

gravity scores used in determining this measurement. These are the same concentrations used in the Sixteenth Tennessee Random Sample Laying Test Report, 1973.

Egg weight was measured by weighing eggs individually on a gram-weight scales one-day each week during the study. Eggs have varying amounts of small, raised areas on the shell which cause the egg to be graded down from U.S.D.A. grade AA or A to B or C. To determine the effect of the treatments on this characteristic of the shell, eggs from one day's collection were compared with an arbitrary set of standards for exterior quality. A scale of 1 to 8 was used, with the scores of 1, 2, and 3 being judged to meet the standards for U.S.D.A. grade AA and A; scores of 4 or 5, U.S.D.A. grade B and 6, 7 and 8 being graded U.S.D.A. grade C. Thus, eggs with the smoothest exterior shells were assigned the lower numbers, and eggs with poor exterior shells were given higher numbers.

Egg production, feed consumption and mortality data were collected by lots, on a 28 day basis throughout the period of study.

Body weight measurements were taken at the beginning and end of the study by weighing each bird on a kilogram scale.

V. ANALYSIS OF DATA

Five orthogonal contrasts were developed to analyse differences among treatments (see Table IV). This type of design permitted the use of a multivariate analysis of variance where the response variables are regression coefficients which describe the relationship between egg

TABLE IV

TABLE OF ORTHOGONAL CONTRAST AND RESEARCH QUESTIONS

Contrast Number	Constant Level of Calcium				Constant Increasing Levels of Calcium				Research Questions
	3.00	3.50	4.00	4.00	3.09	3.11	3.15	3.15	
(1)	0	0	0	0	-1	0	+1	+1	1. Is there a significant linear relationship among the three chosen constant increasing levels of calcium?
(2)	-1	0	+1	+1	0	0	0	0	2. Is there a significant linear relationship among the three chosen constant levels?
(3)	+1	-2	+1	+1	0	0	0	0	3. Is there a significant non-linear relationship among the three constant levels?
(4)	0	0	0	0	+1	-2	+1	+1	4. Is there a significant non-linear relationship among the three chosen constant increasing levels of calcium?
(5)	-1	-1	-1	-1	+1	+1	+1	+1	5. Is there a significant linear relationship among the constant rate of increasing calcium levels?

shell quality and other production parameters over time. The analysis used made it possible to determine if the response was a linear, quadratic or cubic effect with time. The data were analyzed by using the Statistical Analysis System through the University of Tennessee Computing Center.

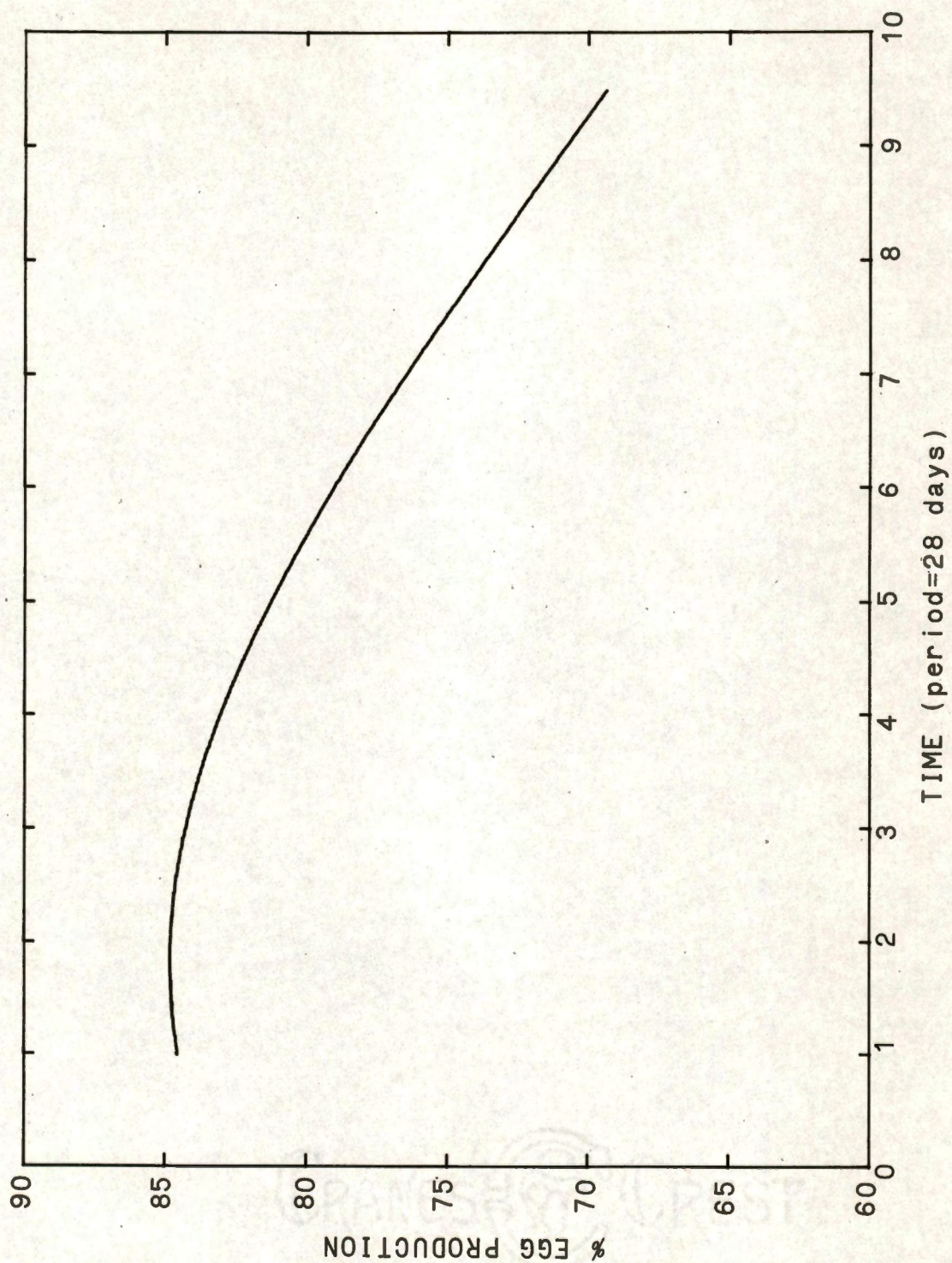


Figure 2. Mean production curve for all treatments as determined by regression coefficients.

TABLE V
SUMMARY OF DATA FOR ALL PARAMETERS MEASURED

Treatment	Production %	Avg. Egg Wt. Grams	Feed/doz. Kg	Feed/bird Kg	Avg. Body Wt. Grams	Avg. Specific Gravity Score	Exterior Shell Score
3.00% Ca	79.76	59.72	1.98	35.09	1844	3.12	2.39
3.50% Ca	77.54	59.17	1.89	34.20	1791	3.21	2.46
4.00% Ca	78.69	59.60	1.81	33.30	1788	3.11	2.59
3.09-3.75% Ca	76.39	58.88	1.93	34.36	1711	3.10	2.40
3.11-4.00% Ca	78.40	58.87	1.83	33.53	1733	3.31	2.36
3.15-4.25% Ca	77.40	58.23	1.86	33.63	1788	3.43	2.34

as the error was noted a new mix of feed was given to the birds and production and specific gravity returned to normal. Under most conditions such errors when noted within 10-14 days will not affect total production. Since there is no logical explanation for this significant difference and since no other significant differences occurred only the regressed mean averages for all treatments is shown in Figure 2.

Egg Weight

The data for average egg weight as affected by dietary calcium levels show nonsignificant differences. Figure 3 shows the regressed average egg weight mean for all dietary calcium levels used in this study since there were no significant difference among treatments. It was concluded from this study that high calcium levels did not have any detrimental effects on egg weight. These results are in agreement with Gerry and Bird (1967), Hinnners, Gholson and Ritchason (1963) who found no significant difference in egg weight with high dietary levels of calcium. Table VI shows the regression coefficients for the production functions of percent egg production and average egg weight, where the production variable is expressed as $Y = a + b_1 (pr) + b_2 (pr^2) + b_3 (pr^3)$ and pr = experimental period. All of the values shown for egg weight were statistically nonsignificant.

Feed Consumption

Feed consumption as measured by feed consumed per hen and per dozen eggs produced was not statistically significant in this study. The high dietary calcium level appeared to have no consistent effect

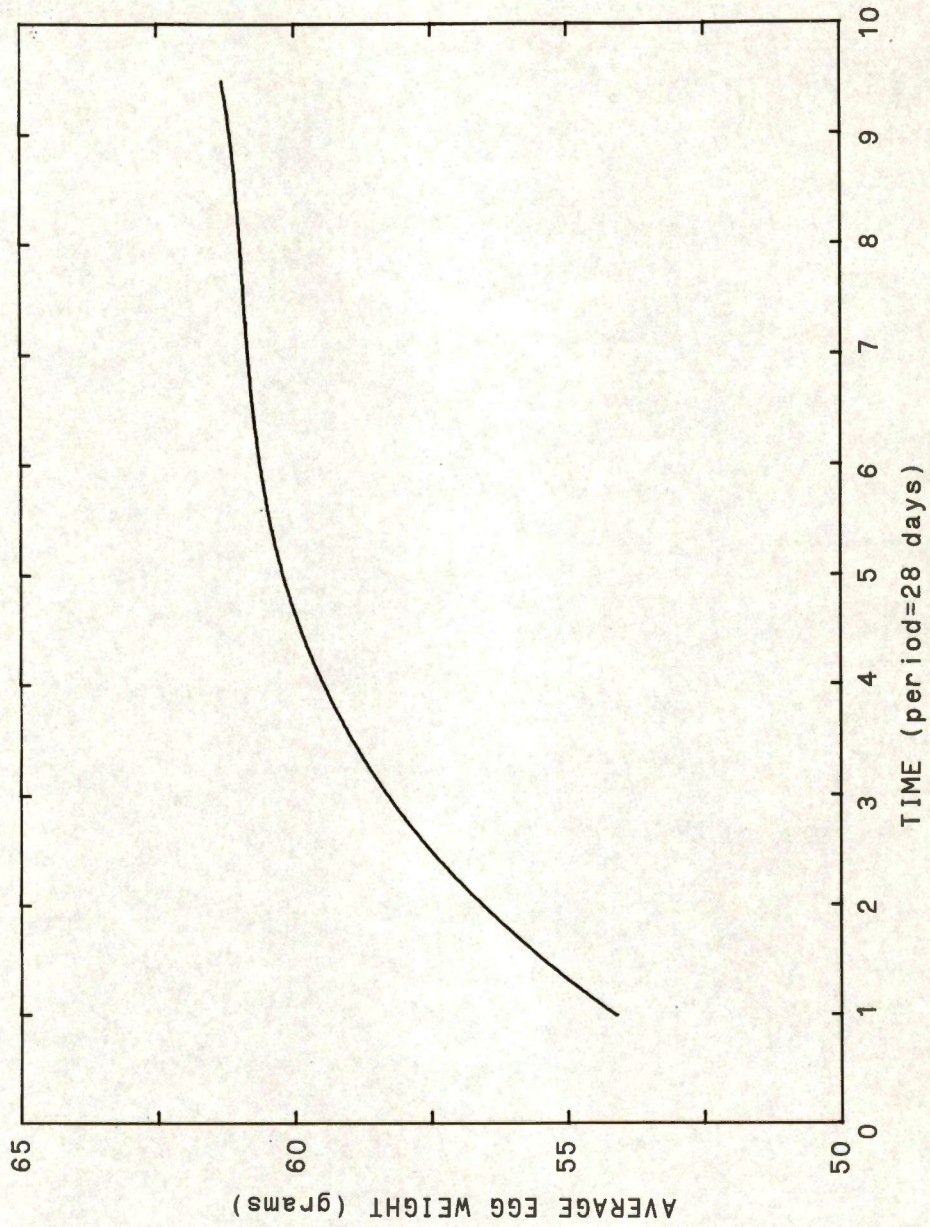


Figure 3. Average regressed egg weight means^a for all treatments.

^a $y = a + b_1(\text{period}) + b_2(\text{period}) + b_3(\text{period}^3)$, where y = production variable and wk = week of experimental period.

TABLE VI
REGRESSION COEFFICIENTS FOR PRODUCTION FUNCTIONS^a

Treatment	Regression Coefficients			
	a	b ₁ (pr)	b ₂ (pr ²)	b ₃ (pr ³)
I				
% Production	82.9134	3.3360	- .8463	.0360
Egg Weight	51.2063	3.8132	- .4760	.0203
II				
% Production	91.7545	-3.9912	.4511	- .0330
Egg Weight	50.1657	4.2550	- .5732	.0264
III				
% Production	84.2514	1.7670	- .4890	.0116
Egg Weight	51.7590	3.4150	- .4238	.0184
IV				
% Production	77.9024	5.7820	-1.4172	.0700
Egg Weight	50.8567	3.5419	- .4330	.0184
V				
% Production	82.0524	1.1510	- .2609	.0150
Egg Weight	50.3219	3.9034	- .5260	.0254
VI				
% Production	81.5904	1.4408	- .5223	.0236
Egg Weight	50.6936	4.2805	- .5880	.0273

^a $Y = a + b_1 (\text{pr}) + b_2 (\text{pr}^2) + b_3 (\text{pr}^3)$, where y = production variable and pr = experimental period.

on feed consumption. This is in agreement with the work by MacIntyre, Chancey, and Gardiner (1963) and in contradiction to the findings of Reddy and Sanford (1963).

Body Weight

MacIntyre, Chancey and Gardiner (1963) fed calcium levels from 1.00 to 6.00 percent for 280 days, without any significant effect on the birds ending body weight. The effect of dietary calcium level on average body weight was nonsignificant in our findings as shown in Table V, page 27.

II. SHELL CHARACTERISTICS

Specific Gravity

It has been reported by Wolford and Tanaka (1970) in a review of 30 papers, that dietary calcium levels in excess of 3.00 percent increased egg shell thickness and egg specific gravity.

Figure 4 shows the mean specific gravity relationship among the dietary treatments used in this study. Figure 4 shows a straight linear relationship in that egg shell quality as measured by specific gravity decreases over time. Since no significant differences in the mean regressed line were observed the regressed average mean for all treatments is shown in Figure 4. The incremental calcium treatments over time failed to show any consistent or statistically significant results (Table V, page 27). These results are in contradiction to that reported by Wolford and Tanaka (1970) in their review.

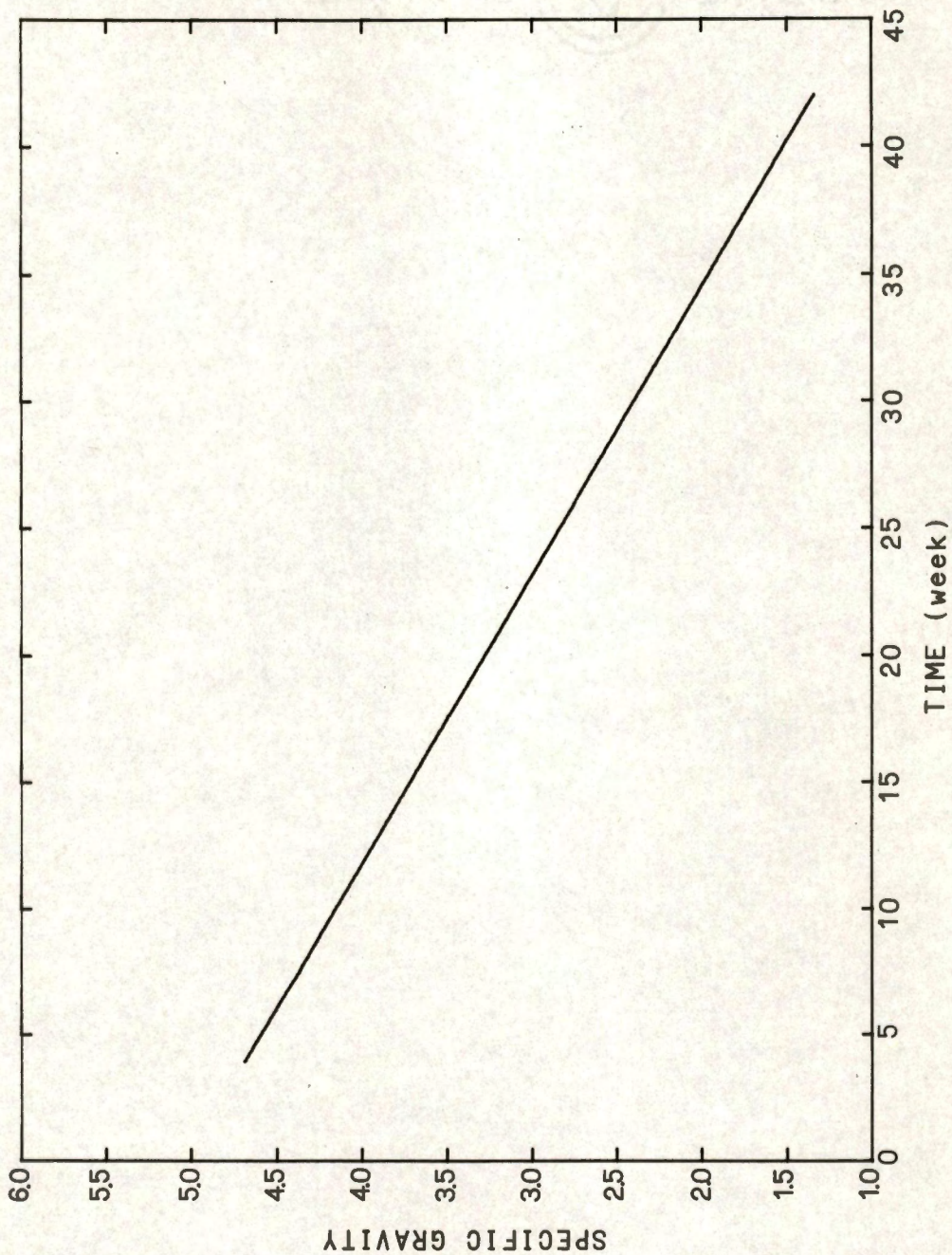


Figure 4. Mean specific gravity relationship for all treatments.^a

^a $Y = a + b_1(wk)$, where Y = function specific gravity and wk = weekly score.

An improvement in shell quality by increasing the calcium content of the diet after several months of lay was reported by Kienholz, McPherron and Orme (1964), who measured shell quality by shell thickness. This is in opposition to the results of this study. When the dietary calcium level was increased after several months of lay, the specific gravity results showed no conclusive or significant differences attributable to higher dietary calcium levels.

Table VII shows results that are in agreement with that of Hull and Scott (1969) who reported that 3.50 percent dietary calcium produced as good shell quality as higher dietary levels. This also substantiates the work of Scott, Hull and Mullenhoff (1970), and Gutowska and Parkhurst (1942).

It is well known that environmental temperatures depress shell thickness (Wilhelm and Heimen, 1938; Warren and Schnepal, 1940; Froning and Funk, 1958; Hall and Helbacka, 1959). As Table VI, page 30 illustrates, the sharpest decline in egg shell quality occurred after the birds had been in production for 4 months. The individual variation among birds and the effects of the rate of production on shell quality are not clearly understood. Henderson, Cook and Lloyd (1941), Tyler and Geake (1958, 1960) and Jenkins and Taylor (1960) have demonstrated that there is a high degree of variability among birds in respect to shell quality. The data from this study tends to agree with other workers concerning the individual variation among birds and the effect of environmental temperature.

TABLE VII

AVERAGE SPECIFIC GRAVITY SCORES BY PERIOD AND CALCIUM LEVELS

Period (28-days)	3.00% Ca	3.50% Ca	4.00% Ca	3.09-3.75% Ca	3.11-4.00% Ca	3.15-4.25% Ca
1	4.96	5.07	5.12	4.88	5.16	4.90
2	4.49	3.37 ^a	4.47	4.40	4.69	4.76
3	4.02	4.17	3.81	3.82	4.15	3.89
4	3.67	4.04	3.69	3.68	3.91	4.08
5	3.35	3.50	3.35	3.24	3.54	3.61
6	2.87	3.09	2.76	2.84	3.00	3.43
7	2.00	2.27	2.16	2.21	2.33	2.59
8	2.39	2.49	2.44	2.44	2.57	2.74
9	1.87	1.92	1.78	1.86	1.82	2.23
10	1.81	1.87	1.76	1.84	2.08	2.22
Average	3.21	3.21	3.11	3.10	3.31	3.43

^aThis value represents a decline in specific gravity due to improperly mixed feed.

Age of the birds has been shown also to affect the quality of egg shells. Peterson et al. (1963), Sullivan et al. (1963), Anderson et al. (1957), and Strain and Johnson (1957) have reported that egg specific gravity decreases with age. The specific gravity data in this study shows a decline, but the effects of environmental temperature and age could not be separated. Therefore, an explanation for this overall decline in specific gravity can not be explained at this point.

Although the data on specific gravity were not significant, the fact that birds on the 3.11-4.00 percent and 3.15-4.24 percent calcium treatments had a higher average specific gravity suggests that further investigation into these incremental calcium treatments might prove worthy of future reserach on the problem of egg shell quality.

Exterior Observations

The incidence of poor exterior shell quality could not be associated with any dietary calcium regime (Table V, page 27). The combined affect of age and environmental temperature appear to be the most likely cause of such decline in exterior quality.

III. CONCLUSIONS

Incremental dietary calcium levels up to 4.24 percent calcium had no consistent or significant effect upon preventing the decline in egg shell quality over time. As shown by the multivariate analysis of variance, where the response variables were expressed as regression coefficients over time. Dietary calcium level had no significant effect

upon rate of egg production except that the birds fed the constant dietary calcium treatments of 3.00 and 4.00 percent calcium were significantly different ($P < 0.05$) from the 3.50 percent constant level of dietary calcium. Egg weight was unaffected by dietary treatment.

Although the data on specific gravity were not significant the fact that the data shows that 3.11-4.00 percent and 3.15-4.25 percent calcium treatments had a higher average specific gravity, suggests that further investigation into these incremental calcium levels might prove worthy in future research work.

The author supports the theory, that the decline in egg shell quality with age is not a nutritional inadequacy per se but a gerontological consequence that cannot be rectified short of a forced molt rest, as stated by Moran, Eyal and Summers (1970).

CHAPTER V

SUMMARY

The purpose of this experiment was to determine the effects of constant and of constant increasing levels of calcium in the diet throughout the laying year on shell quality.

A 40-week study was conducted using sex treatments, 3.00, 3.50 and 4.00 percent constant calcium levels and incremental treatments of 3.09 to 3.75, 3.11 to 4.00 and 3.15 to 4.25 percent dietary calcium, with treatments being increased every eight weeks. Each treatment group consisted of three replicate lots of 24 birds each.

Specific gravity and egg weight measurements were taken on a weekly basis and also average egg weight. The results from the study were as follows:

1. Egg shell specific gravity declined in a linear relationship over time, and was not influenced significantly by treatments.
2. Average egg weight was not affected by the high dietary calcium level used in this study.
3. Egg production was not affected by calcium treatments with the exception that the 3.00 and 4.00 percent dietary calcium treatments were significantly different from the 3.50 percent constant calcium treatment. No biological explanation can be given for this phenomenon.
4. Feed consumption and mortality were unaffected by dietary treatment.

5. No significant difference was observed in exterior shell quality among the treatment groups.

REFERENCES



REFERENCES

- Almquist, H. J., and B. R. Burmester, 1934. Characteristics of an abnormal type of shell. *Poultry Sci.* 13:116-122.
- Anderson, G. J., C. F. Petersen, A. C. Wiese, and C. E. Lampman, 1957. The effect of high level vitamin supplementation of high and low energy rations on egg production and egg shell quality. *Poultry Sci.* 36:1369-1376.
- Arscott, G. H., P. Rachapaetayakom, P. E. Bernier, and F. W. Adams, 1962. Influence of ascorbic acid, calcium and phosphorus on specific gravity of eggs. *Poultry Sci.* 41:485-488.
- Arvat, V. and S. W. Hinners, 1973. Evaluation of egg shells as a low cost calcium source for laying hens. *Poultry Sci.* 52:1996.
- Bletner, J. K. and L. G. McCraney, 1972. Unpublished data. Tennessee Agricultural Experimental Station.
- Cheney, B. and T. M. MacIntyre, 1947. Unpublished data. Dominion Experimental Station, Kentsville, N. S.
- Crowley, T. A., M. W. Pasvogel, A. R. Kemmerer, M. G. Vavich and A. A. Kurnich, 1961. Effects of soft phosphate and dicalcium phosphate on reproductive performance and egg quality. *Poultry Sci.* 40:74-80.
- Deobald, H. J., E. J. Lease, and E. B. Hart, 1936. Studies on the calcium metabolism of laying hens. *Poultry Sci.* 15:179-185.
- Durham, J. I., R. E. Davis, C. W. Deyoe and J. R. Couch, 1960. Effect of calcium level and phosphorus source on egg production and shell quality. *Poultry Sci.* 39:1246.
- Evans, R. J., J. S. Carver and A. W. Brant, 1944a. The influence of dietary factors on egg shell quality. I. Phosphorus. *Poultry Sci.* 23:9-15.
- Evans, R. J., J. S. Carver, and A. W. Brant, 1944b. The influence of dietary factors on egg shell quality. II. Calcium. *Poultry Sci.* 23:36-40.
- Froning, G. W., and E. M. Funk, 1958. Seasonal variations in quality of eggs laid by caged layers and their sisters on the floor. *Poultry Sci.* 37:215-223.

- Gerry, R. W. and F. H. Bird, 1967. The performance of Red x Rock sex links as affected by calcium levels in their growing and laying diets. *Poultry Sci.* 46:1264.
- Gutowska, M. S. and R. T. Parkhurst, 1942. Studies in mineral nutrition of laying hens. II. Excess of calcium in the diet. *Poultry Sci.* 21:321-328.
- Hall, K. N., and N. V. Helbacka, 1959. Improving albumen quality. *Poultry Sci.* 38:111-114.
- Harms, R. H. and P. W. Waldroup, 1961. The influence of dietary calcium level and supplementary ascorbic acid and or diestrol diacetate upon performance of egg production type hens. *Poultry Sci.* 40:1345-1348.
- Henderson, W. M., N. G. Cook and E. A. Lloyd, 1941. Studies in egg quality. *Poultry Sci.* 20:462-463.
- Hinners, S. W., J. T. Gholson and M. L. Ritchason, 1963. The effect of varying levels of calcium and phosphorus on egg production and egg quality. *Poultry Sci.* 42:1277.
- Holder, D. P. and T. W. Sullivan, 1973. Influence of level and particle size of calcium supplement on performance of laying chickens. *Poultry Sci.* 52:2041.
- Hull, S. J. and M. L. Scott, 1969. A study to determine the optimum dietary calcium level for laying hens. *Poultry Sci.* 48:1823.
- Hurwitz, S. and S. Bornstein, 1966. The effect of high dietary calcium on the performance of laying hens fed rations of varying energy levels. *Poultry Sci.* 45:805-809.
- ✓ Jenkins, N. K. and C. Tyler, 1960. Changes in egg shell thickness and white and yolk weight and composition over a period of a year. *J. Agr. Sci.* 55:323-331.
- Kienholz, E. W., T. A. McPherron and L. E. Orme, 1964. The effect of some dietary supplements upon caged hen performance while heat stressed. *Poultry Sci.* 43:1334.
- Lund, W. A., V. Heiman, L. A. Wilhelm, 1937. The relationship between egg shell thickness and strength. *Poultry Sci.* 17:372-376.
- MacIntyre, T. M., H. W. Chancey and E. E. Gardiner, 1963. Effect of dietary energy and calcium level on egg production and egg quality. *Can. J. of Anim. Sci.* 43:337-343.

- Mehring, A. L. and H. W. Titus, 1964. The effects of low levels of calcium in the diet of laying chickens. *Poultry Sci.* 43:1405-1414.
- Moran, E. T., A. Eyal and J. D. Summers, 1970. Effectiveness of extra-dietary calcium supplements in improving egg shell quality and the influence of added phosphorus. *Poultry Sci.* 49:1011-1022.
- Morgan, C. L., 1932. Relationship between breaking strength and the percent of egg shell. *Poultry Sci.* 11:172-175.
- Naber, E. C., E. Mackay and S. P. Touchburn, 1963. The effect of calcium source, calcium gluconate and ascorbic acid on reproductive performance and egg shell quality in chickens. *Ohio Agr. Exp. Sta. Res. Circ. No. 120.*
- National Research Council, 1954. Nutrient requirements of poultry (3rd Ed.) National Academy of Sciences, Washington, D. C.
- National Research Council, 1960. Nutrient requirements of poultry. (4th Ed.). National Academy of Sciences, Washington, D. C.
- National Research Council, 1966. Nutrient requirements of poultry. (5th Ed.). National Academy of Sciences, Washington, D. C.
- National Research Council, 1971. Nutrient requirements of poultry. (6th Ed.). National Academy of Sciences, Washington, D. C.
- North, M. O., 1972. Commercial Chicken Production Manual. The AVI Publishing Company, Inc., Westport, Connecticut.
- Novikoff, M. and H. S. Gutteridge, 1949. A comparison of certain methods of estimating shell strength. *Poultry Sci.* 28:339-343.
- Olsson, N., 1934. Studies on specific gravity of hen's eggs. Otto Harrassowitz, Leipzig.
- Pepper, W. F., J. D. Summers and J. D. McConachie, 1968. The effects of high levels of calcium, fish products and sodium bicarbonate on egg shell quality. *Poultry Sci.* 47:224-229.
- Peterson, C. F., D. H. Conrad, D. H. Lumijarri, E. A. Sauter and C. E. Lampman, 1960. Studies on the calcium requirement of high producing White Leghorn hens. *Idaho Exp. Sta. Res. Bull. No. 44.*
- Peterson, C. F., E. A. Sauter, C. E. Lampman, and A. C. Wiese, 1963. Comparison of controlled and free-choice feeding of calcium upon calcium intake and egg shell quality. *Poultry Sci.* 42:1299.

- Peterson, C. F., E. A. Sauter, A. C. Wiese and D. J. Lumijarri, 1959. Influence of calcium and other nutrients upon shell quality of high producing White Leghorn hens. *Poultry Sci.* 38:1236.
- Quinn, J. P., C. D. Gordon and A. B. Godfrey, 1945. Breeding for egg shell quality as indicated by egg weight loss. *Poultry Sci.* 24: 399-403.
- Quisenberry, J. H. and J. C. Walker, 1970. Calcium sources for egg production and shell quality. *Poultry Sci.* 49:1429.
- Reddy, C. V. and P. E. Sanford, 1963. Influence of dietary calcium in laying rations on shell quality and interior quality of eggs. *Poultry Sci.* 42:1302.
- Reddy, C. V., P. E. Sanford and R. E. Clegg, 1968. Influence of calcium in laying rations on shell quality and interior quality of eggs. *Poultry Sci.* 47:1077-1083.
- Roland, D. A., D. R. Sloan and R. H. Harms, 1973. Influence of pullet sized limestone and various levels of calcium on egg shell quality. *Poultry Sci.* 52:2079.
- Romanoff, A. L., 1929. Study of the physical properties of the hen's egg shell in relation to the function of the shell secretory glands. *Biol. Bull.* 56:351-356.
- Schoorl, P. and Boersma, H. Y., 1962. Research on the quality of the egg shell. A new method of determination. *Proc. 12th World's Poultry Congress*, 432-435.
- Scott, M. L., S. J. Hull and P. A. Mullenhoff, 1970. The calcium requirement of laying hens and effects of dietary oyster shell upon egg shell quality. *Poultry Sci.* 50:1055-1063.
- Scott, M. L., M. C. Nesheim and R. J. Young, 1969. *Nutrition of the Chicken*. M. L. Scott and Associates, Ithaca, New York.
- Stewart, G. F., 1936. Shell characteristics and their relationship to the breaking strength. *Poultry Sci.* 16:119-124.
- Strain, J. H. and A. S. Johnson, 1957. Seasonal, strain and hatch effects on egg quality traits. *Poultry Sci.* 36:539-546.
- Stuart, H. O. and C. R. Hart, 1939. The effect of different calcium intake levels on egg production, shell strength, and hatchability. *Poultry Sci.* 17:3-7.

- Sullivan, T. W., J. L. Admas, W. J. Owings, and T. L. Goodwin, 1963. Effect of age, strain, dietary calcium level and antibiotic regimen on egg production and quality factors. *Poultry Sci.* 42:1311-1312
- Sullivan, T. W. and J. R. Kingan, 1962. Effect of dietary calcium level, calcium lactate and ascorbic acid on the egg production of S. C. White Leghorn hens. *Poultry Sci.* 41:1596-1602.
- Tyler, C. and F. H. Geake, 1958. Studies on egg shells. IX. The influence of individuality and season on certain characteristics of egg shells from pullets. *J. Sci. Food Agr.* 9:473-483.
- Tyler, C. and F. H. Geake, 1960. Studies on egg shells. XIII. Influence of individuality, breed, season and age of certain characteristics of egg shells. *J. Sci. Food Agr.* 11:535-547.
- Warren, D. C. and R. L. Schnepel, 1940. The effect of air temperatures on egg shell thickness in the fowl. *Poultry Sci.* 19:67-72.
- Wells, R. G., 1966. The relationship between egg specific gravity and egg shell deformation and their reliability as indicators of shell strength. *Brit. Poultry Sci.* 8:193-199.
- Wilhelm, L. A. and V. Heiman, 1938. The seasonal variations in interior egg quality on new laid eggs. *Washington Agr. Exp. Sta. Tech. Paper* 358.
- Wolford, J. H. and K. Tanaka, 1970. Factors influencing egg shell quality—a review. *World's Poultry Sci. J.* 26:763-779.

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