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The response of four strains of White Leghorn layers to two levels of dietary phosphorus

Robert F. Ingram

To the Graduate Council:

I am submitting herewith a thesis written by Robert F. Ingram entitled "The response of four strains of White Leghorn layers to two levels of dietary phosphorus." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

James K. Bletner, Major Professor

We have read this thesis and recommend its acceptance:

H. V. Shirley, R. L. Tugwell

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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and recommend its acceptance:

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Accepted for the Council:

Hilton A. Smith

Vice Chancellor
Graduate Studies and Research

THE RESPONSE OF FOUR STRAINS OF WHITE LEGHORN LAYERS TO TWO LEVELS OF DIETARY PHOSPHORUS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Robert F. Ingram

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ABSTRACT

The purpose of this experiment was to determine the response of four high producing strains of Single Comb White Leghorn-type hens to dietary phosphorus levels of 0.4 and 0.6 percent as measured by shell quality, egg production, egg weight, feed consumption, body weight and mortality.

This study was conducted for 11 - 28 day periods. Results were subjected to analysis of variance and when significance was determined ($P \leq 0.05$) mean separation was performed using Duncan's Multiple Range test.

The results showed no significant relationship between dietary phosphorus level and egg production, egg weight, feed per hen, feed per dozen or mortality. Dietary phosphorus level had a significant effect on egg shell quality and body weight in that the lower phosphorus diet resulted in significantly improved egg specific gravity but reduced final body weight and body weight gain. Egg shell quality declined with length of lay and responded to environmental temperature by improving during the final period which was much cooler than the previous periods. Significant differences between strains were observed for all parameters studied and a significant difference in strain response to the two diets was observed for egg production. One strain had significantly lower egg production on the 0.4 percent phosphorus diet whereas another strain had improved egg production on the same diet. There appeared to be differences in strain response for mortality but these differences proved statistically nonsignificant.

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CHAPTER I

INTRODUCTION

Egg quality is an important consideration at all levels of the egg industry from the producer to the consumer. Various exterior and interior factors comprise egg quality. Eggs with poor shell quality are easily broken or cracked in industrial handling. Eggleton and Ross (1971) estimate that as high as 7.94 percent of the eggs produced never reach the commercial market. The use of labor saving machinery such as mechanical egg gatherers, automatic washers and graders, and automatic packers has a tendency to increase cracking of eggs with poor shell quality. Thus, shell quality must be maintained at optimum levels for economical reasons.

The term "shell quality" refers to a variety of traits including breaking strength, percent shell, shell thickness, shape deformation, color, and smoothness and texture of the egg shell. For the purpose of this study shell quality will denote percent shell as assessed by specific gravity. Factors influencing egg shell quality have been the basis for numerous investigations. Nutrition plays an extremely important role but such factors as disease, medicines, length of lay, time of oviposition, temperature, housing systems, heredity, and neuro-humoral reproductive control mechanisms are also involved.

From the nutritional aspect, calcium has undoubtedly been the nutrient studied most intensively. However, some work has been done with phosphorus in relation to shell quality but in the majority of these experiments shell quality was only a secondary parameter studied. Results from these studies often varied and conflicted with one another indicating that more research is needed.

In work at the University of Tennessee Agricultural Experiment Station, Singh, Bletner and Goff (1971) noted that in experimental diets varying in calcium and phosphorus levels, shell quality improved as phosphorus levels decreased. Bletner and McGhee (1975) reported that a phosphorus level of 0.4 percent was adequate for maximum production and shell quality but this level of phosphorus has been reported by other researchers to be too low for high producing layers. It appeared that genetic differences in the phosphorus requirement of layers of different breeding might account for some of the literature contradictions. Therefore, an experiment was designed to study the effect of a low phosphorus diet on egg shell quality and other production parameters of four strains of Leghorn-type layers.

CHAPTER II

LITERATURE REVIEW

I. NATIONAL RESEARCH COUNCIL RECOMMENDATIONS OF PHOSPHORUS FOR THE LAYING HEN

The current National Research Council recommendations for poultry (NRC 1971) sets the phosphorus requirement for laying hens at 0.6 percent of which at least a portion should be inorganic phosphorus. However, it was stated that the requirement for inorganic phosphorus is lower and is not as well defined as that for starting chicks.

Upon reviewing the literature cited under phosphorus in NRC (1950, 1954, 1960, 1966 and 1971), it was found that only two references concerned phosphorus levels for the diets of laying hens. One was a short abstract by Evans and Carver (1942). The other was an earlier work by Miller and Bearse (1934) which supports a high level of phosphorus in the diet. Although much research has been conducted and the results published in the last quarter century on phosphorus levels in the diet of laying hens, the only other references cited under phosphorus concerned either broilers or other avian species.

In the work reported by Evans and Carver (1942), the phosphorus levels of the diets ranged from 0.6 to 1.2 percent phosphorus. Phosphorus levels less than 0.6 percent were not included in that study. From this it is obvious that more research is needed concerning the phosphorus requirements of the laying hen.

NRC (1950) recommended a dietary phosphorus level of 0.75 percent for laying hens. The NRC recommended level of dietary phosphorus for the laying hen has been 0.6 percent since 1954. Thus, the phosphorus requirement has been lowered within the past two decades.

Phosphorus from non-plant sources, such as rock phosphate, is considered to be inorganic phosphorus and 30 percent of plant phosphorus is considered to be non-phytin and can be considered inorganic. NRC (1971) continues to recommend that a portion of the phosphorus requirement of growing chickens and laying and breeding hens must be supplied in organic form.

II. EFFECTS OF LOW LEVELS OF PHOSPHORUS

In a study using phosphorus levels ranging from 0.40 to 1.08 percent, Miller and Bearse (1934) concluded that the level of phosphorus fed apparently did not influence egg shell quality, egg weight, or mortality. However, egg production was influenced with 0.80 percent giving a significantly higher production than the 0.40 percent level.

O'Rourke _et_ _al_. (1954) fed rations ranging from 0.19 to 0.60 percent phosphorus and concluded that no more than 0.30 percent phosphorus was required by laying pullets to maintain normal rate of production of viable eggs. The 0.19 percent phosphorus ration could not support normal egg production and was inadequate for maintaining normal hatchability. When this ration was supplemented with $CaHPO_4 \cdot 2H_2O$ to raise the phosphorus level to 0.30 percent, production and hatchability returned to normal.

In further work with phosphorus levels in poultry diets, O'Rourke, Phillips and Cravens (1955) found that no more than 0.43 percent phosphorus was needed to maintain normal egg production in caged layers. Since 0.43 percent was the lowest phosphorus level used no adverse effects to low phosphorus were demonstrated.

Pepper et al. (1959) confirmed the findings of O'Rourke and co-workers (1954 and 1955) in demonstrating a diet containing 0.38 percent total phosphorus and 0.11 percent non-phytin phosphorus was adequate for normal egg production in various strains of Single Comb White Leghorns. The rations used in this study were not low enough in phosphorus to demonstrate any adverse effects.

Walter and Aitken (1962) contradicted the results of O'Rourke and co-workers (1954 and 1955) and Pepper et al. (1959) in demonstrating that a ration containing 0.40 percent phosphorus was not adequate for maintaining body weight and egg production. However, the 0.4 percent phosphorus ration was adequate for promoting egg weight, feed efficiency, and shell quality. The highest production was achieved with diets containing 0.60 and 0.70 percent phosphorus.

Crowley et al. (1961) reported that a diet containing

0.41 percent total phosphorus supported normal egg production but a level of 0.71 percent depressed egg production.

In the study by Singsen et al. (1962) rations varying from 0.20 to 0.70 percent phosphorus were fed to laying hens housed on wire and litter floors. The birds on litter floor reached maximum production on 0.50 percent phosphorus but there was no significant difference between the production of layers fed the 0.40, 0.50, or 0.60 percent levels. The birds housed on wire floor required more than 0.40 percent but less than 0.60 percent phosphorus for optimum performance. The birds on litter floor required less phosphorus in the diet due to supplemental phosphorus sources in the litter from bacterial breakdown of phytic acid from fecal excretion. Egg production was significantly depressed at 0.70 percent phosphorus but egg weight, shell thickness, and specific gravity were not affected by any of the diets fed. The 0.20 percent phosphorus diet decreased production during the latter part of the laying period, reduced body weight, decreased hatchability, and increased mortality for the birds housed on wire floor.

Results obtained by Crowley, Kurnick, and Reid (1963) support the evidence by Singsen et al. (1962) that hens on litter have lower phosphorus requirements than hens in cages. In the study by Crowley, Kurnick, and Reid (1963) it was found that birds maintained on litter required no more than 0.269 percent total phosphorus while caged layers required no more than 0.41 percent total phosphorus.

Evidence was also shown that no significant relationship existed between the level of dietary phosphorus fed during the first 20 weeks of production and the phosphorus requirement during the latter laying period. A basal diet of 0.213 percent phosphorus would not support normal egg production and resulted in increased mortality. A basal diet of 0.193 percent phosphorus lowered egg production significantly, increased mortality, would not support normal body weight, and lowered shell quality as measured by shell thickness. Average egg weight did not appear to be related to dietary phosphorus level.

In work with calcium and phosphorus levels of White Leghorn pullets, Berg, Bearse, and Merrill (1964) demonstrated that the phosphorus requirement for pullets was not over 0.30 percent. This level of phosphorus supported normal egg production as well as diets containing 0.40, 0.50, and 0.60 percent phosphorus. The level of phosphorus in the diets (from 0.30 to 0.60 percent) had no effect on age at 50 percent lay, peak rate of lay, average egg weight, or specific gravity of eggs.

Taylor (1965) demonstrated that birds fed a low phosphorus diet (0.46 percent) had increased shell thickness. Arscott et al. (1962) showed a fall in mean specific gravity of eggs when the dietary phosphorus level was raised from 0.60 to 0.90 percent. This is the first article reviewed which indicated that a lower phosphorus level improved shell quality. It was stated that there may be a disadvantage, in the form of thinner shells, associated with high levels of dietary phosphorus.

Smith (1968) demonstrated a 0.45 percent phosphorus level for laying hens to be superior in egg production and feed efficiency to a diet containing 0.83 percent phosphorus. However, no visual difference in egg shell quality was noted between the two groups.

Harms (1968) indicates the phosphorus requirement of hens on litter is 0.40 percent while the requirement for hens maintained in cages is 0.60 percent.

Mostert and Swart (1969) supported the work of Taylor (1965) by demonstrating that a ration with 0.45 percent phosphorus will increase shell thickness when compared to a 0.65 percent ration. However, egg production was lower on the 0.45 percent phosphorus ration.

Salman, Ali, and McGinnis (1969) observed that a calculated level of 0.30 percent plant phosphorus was adequate for normal egg production and overall performance of Single Comb White Leghorn pullets. The lowered phosphorus level in the diet did not increase mortality and there was no significant difference in shell thickness between diets containing 0.60 percent and 0.30 percent phosphorus.

Pepper *et al*. (1969) demonstrated that a diet of 0.39 percent phosphorus (all from plant sources) was sufficient to sustain good production. The results from this study indicated that birds housed two per cage have a higher phosphorus requirement than birds caged individually. The low phosphorus ration decreased weight gain without lowering production.

Hunt and Chancey (1970) conducted a study on the influence of dietary phosphorus on shell quality of White Leghorns housed in cages. It was found that egg production and shell quality as assessed by specific gravity were both inversely proportional to dietary phosphorus level. In diets ranging from 0.36 to 0.96 percent phosphorus the lower level gave better shell quality and egg production.

Singh, Bletner, and Goff (1971) in a study on various phosphorus and calcium levels found that at a 3.5 percent calcium level egg specific gravity was lowered by increasing phosphorus levels above 0.40 percent and egg production was maximum at the 0.60 percent phosphorus level.

Mraz (1972) studied the absorption of ^{45}Ca, ^{85}Sr, and ^{32}P by White Leghorn pullets fed varying levels of Ca and P in the diet. The phosphorus levels ranged from 0.40 to 0.80 percent with no effect on egg production. It was found that as phosphorus levels increased the ratio of ^{32}P : ^{45}Ca absorbed decreased.

Ademosun and Kalango (1973) in a study of hybrid layers in Nigeria, obtained results similar to those of Walter and Aitken (1962) and Singsen et al. (1962) in that 0.40 percent phosphorus gave lower egg production as compared to 0.60 percent for hens maintained in cages. Egg shell quality as measured by shell weight per unit area of surface was not significantly affected by phosphorus level although the low level tended to give slightly better shell quality.

Shirley (1974) in a random sample laying test involving various strains of commercial laying hens demonstrated improved specific gravity of eggs from hens fed a low (0.36 percent) phosphorus diet as compared to hens fed a high (0.80 percent) phosphorus diet. A significant interaction between strain and phosphorus level was observed for Haugh units and there appeared to be differences in strain response to the low phosphorus diet for other parameters studied.

Damron, Andrews, and Harms (1974) used phosphorus levels of 0.50, 0.65, or 0.80 percent to compare Curacao Island phosphate to dicalcium phosphate. It was found that egg production was lower with the Curacao Island product and was significantly reduced by the 0.80 percent phosphorus level. Shell quality was not a parameter examined in this study.

Scott, Antillon, and Mullenhoff (1975) in work with calcium, phosphorus, and vitamin D reported that a decrease from 0.55 percent to 0.26 percent available phosphorus did not affect egg production but significantly increased egg breaking strength. Available phosphorus levels of 0.13 percent slightly reduced production and shell quality.

III. EFFECTS OF HIGH LEVELS OF PHOSPHORUS

In an early study on various phosphorus levels, Miller and Bearse (1934) obtained optimum production with a level of 0.80

percent. When the ration was increased to above 1.0 percent phosphorus egg production dropped slightly. There was a slight tendency for percent shell and shell index to be lower at the higher phosphorus levels although this was not significant.

Evans, Carver, and Brant (1944) support Miller and Bearse (1934) in that 0.80 percent phosphorus gave overall better results than 1.0 or 1.2 percent phosphorus levels in the diet of S. C. White Leghorns. However, at a 2.5 percent calcium level the 0.80 percent phosphorus ration tended to produce egg shells of poorer texture than the 0.60 percent ration. With another trial in this study involving two calcium levels, 0.60 percent phosphorus gave better egg production than a ration containing 0.80 percent phosphorus.

O'Rourke, Phillips and Cravens (1955) conducted experiments to determine the phosphorus requirement of laying pullets. With rations varying in phosphorus levels from 0.43 to 0.80 percent there was a slight tendency for the higher phosphorus rations to have decreased egg production.

Arscott et al. (1962) in an experiment with ascorbic acid, calcium and phosphorus demonstrated that in a ration containing 2.25 percent calcium raising the phosphorus level from 0.60 percent to 0.90 percent reduced egg shell thickness as assessed by specific gravity.

Hinners, Gholson and Ritchason (1963) contradict Arscott et al.

(1962) in stating that increasing phosphorus levels from 0.705 to 1.018 percent failed to show any significant changes in shell thickness, or hen-day production. No significant differences in egg weight, albumen height, Haugh units, body weight or mortality were associated with changes in phosphorus levels of the diet. However, the hens in this experiment were not placed on experiment until after six months of lay.

Talyor (1965) demonstrated that a high phosphorus diet (1.00 percent) significantly decreased shell thickness as compared to a low phosphorus diet (.46 percent). It was found that when the birds were transferred from the low to the high phosphorus diet the first egg on the new high phosphorus diet was thinner than the last egg on the old low phosphorus diet.

Hunt and Chancey (1970) in experimenting with the influence of dietary phosphorus on shell quality demonstrated that shell quality was inversely proportional to dietary phosphorus levels. In diets with phosphorus levels of 0.36, 0.66 and 0.96 percent, the 0.36 percent phosphorus had the highest specific gravity scores with the 0.96 percent diet giving the lowest score. Also the higher phosphorus levels resulted in a lower rate of lay per unit feed consumed than the low P ration.

Damron, Andrews and Harms (1974) in a study comparing Curacao Island phosphate with dicalcium phosphate demonstrated that a 0.80 percent phosphorus ration supplemented with Curacao Island phosphate significantly reduced egg production as compared to lower phosphorus rations.

IV. VARIANCE IN NUTRIENT REQUIREMENTS AMONG BREEDS AND STRAINS

Breeds and strains of chickens may differ in utilization and metabolism of various nutrients. Gardiner (1969) demonstrated a breed difference in response to various phosphorus levels with Single Comb White Leghorns versus a commercial broiler crossbred. In an earlier study, Pepper _et al_. (1959) observed significant differences among strains in the availability of phosphorus from soft phosphate as compared with dicalcium phosphate. Martin and Patrick (1962) demonstrated a difference in Ca^{45} uptake among three strains of chickens. McDonald and Bielharz (1962) reported a breed difference in the ability to retain calcium reserves. In a study of the effect of breed and phosphorus levels in the diet on calcium requirements, Gardiner (1971) demonstrated a significant breed X calcium interaction indicating that the Leghorn and broiler-type chickens differ in dietary calcium requirements.

Neisheim and Hutt (1962) found significant differences in the requirements of arginine between strains of White Leghorn chickens and among sire families within those strains. Hegsted _et al_. (1941) in an earlier study observed a difference in arginine requirement between White Leghorns and Barred Plymouth Rocks.

Donovan (1965) demonstrated a difference in vitamin A requirement between two strains of White Leghorns and two strains of broiler-type crossbreds. Yoshida, Hoshii and Morimoto (1966) demonstrated a difference in niacin and riboflavin requirements between White Leghorns and two strains of broiler crossbreds.

A significant difference in protein requirements among five strains of White Leghorns was demonstrated by Balloun and Speers (1969). Aitken et al. (1972) in working with 17 egg production strains observed significant strain X dietary protein level interactions for egg weight, albumin quality and feed consumption. Harms and Waldroup (1962), Moreng et al. (1964), Deaton and Quisenberry (1965), and Harms, Damron and Waldroup (1966) all demonstrated significant genotype X dietary protein level interactions.

V. SPECIFIC GRAVITY AS A MEASURE OF SHELL QUALITY

For the purpose of this experiment the primary factor in shell quality was shell strength. Shell strength is of major importance due to the possibility of cracking in egg processing and transportation. Munro (1940, 1942) and Novikoff and Gutteridge (1949) indicate shell strength to be indicative of the hatching power of eggs. Wolford and Tanaka (1970) cite numerous factors influencing shell strength including diet, rate of production, age of hen, disease, and various other factors.

Numerous devices have been designed and various methods adapted to measure egg shell strength. For practical application, a method which is accurate, easy to use, relatively fast, cheap, non-destructive to the egg, and allows large quantities of eggs to be measured is needed. A review of the various methods proved none to be perfect and that the method chosen should lend itself closest to the experimental objectives.

Tyler (1961) gives a summary of various methods and devices used in calculating shell strength used in past research. Herrasti (1916), Kennard (1925), Alder (1927), Romanoff (1929), Stuart and Hart (1938), Brooks and Hale (1955), and other authors are cited by Tyler (1961) as using variations of a method using crushing devices. The methods described were sometimes crude and in most cases slow and involved destroying the egg.

Willard and Shaw (1909), Needham (1931), Tully and Franke (1934), Mueller (1957), and Novikoff and Gutteridge (1949) are cited by Tyler (1961) as using devices involving puncturing the egg to determine shell strength. However, these methods were time consuming and impractical for measuring a large quantity of eggs. These methods generally imparted pressure to an egg by means of a rod and determined the pressure required to puncture through the shell.

Tyler (1961) described a method using impact to determine shell strength. This method involved a falling ball dropped on an egg or a case where the egg itself was allowed to drop. Swenson and James

(1932), Hale (1954), Mueller (1957), and Novikoff and Gutteridge (1949) are cited by Tyler (1961) as using variations on this technique. This method, like the previous methods, was impractical for large quantitites of eggs due to the time involved and the fact the eggs were left unfit for commercial use.

Hunton (1969) presented a comparison of beta-backscatter, quasi-static compression, non-destructive deformation, and direct shell thickness measurement as methods of determining shell strength. All of these methods had various disadvantages ranging from cost of operation to time required per egg.

Hunton and Voisey (1972) gave a comparison of two measuring devices for shell deformation as a means of assessing shell quality. Although the machines were fairly accurate, one took 8 minutes to measure 25 eggs whereas the other took 20 minutes.

Novikoff and Gutteridge (1949) described a specific gravity method which measures percent shell. This method allowed a calculation of shell strength without injury to the intact egg and could be adapted for use with a large quantity of eggs. This specific gravity method was simply a flotation method where eggs were dipped into brine solutions having a range of specific gravity from 1.062 to 1.102 in intervals of .004 with the end point being the lowest specific gravity in which the egg floats. Novikoff and Gutteridge (1949) compared this specific gravity method with a penetration method using a penetrometer and concluded that the specific gravity method was more sensitive as a measure of resistance to breakage and also less variable allowing a greater accuracy in separating eggs of good and poor shell strength.

Wells (1967) demonstrated a very close correlation between shell thickness as assessed by specific gravity and shell deformation under an imposed load. It was stated that egg specific gravity was significantly related to the incidence of egg shell failure in the field. Both methods were advantageous in that they did not damage the egg, were relatively fast, and required minimum labor. However, the specific gravity method was much cheaper because there were no large expenses as in the case of the deformation machine.

CHAPTER III

EXPERIMENTAL PROCEDURES

I. EXPERIMENTAL ANIMALS

One thousand and eight Single Comb White Leghorn-type pullets representing four high producing commercial strains were used in this experiment and maintained at the Cherokee Farm of the University of Tennessee Agriculture Experiment Station, Knoxville.

The birds were obtained from commercial hatcheries in June, 1974 and randomly assigned by strain to growing pens. Throughout the growing period the birds were raised under identical conditions, fed the same diets and were debeaked and vaccinated for Marek's disease, infectious bronchitis, Newcastle disease and fowl pox. At twenty-one weeks of age the birds were transferred to caged laying houses, with two birds assigned to each 25.4 by 45.7 cm cage and placed on experimental diets.

II. COMPOSITION OF DIETS

The experimental diets were formulated to be practically isocaloric, isonitrogenous and isocalcic. The only calculated analytical variable was the phosphorus content (0.4 and 0.6 percent). To assure diet consistency throughout the experiment each batch of experimental diet mixed was analyzed for phosphorus and calcium content and certain batches were analyzed for crude protein percentage. The composition of the two experimental diets is shown in Table I. Diets of this type have been used for several years at the Tennessee Agricultural Experimental Station in studies on egg shell quality.

III. EXPERIMENTAL DESIGN

The experimental design chosen to determine the response of the four strains of Single Comb White Leghorn pullets to two phosphorus levels (0.4 and 0.6 percent) involved eight treatments (four strains and two diets). In two laying houses, nine consecutive cages composed a replicate lot with seven replicates per treatment. Treatments were assigned to lots according to a randomized block design.

IV. METHODS OF DATA COLLECTION

Experimental data were collected following a four week adjustment period. Data for all parameters of study, with the exception of body weight, were collected by lots on a 28 day period basis for eleven periods. Egg production, feed consumption, and mortality were monitored daily and calculated by period throughout the eleven period study.

Egg weight and specific gravity data were collected on eggs by lots one day each week throughout the study and averaged for each period. Egg weight was measured by weighing eggs individually on a gram-weight scale.

TABLE I

VARIABLES AND NONVARIABLES USED IN EXPERIMENTAL DIETS

Feedstuff	Percent in Diet	
Nonvariables	.6% P	.4% P
Soybean meal, 48.5% protein	17.300	17.300
Fishmeal (menhaden)	2.500	2.500
Alfalfa meal, 17% protein	5.000	5.000
Vitamin mix[a]	.500	.500
Salt	.500	.500
Manganese sulfate	.025	.025
Variables		
Yellow corn[b]	66.345	66.801
Ground limestone,[b] 38% Ca	6.540	7.170
Defluorinated rock phosphate, 22% Ca, 18.5% P	1.290	.204
Total	100.000	100.000
Calculated analysis		
Crude protein, %	16.89	16.93
Metabolizable energy, Cal./kg.	2817.00	2832.00
Calcium, %	3.00	3.00
Phosphorus, %	0.60	0.40
Vitamin A, I.U./kg.	10107.00	10117.00
Vitamin D_3, I.C.U./kg.	3000.00	3000.00
Riboflavin, mg./kg.	6.52	6.53
Niacin, mg./kg.	46.64	46.74
Pantothenic acid, mg./kg.	12.60	12.63
Choline, mg./kg.	1392.59	1394.59

[a]Vitamin mix supplied the following amounts per kilogram of diet: 2,498 I.U. of vit. A; 3,000 I.C.U. of vit. D_3; 4.55 mg. of riboflavin; 25.00 mg of niacin; 441 mg of choline; 4.76 mg. of pantothenic acid; and 6.6 µg of vit. B_{12}.

[b]Corn and limestone were included as variables because their portions were varied to compensate for the difference in phosphorus content.

Specific gravity of the eggs was determined according to the method used in the Sixteenth Tennessee Random Sample Laying Test Report, (Shirley, 1973). Eggs were submerged into a series of sodium chloride solutions of increasing concentrations. The solution in which a given egg floated was the specific gravity score of that egg. Table II shows the specific gravity of the solutions and their assigned scores.

Measurements of body weight were taken at the beginning and end of this study by weighing birds individually on a kilogram scale.

All birds that died were submitted to the departmental diagnostic laboratory for necropsy.

V. ANALYSIS OF DATA

A preliminary analysis of variance in which each strain diet sub cell was considered as a separate treatment was conducted according to the following model:

$Y_{ij} = \mu + t_i + r_j + (t \times r)_{ij}$

Y_{ij} = an individual observation of egg production, egg quality and physiological parameters on the ijk^{th} pen of birds.

μ = overall mean, assuming equal subclass numbers

t_i = the i^{th} strain-diet subclass (treatment), i = 1, 2, ··· 8

r_j = the j^{th} replication, j = 1, 2, ··· 7

$(txr)_{ij}$ = the interaction of treatment and replication

TABLE II

SPECIFIC GRAVITY OF SALT WATER SOLUTIONS FOR EGG SPECIFIC GRAVITY DETERMINATIONS*

Specific Gravity	Score
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

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

Final analysis of variance was designed to separate strain and diet effects and was performed using the following model:

$$Y_{ijk} = \mu + s_i + d_j + r_k + (s \times d)_{ij} + (s \times r)_{ik} + (d \times r)_{jk} + (s \times d \times r)_{ijk}$$

Y_{ijk} = an individual observation of egg production, egg quality and physiogical parameters on the ijklth pen of birds

μ = overall mean, assuming equal subclass numbers

s_i = the i^{th} strain, i - 1, 2, 3, 4

d_j = the j^{th} diet, j = 1, 2

r_k = the k^{th} replication, k = 1, 2, $\cdots$ 7

$(s \times d)_{ij}$ = the strain x diet interaction

$(d \times r)_{jk}$ = the strain x diet interaction

$(s \times r)_{ik}$ = the strain x replicate interaction

$(s \times d \times r)_{ijk}$ = the strain x diet x replicate interaction

When a significant F test was observed in the preliminary and final analysis of variance, mean separation was performed using the Duncans Multiple Range Test at the 0.05 percent level.

CHAPTER IV

RESULTS AND DISCUSSION

I. EGG PRODUCTION

The effect of dietary phosphorus level on egg production in laying hens has been the basis for extended research for many years. Many published results have been contradictory. In this experiment the effects of the 0.4 and 0.6 percent phosphorus diets on percent hen day egg production varied between and within the four strains. The mean values in Table III show that strains 1, 2 and 3 laid at the same rate when fed the two experimental diets but that strain 4, when fed the 0.4 percent phosphorus diet, failed to lay as well as when fed the 0.6 percent phosphorus diet. When the data between strains were compared strain 4 laid at a significantly lower rate of production than the other strains. This appeared to be due primarily to the response of strain 4 to the low phosphorus diet. Production differences between the two diets were significant. These results support the work of O'Rourke et al. (1954), O'Rourke, Phillips and Cravens (1955), Pepper et al.(1959, 1969), Crowley Kurnick and Reid (1963), Berg, Bearse and Merrill (1964), Salman, Ali and McGinnis (1969), Hunt and Chancey (1970), Mraz (1972) and Scott, Antillon and Mullenhoff (1975) in that a dietary phosphorus level of approximately 0.40 percent will support normal production for high producing layers. However, the results of this research as well as that of the above authors contradicts the results obtained by Miller and Bearse (1934), Singsen et al. (1962), Walter and Aitken

TABLE III

SUMMARY OF DATA FOR EGG PRODUCTION AND QUALITY*

Strain	Diet (% P)	Production (%)	Avg. Egg Wt. (grams)	Avg. Specific Gravity Score
Diets Within Strains				
1	.4	77.4[a]	60.7[a]	3.28[ef]
	.6	77.8[a]	59.9[ab]	3.19[f]
2	.4	77.5[a]	59.5[b]	3.82[a]
	.6	76.8[a]	59.3[b]	3.77[ab]
3	.4	76.3[a]	57.7[c]	3.72[abc]
	.6	77.4[a]	58.0[c]	3.50[cde]
4	.4	71.5[b]	56.5[c]	3.55[bcd]
	.6	75.5[a]	56.9[c]	3.32[def]
Between Strains				
1		77.6[a]	60.3[a]	3.24[a]
2		77.1[a]	59.4[b]	3.80[a]
3		76.8[a]	57.9[c]	3.61[ab]
4		73.6[b]	56.7[d]	3.43[bc]
Between Diets				
	.4	75.7[a]	58.6[a]	3.59[a]
	.6	76.9[a]	58.5[a]	3.44[b]

*Values under each subheading within each column with different superscripts are significantly different ($P \leq 0.05$).

(1962), Mostert and Swart (1969) and Ademosun and Kalango (1973) who demonstrated that a dietary phosphorus level of 0.4 percent would result in reduced egg production over higher phosphorus diets. A comparison of these papers offers no concrete explanation for these differences as there were similarities in experimental procedures among many of the contradicting articles. The response difference within strains to the two levels of dietary phosphorus observed in this experiment can lead to the postulation that the use of different strains might account for those contradictions. However, in most of these reports the author only identified breed and not genetic strain of the layers they used.

II. SHELL QUALITY

The measurement of egg specific gravity as an assay of shell quality is supported by Novikoff and Gutteridge (1949) and Wells (1967) in articles reviewing the measurement of shell quality. Table III shows the mean specific gravity relationships studied in this experiment. Feeding the 0.4 percent phosphorus diet resulted in significantly improved egg shell quality as compared to feeding the 0.6 percent diet. This observation is supported by Evans and Carver (1942), Evans, Carver and Brant (1944), Arscott et al. (1962), Taylor (1965), Hunt and Chancey (1970), Singh, Bletner and Goff (1971) and Scott, Antillon and Mullenhoff (1975) who observed a significant inverse relationship between dietary phosphorus level and egg shell quality. Pepper et al. (1959) and Singsen et al. (1962) also observed this effect but their results were not statistically significant. Miller and Bearse (1934), Walter and Aitken (1962), Crowley, Kurnick and Reid (1963), Hinners, Gholson and Ritchason (1963) and Ademosun and Kalango (1973) contradict these results by observing no difference in shell quality between dietary phosphorus levels in the 0.4 percent range as compared to higher levels. A comparison of the contradictory articles offers no explanation for these discrepancies. Table III shows significant differences between strains for average specific gravity but there were no differences in dietary response within strains as each strain exhibited improved shell quality when fed the low phosphorus diet.

Figure 1 shows the average specific gravities for diets graphed by periods. Egg shell quality declined with length of lay until the tenth period when it improved. This improvement was attributed to a lowered environmental temperature experienced during this period. Wolford and Tanaka (1970) in a review of various factors influencing egg shell quality substantiate these two observations by stating that egg shell quality declines with length of lay and high environmental temperature.

III. EGG WEIGHT

The results on average egg weight observed in this experiment support the work of Miller and Bearse (1934), Walter and Aitken (1962), Singsen _et al_. (1962), Crowley, Kurnick, and Reid (1963), Hinners and Gholson (1963), Berg, Bearse and Merrill (1964), Salman, Ali and

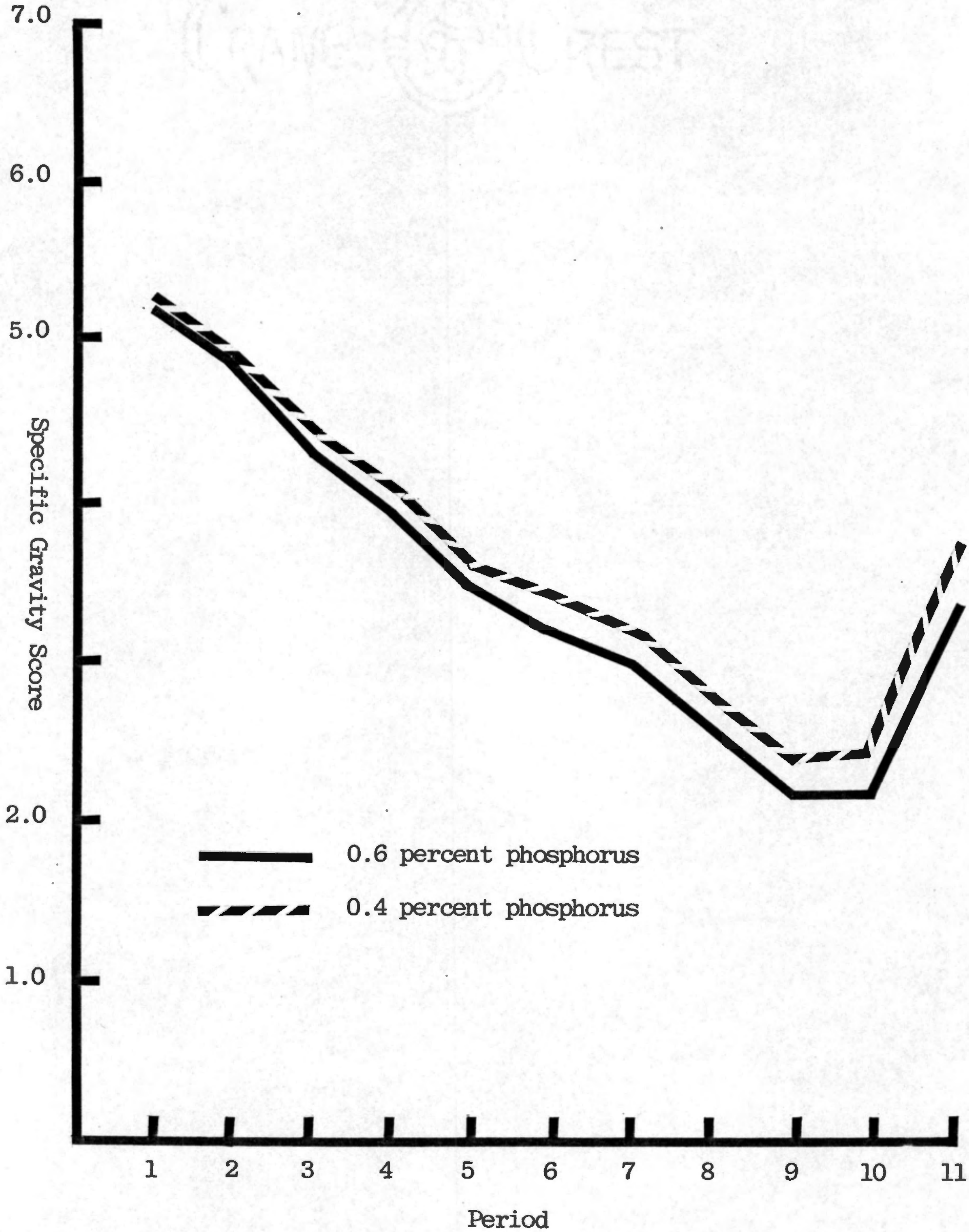

Figure 1. Average specific gravity score for diets by periods.

McGinnis (1969), Hunt and Chancey (1970) and Damron, Andrews and Harms (1974) who concluded that egg weight was not related to dietary phosphorus level. There were no contradictions to this observation found in the literature. Table III shows the mean egg weights for this study. There were no significant differences between diets or for diets within strains. Egg weight means for the four strains were all significantly different.

IV. FEED CONSUMPTION

Feed consumption in this study was analyzed by feed per hen and feed per dozen. There were no significant differences between the two dietary phosphorus levels for these two parameters. Pepper et al. (1959), Singsen et al. (1962), Crowley, Kurnick and Reid (1963) and Salman, Ali and McGinnis (1969) all demonstrated that a dietary phosphorus level in the 0.4 percent range provided feed efficiency in terms of feed per dozen equal to higher dietary phosphorus levels. However, Ademosun and Kalango (1973) observed a 0.4 percent dietary phosphorus level increased the feed requirement for egg production when compared to a 0.6 percent phosphorus level. Conversely, Hunt and Chancey (1970) demonstrated a 0.39 percent phosphorus ration supported a higher rate of lay on less feed per dozen than dietary phosphorus levels of 0.51, 0.60 and 0.72 percent. No explanation for these discrepancies can be given as there were no significant differences in dietary response within any of the four strains studied in this experiment. It is recognized that feed per dozen eggs is affected by both rate of production and total feed consumption. Generally high producing hens consume less feed per dozen eggs than low producing hens. The mean values for feed per hen and feed per dozen are shown in Table IV. The only significant differences observed were between individual strains and not in strain response to phosphorus levels.

V. MORTALITY

Mortality was not affected by dietary phosphorus level in this study. Examination of the literature supports this observation for all research carried out on dietary phosphorus levels in the 0.4 and 0.6 percent range. The only significant differences observed were among strains and the means in Table IV show that strain 4 had a significantly lower mortality rate than the other three strains. It is interesting to note that although there were no statistical differences for diets within individual strains there appeared to be some strain response to the phosphorus level in the diet. Strains 1 and 4 exhibited higher mortality on the 0.4 percent phosphorus diet whereas strains 2 and 3 showed reduced mortality on the 0.4 percent diet. Although low phosphorus diets are considered by commercial poultrymen to be a cause of cage layer fatigue, no incidence of cage layer fatigue was observed in this experiment. No specific cause of mortality was associated with strain or diet.

TABLE IV

SUMMARY OF DATA FOR FEED CONSUMPTION AND MORTALITY*

Strain	Diet (% P)	Feed/Hen (Kilograms)	Feed/Dozen (Kilograms)	Mortality (%)
Diets Within Strains				
1	.4	32.70[a]	1.65[ab]	15.08[a]
	.6	32.76[a]	1.64[ab]	10.32[a]
2	.4	33.43[a]	1.69[a]	8.73[a]
	.6	33.18[a]	1.69[a]	15.08[a]
3	.4	30.41[bc]	1.56[c]	7.94[a]
	.6	31.13[b]	1.57[bc]	9.53[a]
4	.4	29.91[c]	1.63[ab]	5.56[a]
	.6	30.58[bc]	1.61[bc]	4.76[a]
Between Strains				
1		32.75[a]	1.65[a]	12.70[a]
2		33.29[a]	1.69[ab]	11.90[a]
3		30.75[b]	1.56[c]	8.70[ab]
4		30.25[b]	1.62[b]	5.70[b]
Between Diets				
	.4	31.62[a]	1.63[a]	9.93[a]
	.6	31.93[a]	1.63[a]	9.33[a]

*Values under each subheading within each column with different superscripts are significantly different ($P \leq 0.05$).

VI. BODY WEIGHT

Body weight in this study was divided into the parameters of average initial body weight, average final body weight and average body weight gain. Average initial body weight did not differ between diets or between diets within strains. There were significant differences among strains for initial body weight. Average final body weights were significantly different between strains and between the two phosphorus diets and in addition there was a significant difference for diets within strains. The mean values in Table V show that within strain 4 there was a significant difference between diets. Average body weight gain differed significantly between diets and among strains but there were no significant differences for diets within individual strains. In general it appeared that the 0.6 percent phosphorus diet supported a higher final body weight and body weight gain than the 0.4 percent diet. This is substantiated by the work of Walter and Aitken (1962) who reported that dietary phosphorus levels of 0.7, 0.6 and 0.5 percent were superior to a 0.4 percent level for maintenance of body weight in laying hens. Ademosun and Kalango (1973) also observed a 0.4 percent dietary phosphorus level to result in significantly lowered body weight when compared to a 0.6 percent level. However, this was significant only up to eight months of production. Hunt and Chancey (1970) contradict these results by demonstrating dietary phosphorus

TABLE V

SUMMARY OF DATA FOR BODY WEIGHT PARAMETERS*

Strain	Diet (% P)	Avg. Initial Body Wt. (grams)	Avg. Final Body Wt. (grams)	Avg. Body Wt. Gain (grams)
<u>Diets Within Strains</u>				
1	.4	1597^{a}	1762^{abc}	165^{c}
	.6	1599^{a}	1824^{ab}	226^{abc}
2	.4	1568^{a}	1786^{ab}	218^{abc}
	.6	1563^{a}	1833^{a}	270^{a}
3	.4	1515^{a}	1701^{cd}	186^{bc}
	.6	1539^{a}	1752^{bc}	213^{abc}
4	.4	1452^{a}	1668^{d}	216^{abc}
	.6	1511^{a}	1756^{abc}	244^{ab}
<u>Between Strains</u>				
1		1598^{a}	1793^{a}	196^{b}
2		1566^{a}	1810^{a}	244^{a}
3		1527^{b}	1727^{b}	200^{b}
4		1482^{c}	1712^{b}	230^{ab}
<u>Between Diets</u>				
	.4	1533^{a}	1729^{b}	196^{b}
	.6	1553^{a}	1791^{a}	238^{a}

*Values under each subheading within each column with different superscripts are significantly different ($P \leq 0.05$).

levels ranging from 0.38 to 0.72 percent had no effect on final body weight or body weight gain of layers. This is supported by Pepper *et al*. (1959) and Singsen *et al*. (1962) who observed similar body weights of hens fed dietary phosphorus levels in the 0.4 percent range and those fed diets higher in phosphorus content.

VII. CONCLUSIONS

The results of this study support the theory that breeds and strains of chickens may differ in the efficiency of utilization of phosphorus in that a 0.4 percent phosphorus diet was sufficient for three of the four strains of layers but one of the four strains performed superiorly on the 0.6 percent phosphorus.

CHAPTER V

SUMMARY

The purpose of this experiment was to determine the response of four strains of high producing Single Comb White Leghorn-type hens to two levels of dietary phosphorus as measured by egg production, egg shell quality, egg weight, feed efficiency, body weight and mortality.

A 44-week study was conducted using eight treatment groups composed of two diets (0.4 and 0.6 percent phosphorus) and four strains. Each treatment group consisted of seven replicate lots of 18 birds each.

Measurements of specific gravity and egg weight were taken on a weekly basis throughout the experiment. The results from the study were as follows:

1. Egg production was not affected by phosphorus level for combined strains but varied among strains. There was a difference in strain response to the two diets.
2. Egg shell quality as assayed by specific gravity declined linearly with length of lay and responded to a change in environmental temperature. The low phosphorus diet resulted in significantly improved egg shell quality as compared to the higher phosphorus diet. Strains differed significantly from one another.

3. Average egg weight was not affected by dietary phosphorus level but varied between strains.
4. Feed consumption varied between strains but was not related to phosphorus level in the diet.
5. Body weight as assayed by final body weight and body weight gain was significantly reduced on the lower phosphorus diet and varied among strains.
6. Mortality was not affected by dietary phosphorus level but varied among strains.

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