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I am submitting herewith a thesis written by Huthail Najib entitled "The Effect of Two Levels of Dietary Phosphorus on Laying House Performance of Four Strains of White Leghorn Layers." 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 EFFECT OF TWO LEVELS OF DIETARY PHOSPHORUS ON LAYING HOUSE PERFORMANCE OF FOUR STRAINS OF WHITE LEGHORN LAYERS

A Thesis

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ABSTRACT

The objective of this study 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 specific gravity, egg weight, feed efficiency, mortality, and the percent tinted eggs and to study the effect of time of oviposition on egg specific gravity.

The experiment was conducted for eleven 28—day periods using January hatched pullets housed at the rate of two birds per 20.3 cm. wide cage. Two diets containing two levels of phosphorus, 0.4 percent and 0.6 percent, were compared. Each was fed to four lots of 30 birds of each four strains of layers. The four strains of S. C. White Leghorn—type layers responded to the two dietary phosphorus levels in a similar manner. In only two comparisons were the differences large enough to be significant ($P < 0.05$). The birds of strain 4 when fed the 0.4 percent phosphorus diet laid eggs that had a specific gravity score that was significantly larger than that of the eggs of birds of the same strain fed the 0.6 percent phosphorus diet. Strain 2 birds fed the 0.4 percent phosphorus diet laid significantly more eggs with tinted shells than did birds of the same strain fed the 0.6 percent phosphorus diet. There was a marked tendency for birds of all strains to gain more body weight when fed the 0.6 percent phosphorus diet, to consume more feed and to lay fewer eggs with tinted shells. The strains differed significantly ($P < 0.05$) in average egg weight, initial and final body weight, and in

the percent of tinted eggs laid. Analyses of the data to determine diet effects failed to identify any differences in the overall response to the diets.

Eggs laid in the afternoon had higher specific gravity than those laid earlier in the day.

Eggs laid between 8:00 a.m. and 10:15 a.m. and between 10:15 a.m. and 1:00 p.m. have the highest coefficients of variability but appeared to vary the least from day to day when compared with eggs laid earlier or later in the day.

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CHAPTER I

INTRODUCTION

Cracked eggs are a serious problem facing the egg producer and processor because these broken eggs are unmarketable. The poultry industry loses millions of dollars per year because of cracked and/or broken eggs resulting from poor shell quality.

It has been estimated by the United States Department of Agriculture (Berry, 1976) that U.S. egg production was approximately 184 million cases in 1974, and that the annual loss to the industry could have been almost two million cases for each 1 percent of broken eggs. Unfortunately, the stress of high production, high density housing, increased social tension and use of mechanical egg gathering and grading equipment by commercial egg producers tends to increase the number of cracked and broken eggs. This makes it important that egg shell quality be maintained at as high a level as possible.

"Shell quality" is a term used by researchers to refer to several factors such as shell thickness, shape, smoothness, color, the presence or absence of dirt or stains, breaking strength and texture of the egg shell.

Several factors, in addition to nutrition, play important roles in the production of eggs of good shell quality such as, temperature, medicinals, air flow, light, heredity, disease, age of hen and time of oviposition.

In this thesis, the use of the term "shell quality" will be limited to concepts of percent shell, breaking strength, and shell thickness as measured by the specific gravity method.

The role of phosphorus in producing eggs with good shell quality has received much less attention by nutritionists than has calcium but the former may be quite important. Research at the University of Tennessee has demonstrated that lowering the phosphorus levels of the laying diet to approximately 0.4 percent improves shell quality (Singh, 1971; Singh, Bletner, and Goff, 1971; Shirley, 1974: Bletner and McGhee, 1975; Ingram, 1976). However, industry members have reported that they cannot use or recommend such a low phosphorus level. The most apparent reason for differences in the response of layers to low phosphorus diets under experimental and commercial conditions is that layers from different breeds or strains may respond differently or have a different phosphorus requirement than those used in experimental research. Ingram (1976) has reported this finding to be true.

Further comparisons of the requirements for phosphorus of layers of different genetic backgrounds should be undertaken.

Observations at the University of Tennessee have indicated that specific gravity determinations vary greatly between replicate lots of layers fed the same diet. Eggs laid at different times in a clutch and, therefore, at differents times of the day will vary in specific gravity. It is possible that by using only those eggs laid at a given time each day that the variability between replicate lots could be reduced and the actual number of eggs used in making specific gravity determinations could be reduced. Therefore, an experiment was designed to determine the responses of four strains of high producing Single Comb White Leghorn—type hens to two levels of dietary phosphorus as measured by egg production, egg specific gravity, egg weight, feed efficiency and mortality, and to study the effect of time of oviposition on egg shell quality.

CHAPTER II

LITERATURE REVIEW

I. PHOSPHORUS REQUIREMENT OF LAYING HENS

General

The phosphorus requirement of the laying hen has been studied by a considerable number of researchers during the last fifty years.

The National Research Council (NRC) (1954) recommendation for total phosphorus was 0.6 percent for laying chickens. It was further indicated that all the phosphorus in the non-plant feed ingredients should be considered to be inorganic. Approximately 30 percent of the phosphorus of plant products in non-phytin phosphorus and may be considered as part of the inorganic phosphorus required. A portion of the phosphorus requirement of growing chickens and laying hens must be supplied in inorganic form. NRC (1960, 1966 and 1971) recommended the same level of phosphorus and gave the same suggestion on the inorganic phosphorus requirement.

Normally the phosphorus content of the ration or the requirement of the bird is expressed in one or more of three ways: total phosphorus, inorganic phosphorus, or available phosphorus.

The term "available phosphorus" has several definitions in the literature. It is widely recognized that feed grade phosphorus concentrates may vary widely in availability of their phosphorus to chickens. Thus the term is sometimes used to describe the relative biological value of a concentrate. However, when the term is used to refer to the amount of phosphorus that should be included in a poultry diet it refers to the total phosphorus supplied by the source of inorganic phosphorus plus a percentage of that supplied by the plant products. The NRC (1971) indicated that 30 percent of the phosphorus of plant products to be inorganic. The requirement of laying hens for inorganic phosphorus so calculated was indicated as being less than the 0.4 percent level given for young chickens but it was stated that the amount required for laying hens is not well defined. Summers, Pepper, and Moran (1970) formulated diets for the Canadian poultry industry considering that 50 percent of the plant phosphorus was available to the laying hen while North (1972) reported that the adult bird can utilize an average of 75 percent of the plant phosphorus. Thus, it is difficult to evaluate the research when the authors fail to define "available phosphorus" and to give the composition of their diets.

In terms of available phosphorus North (1972) indicated that the percent of available phosphorus in the laying diet should be in the range of 80 to 90 percent of total. Scott (1975) recommended 0.45 percent available phosphorus for laying chickens but the method of calculating available phosphorus was not described.

Egg Production

In early work attempting to establish the lowest dietary level of phosphorus for satisfactory egg production, Miller and Bearse, (1934) indicated that hens fed a diet containing less than 0.8 percent phosphorus failed to maintain satisfactory egg production. Later Evans, Carver and Brant (1944), Hinners, Gholson and Ritchason (1963), and Harms, Damron, and Waldroup (1965) reported that the minimum phosphorus level required for normal egg production would be near the 0.7 or 0.8 percent level. Other researchers have reported that a maximum level of production was obtained with 0.6 percent total dietary phosphorus (Walter and Aitken, 1962; Mostert and Swart, 1968; Singh, Bletner and Goff, 1971; and Ademosun and Kalango, 1973).

Other researchers have reported that about 0.4 percent total dietary phosphorus gave satisfactory egg production (O'Rourke, Phillips and Cravens, 1955; Pepper et al., 1959; Singsen et al., 1962; Hunt and Chancey, 1970; Damron, Eldred and Harms, 1974; Bletner and McGhee, 1975; Shirley, 1974; and Summers, Grandhi and Leeson, 1976). Ingram (1976) reported that 0.4 percent phosphorus was sufficient for three of four strains of layers tested. O'Rourke et al. (1954), Singsen et al. (1967), Salman, Ali and McGinnis (1969), and Scott Antillon and Mullenhoff (1975) reported data indicating that 0.3 percent total phosphorus (in some studies all of the phosphorus being from plant sources) was sufficient for maximum egg production. It is impossible to explain at this time why some researchers have been able to obtain maximum egg production with diets containing as little as 0.3 percent phosphorus all from plant sources while others indicated that at least 0.8 percent phosphorus would be required.

Shell Quality

The effect of dietary phosphorus on egg shell quality has been studied by several workers but there has been little agreement regarding this subject.

Pepper et al. (1959), Taylor (1961), Walter and Aitken (1962), Arscott, et al. (1962), Taylor (1965), Mostert and Swart (1968), Hunt and Chancey (1970) (for birds housed on litter), Singh, Bletner and Goff (1971), Damron, Eldred and Harms (1974), Shirley (1974), Scott, Antillon and Mullenhoff (1975), Bletner and McGhee (1975), Summers, Grandhi and Leeson (1976) and Ingram (1976) reported that feeding a low level of dietary phosphorus to laying hens did improve egg shell quality while Evans, Carver and Brant (1944) and Crowley, Kurnick and Reid (1963) reported that low dietary levels of phosphorus decreased egg shell quality.

Other groups of workers found that egg shell quality was not affected by feeding different levels of dietary phosphorus (Miller and Bearse, 1934; Singsen et al., 1962; Hinners, Gholson and Ritchason, 1963; Berg, Bearse and Miller, 1964; Wolford and Tanka, 1970; Hunt and Chancey, 1970, for birds housed in cages; Ademosun and Kalango, 1973).

Egg Weight

Miller and Bearse (1934); Pepper et al. (1959); Singsen et al. (1962); Arscott et al. (1962); Crowley, Kurnick and Reid (1963); Hinners, Gholson and Ritchason (1963); Harms, Damron and Waldroup (1965); Damron, Andrews and Harms (1974); Roland and Harms (1976) and Ingram (1976) found that dietary phosphorus had no influence on egg weight. Several researchers have reported that low dietary phosphorus improved egg weight (Walter and Aitken, 1962; Salman, Ali and McGinnis, 1969; Damron, Eldred and Harms, 1974). Shirley (1974) reported that the ratio of calcium to phosphorus influenced the percent of large size eggs. He further stated that very wide or very narrow ratios resulted in a significant reduction in percent of large eggs.

Body Weight

Compared to what has been published on the effect of phosphorus on egg production and egg shell quality, few articles have mentioned the effect of phosphorus on body weight.

Pepper et al. (1959), Hinners, Gholson and Ritchason, (1963), Salman, Ali and McGinnis (1969), Hunt and Chancey (1970), and Ademosun and Kalango (1973) reported that feeding different levels of dietary phosphorus failed to produce any changes in body weight.

Walter and Aitken (1962); Crowley, Kurnick and Reid (1963); and Ingram (1976) reported that body weight was maintained by feeding a low level of dietary phosphorus.

Feed Consumption

Few articles have dealt with the effect of dietary phosphorus on feed consumption. Harms, Damron and Waldroup (1965); Mostert and Swart (1968); Ademosun and Kalango (1973); Damron, Andrews and Harms (1974); Roland and Harms (1976) and Ingram (1976) reported no effect of dietary phosphorus on feed consumption. Hunt and Chancey (1970) and Damron, Eldred and Harms (1974) found that with low dietary phosphorus the feed consumption was reduced, while Shirley (1974) reported a lower feed consumption when layers were fed a high dietary level of phosphorus.

II. SHELL QUALITY AND TIME OF OVIPOSITION IN LAYING HENS

Very few studies have dealt with the specific subject of egg shell quality as related to time of oviposition. Three studies are mainly related to this subject. Roland, Sloan and Harms (1973) and Roland and Harms (1974) conducted experiments in which the eggs were collected at different times during the day. They found that eggs laid in the afternoon had an average specific gravity greater than eggs laid in the morning. Roland and Harms (1974) further reported that eggs laid in the afternoon weighed less than did eggs laid in the morning.

Washburn and Potts (1975) reported an increase shell strength of eggs collected at 12 noon, 2:00 p.m. and 4:00 p.m. They also reported that no consistent significant differences were observed between strains and time of oviposition.

III. JUSTIFICATION OF SPECIFIC GRAVITY AS A MEASUREMENT OF EGG SHELL QUALITY

For many years, cracked eggs have been a considerable problem to the farmer, packer and consumers. This has led to the development of a variety of methods for measuring egg shell strength.

Shell strength is an extremely variable characteristic which may be influenced by numerous environmental and physiological factors such as diet, rate of egg production, length of period of egg production, position of egg in the clutch, breeding and climatic conditions. Considerable research has been performed to establish methods for measuring shell strength. These methods utilize equipment of varying cost and complexity which also vary in accuracy and in the physical characteristics studied.

Tyler (1962) in reviewing the various methods for measuring shell strength concluded that there are three basic methods for measuring shell strength of whole eggs; namely, by crushing, by puncturing and by impact, while pieces of shell may also be punctured or broken. However, many characteristics of eggs are related to shell strength and have been studied in detail. Some of these are shell thickness, weight loss, percent shell, specific gravity, deformation, and weight per unit of shell. Some of these methods have been widely used for measuring shell quality in particular the specific gravity method. Olsson (1934) demonstrated that the specific gravity of the whole egg is a good indication of the percentage of shell.

The advantage of this method over all the others is, of course, that it can be used without destruction of the egg. Another advantage of the specific gravity method over other methods is that a large number of eggs can be measured at the same time.

The specific gravity method was described by Novikoff and Gutteridge (1949) as simply dipping the eggs into brine solutions having a specific gravity range from 1.062 to 1.102 in intervals of 0.004, the end point being the lowest specific gravity in which the egg floats. After comparing this method with several methods for measuring shell strength, they concluded that the specific gravity method was more sensitive as a measure of resistance to breakage than the penetrometer.

Specific gravity is the standard method for determining shell quality in all the random sample laying tests in the United States and Canada (USDA, 1975).

Tyler and Geake (1961) reported that specific gravity by flotation is reasonably good if suitable precautions are taken, for instance, reducing the differences between successive solutions to 0.001 (1 unit) and checking solutions with a specific gravity bottle rather than with a hydrometer. Furthermore, changes in such solutions by evaporation will produce relatively larger error than when the differences between successive solutions are larger.

Schoorl and Boersma (1962) designed a new apparatus to evaluate shell quality by measuring the change in shape (deformation) of an egg shell by applying a certain weight on the egg shell. They reported that the advantages of the deformation instrument are that it is reproducible and it does not affect the quality of the shell and the egg contents. They compared the deformation of the egg shell with other methods of evaluating shell quality such as breaking strength, shell thickness and percentage shell. The highest correlation was found between deformation and breaking strength.

Wells (1967a) compared four methods of measurement of egg shell quality, namely, resistance to crushing by a hydraulic method, resistance to impact by falling ball technique, specific gravity by hydrometer method and shell weight per unit area. Correlations between these assessments of shell strength and the percentage of cracked eggs produced by each hen were highly significant. He concluded that from a practical standpoint egg specific gravity was the best method used. He also suggested that it is worthy to compare the recently developed test of shell deformation of Schoorl and Beorsma (1962) with specific gravity as an indicator of shell strength in future work. Wells (1967b) in a second experiment reported a correlation of 0.8 to 0.9 between deformation and specific gravity. As specific gravity increased the deformation score decreased.

Ahmad, Froning and Mather (1975) reported that egg specific gravity was significantly related to shell stiffness. They further reported that specific gravity and shell thickness were significantly correlated.

CHAPTER III

EXPERIMENTAL PROCEDURES

I. EXPERIMENTAL ANIMALS

Nine hundred sixty pullets of four strains of Single Comb White Leghorn—type chickens were used in this research. Strain 1 chicks were hatched on January 6, 1975 and the other three strains on January 10, 1975. All chicks were vaccinated for Marek's disease and dubbed at one day of age. Also at hatching time the chicks were wingbanded with color coded bands for strain identification. During the growing period the chicks were vaccinated for Newcastle, infectious bronchitis and fowl pox diseases. They were fed a coccidiostatic drug in their starting and growing diets until they were 14 weeks of age.

When the pullets were about 20 weeks of age, they were transferred from solid floored growing pens to laying cages and housed at the rate of two pullets per 20.3 cm. wide cage.

II. EXPERIMENTAL DIETS

During a pre-experimental period of four weeks the pullets were fed the regular farm laying diet (LR4) calculated to contain about 17 percent crude protein, 0.6 percent phosphorus, and 3.0 percent calcium. When the pullets were approximately 24 weeks old they were fed their experimental diets. The two diets compared were calculated to be approximately isocaloric, isonitrogenous, and isocalcic and to maintain a constant of 0.4 or 0.6 percent phosphorus. Both diets were calculated to contain 16.9 percent protein, 3.00 percent calcium and 2817 kilocalories metabolizable energy per kilogram for the 0.6 percent phosphorus and 2832 kilocalories for the 0.4 percent phosphorus diets.

Diets were subjected to chemical analyses to assure diet consistency. Calcium content was checked by the atomic absorption spectrophotometry method according to Perkin and Elmer (1968). Phosphorus content was checked by a spectrophotometer method according to AOAC (1975).

The composition of the nonvariable and variable portions of the diets is indicated in Table I.

III. EXPERIMENTAL DESIGN

This experiment was designed to determine the response of four strains of S. C. White Leghorn—type layers to two levels of dietary phosphorus.

The strains and diets were assigned to pens on the basis of a randomized complete block design (Sokal and Rohlf,1969) involving four blocks. There was a total of eight combinations of four strains and two diets. Each pen (lot) consisted of 15 cages each containing two pullets. Data were collected for 11 periods each 28 days in length starting June 25, 1975, and ending April 27, 1976.

IV. METHOD OF DATA COLLECTION

All eggs laid by each pen on one day each week were identified by pens and used for specific gravity, egg weight, and percent shell tint determinations.

TABLE I

VARIABLES AND NONVARIABLES USED IN EXPERIMENTAL DIETS

Feedstuff	Phosphorus 0.6%	0.4%
Nonvariables		
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]	0.500	0.500
Salt	0.500	0.500
Manganese sulfate	0.025	0.025
Subtotal	25.825	25.825
Variables		
Yellow corn[b]	66.345	66.801
Ground limestone, 38% Ca	6.540	7.170
Defluorinated rock phosphate	1.290	0.204
Subtotal	74.175	74.175
Total	100.000	100.000
Calculated Analysis		
Crude Protein, %	16.89	16.93
Metabolizable energy, Kcal./kg.	2817.00	2832.00
Calcium, %	3.00	3.00
Phosphorus, %	0.60	0.40

[a]Vitamin mix supplied the following amounts per kilogram of diet: 2,498 I.U. of vitamin A, 3,000 I.C.U. of vitamin D_3, 4.59 mg. of riboflavin, 25.00 mg. of niacin, 441 mg. of choline, 4.76 mg. of pantothenic acid, and 0.66 mg. of vitamin B_{12}.

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

The specific gravity of the eggs was determined by placing the eggs from one pen from one day's production in a basket and submerging the basket with the eggs in a series of sodium chloride solutions of known concentrations. The solutions were numbered 0 to 8 with the 0 solution having the lowest specific gravity. The specific gravity score was the number of the solution in which the eggs floated. The relative concentrations and specific gravity scores used in this determination are shown in Table II.

The specific gravities of solutions were the same as those used in the random sample laying tests in the United States and Canada as described by the United States Department of Agriculture (1975).

Percent tint determinations were taken on individual eggs by comparing the eggs with an arbitrary set of standards for exterior shell color. Any egg shells not chalky white under fluorescent lighting were judged to be tinted.

Egg production data were collected by pens daily from Monday through Friday of each week. Feed consumption was determined for each pen of layers for each 28—day period.

Mortality records were established by removing the dead birds and recording the date of death of all birds that died during the experiment. Birds that died during the experiment were submitted to diagnostic laboratory for necropsy to determine the cause of death.

Body weight was taken individually just prior to the beginning of the experiment and again just before the experiment was completed on April 27.

TABLE II

SPECIFIC GRAVITY OF SALT WATER SOLUTIONS FOR EGG SPECIFIC GRAVITY DETERMINATION

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

[a]Scores used in random sample laying tests (U.S.D.A., 1975). Eggs floating in the various specific gravity solutions are given the corresponding score except that eggs which sink in the 1.100 specific gravity solutions are scored 9.

The effect of time of oviposition on egg shell quality was determined by collecting eggs six times a day: 6:30 a.m., 8:00 a.m., 10:30 a.m., 1:00 p.m., 4:00 p.m., and 7:30 p.m. for four days. These eggs were subjected to the specific gravity procedure after each day's collection.

V. ANALYSIS OF DATA

All data were subjected to analysis of variance according to the procedure for a randomized complete block design (Sokal and Rohlf, 1969).

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

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

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

μ = overall mean, assuming equal subclass numbers

t_i = the ith strain—diet subclass (treatment), $i = 1, 2, \cdots 8$

r_j = the jth replication, $j = 1, 2, \cdots 4$.

$(t \times r)_{ij}$ = the interaction of treatment and replication.

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

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

Y_{ijkl} = an individual observation of egg production, egg quality and physiological parameters on the ijklth pen of birds.

μ = overall mean, assuming equal subclass numbers.

s_i = the ith strain, $i = 1, 2, 3, 4$

d_j = the jth diet, $j = 1, 2$

r_k = the k^{th} replication, k = 1, 2, ··· 4

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

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

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

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

When significant differences were found those treatments which differed significantly were identified by Duncan's Multiple Range Test (1955). Only differences large enough to be significant at the 5 percent level of probability are identified in this thesis.

Data concerning the effect of time of oviposition on egg shell quality were subjected to analysis of variance and to a procedure for determination of coefficient of variation which measures the relative dispersions (Nash, 1958). The formula for relative dispersion which is termed the coefficient of variation is:

$CV = \frac{s}{\overline{X}} \times 100$ where CV = the coefficient of variation

s = the standard deviation of the sample

$\overline{X}$ = the mean of the sample

CHAPTER IV

RESULTS AND DISCUSSION

I. EGG PRODUCTION

In this study the effect of feeding two levels of dietary phosphorus, 0.4 and 0.6 percent, on hen day production of four strains of layers was studied.

The mean values for hen day production in Table III indicate that there were no significant differences in the response of strains to the diets, between strains or between diets. Strains 1 and 4 had larger numerical values for percent hen day production when fed the 0.4 percent phosphorus diet while strains 2 and 3 had larger numerical values for percent hen day production when fed the 0.6 percent phosphorus diet.

These results confirmed the work of O'Rourke et al. (1954), O'Rourke, Phillips and Carvens (1955), Pepper et al. (1959), Singsen et al. (1962), Singsen et al. (1967), Salman, Ali and McGinnis (1969), Hunt and Chancey, (1970), Damron, Eldred and Harms (1974), Bletner and McGhee (1975), Scott, Antillon and Mullenhoff (1975), and Summers, Grandhi and Leeson (1976) in that a low dietary phosphorus will maintain normal production for high producing layers. However, the results of this study as well as that of other researchers were in contrast to the results obtained by Miller and Bearse (1934), Evans, Carver and Brant (1944), Walter and Aitken (1962), Hinners, Gholson and Ritchason (1963), Harms, Damron and Walldroup (1965), Mostert and Swart (1968), Singh, Bletner and Goff

TABLE III

EFFECT OF STRAIN AND DIET ON EGG PRODUCTION AND QUALITY SCORE*

Strain	Diet (% P)	Production (percent)	Avg. Egg Wt. (grams)	Avg. Specific Gravity Score
Diets within strains				
1	0.4	74.1[a]	61.4[a]	3.74[bc]
	0.6	73.8[a]	61.8[a]	3.82[abc]
2	0.4	74.9[a]	59.3[b]	4.03[a]
	0.6	76.2[a]	60.1[b]	3.85[abc]
3	0.4	73.7[a]	58.1[c]	4.04[a]
	0.6	74.9[a]	57.4[cd]	3.99[ab]
4	0.4	75.6[a]	56.6[d]	4.08[a]
	0.6	75.3[a]	57.4[cd]	3.71[c]
Between strains				
1		74.0[a]	61.6[a]	3.78[a]
2		75.5[a]	59.7[b]	3.94[a]
3		74.3[a]	57.7[c]	4.01[a]
4		75.4[a]	57.0[c]	3.89[a]
Between diets				
	0.4	74.5[a]	58.8[a]	3.97[a]
	0.6	75.1[a]	59.2[a]	3.84[a]

*Values under each subheading within each column with different supersucripts are significantly different ($P < 0.05$).

(1971), and Ademosun and Kalango (1973) who showed that feeding a high level of phosphorus is necessary for normal egg production.

The explanation for these differences is unclear from these contradictory articles since most of them had similar experimental procedures.

Ingram (1976), using the same strains that were used in this experiment, found that strain 4 failed to lay as well as the other three strains when 0.4 percent phosphorus was fed. This finding was contrary to the results of this experiment. The only apparent explanation that can be given at this time is that Ingram used June hatched birds, while in this experiment January hatched birds were used. This indicates that the time of the year when the pullets are hatched might alter the phosphorus requirement for optimum production of the layers. In addition Ingram (1976) used 25.4 cm. cages for each two layers while 20.3 cm. cages for each two layers were used in this experiment. It is possible that stress due to cage size might have affected their requirements.

The slight response of within strains to the two levels of dietary phosphorus in this study might be attributed to these contradictory factors. However, most published research articles have not identified the genetic strains of the layers used.

II. EGG WEIGHT

The means for egg weight for this experiment are presented in Table III, p. 21. There were no significant differences between diets. This observation was similar to those reported by Miller and Bearse (1934), Pepper et al. (1959), Singsen et al. (1962), Arscott, et al. (1962), Crowley, Kurnick and Reid (1963), Harms, Damron and Waldroup (1965), Damron, Andrews and Harms (1974), and Ingram (1976). Shirley (1974) reported that a very wide or very narrow calcium to phosphorus ratio reduced the percent of large eggs.

The egg weight means for the different strains did differ significantly with those of strain 1 being significantly larger than the other strains. The average weight of the eggs from strain 2 was next largest and differed significantly from that of strains 1, 3, and 4 while the average egg weights from strains 3 and 4 did not differ significantly. The data are very similar to those reported by Ingram (1976) except that the egg weight of strains 3 and 4 differed significantly in his study. The numerical ranking of the egg weights was the same for both studies.

There was no significant difference in the response of any of the strains due to dietary phosphorus levels (Table III, p. 21). This is in agreement with the data reported by Ingram (1976).

The average egg weight for diets graphed by periods is shown in Figure I. The eggs tended to increase in egg weight with the length of lay of the hens on both diets.

III. SHELL QUALITY

Shell quality is a term used by researchers to refer to shell smoothness, shell texture, shell color, shell thickness, shell breaking strength, and other parameters.

In this experiment the specific gravity of the eggs, a measure correlated with the percent shell of eggs, was determined and the data

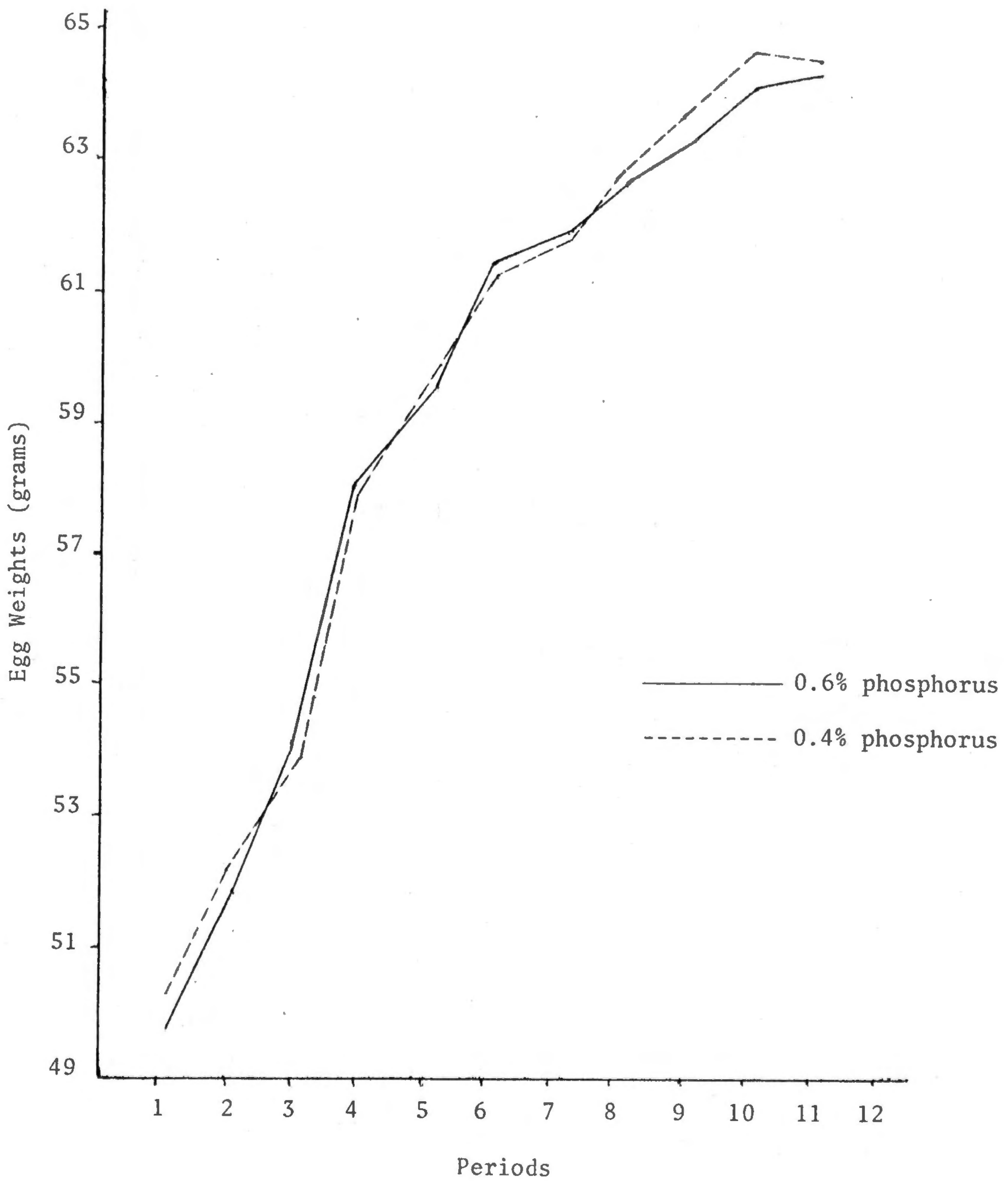

Figure I. Average egg weights by periods.

recorded by indicating the number of the solution of the lowest specific gravity in which the egg floated.

The mean specific gravity scores of the eggs are presented in Table III, p. 21.

Strain 4 birds fed the 0.4 percent phosphorus diet laid eggs with significantly higher average specific gravity than did birds of that strain fed the 0.6 percent phosphorus diet. The eggs of birds of strains 2 and 3 fed the 0.4 percent phosphorus diet had numerically higher specific gravity scores and those of strain 1 numerically lower specific gravity scores than the eggs of birds of the same strains fed the 0.6 percent phosphorus diets. When the data were analyzed for diets and strain effects no significant differences were found. Ingram (1976) observed that the eggs of layers of each strain had numerically higher specific gravity scores when fed the 0.4 percent phosphorus diet but none differed significantly. When the data were analyzed for diet effects the differences were found to be non-significant. In other work at the Tennessee Agricultural Experiment Station when only diet effects have been considered, Singh (1971), Singh, Bletner and Goff (1971), Shirley (1974), Bletner and McGhee (1975) and Ingram (1976) found that reducing the phosphorus to 0.4 percent of the diet improved egg shell quality but the differences have not always been significant.

Ingram (1976) found that the eggs from strain 2 layers had the highest specific gravity, followed in order by those from strains 3, 4 and 1. The score for strain 2 layers differed significantly from those of strains 1 and 4; those of strain 3 from strain 1; those of strain 1 from strains 2 and 3.

The relative scores obtained in this study are quite similar to those obtained by Ingram (1976) except that strain 3 had the highest numerical score followed by strains 2, 4, and 1, in order, and the differences were not significant. Improvement of egg shell quality by feeding a low level of phosphorus has been noted by several other researchers. Pepper et al. (1959); Taylor (1961); Walter and Aitken (1962); Arscott, et al. (1962); Taylor (1965); Mostert and Swart (1968); Hunt and Chancey, for birds housed on litter, (1970); Damron, Eldred and Harms (1974); Scott, Antillon and Mullenhoff (1975); and Summers, Grandhi and Leeson (1976) reported that feeding a low level of dietary phosphorus to laying hens improved egg shell quality. Conversely Evans, Carver and Brant (1944) and Crowley, Kurnick and Reid (1963) reported that a low level of dietary phosphorus decreased egg shell quality and some other workers found that feeding different levels of phosphorus had no effect on egg shell quality, (Miller and Bearse, 1934; Singsen et al. 1962; Hinners, Gholson and Ritchason, 1963; Berg, Bearse and Miller, 1964; Wolford and Tanka, 1970; Hunt and Chancey, for birds housed in cages, 1970; and Ademosun and Kalango, 1973).

The average specific gravities of eggs from layers on the two diets are graphed by periods demonstrated in Figure II. Egg shell quality declined in the first three periods during the hot summer months. Period 1 started in June.

Bennion and Warren (1933); Huston (1958) and Wolford and Tanka (1970) supported this observation by reporting that egg shell quality is decreased when laying hens are subjected to high environmental temperature.

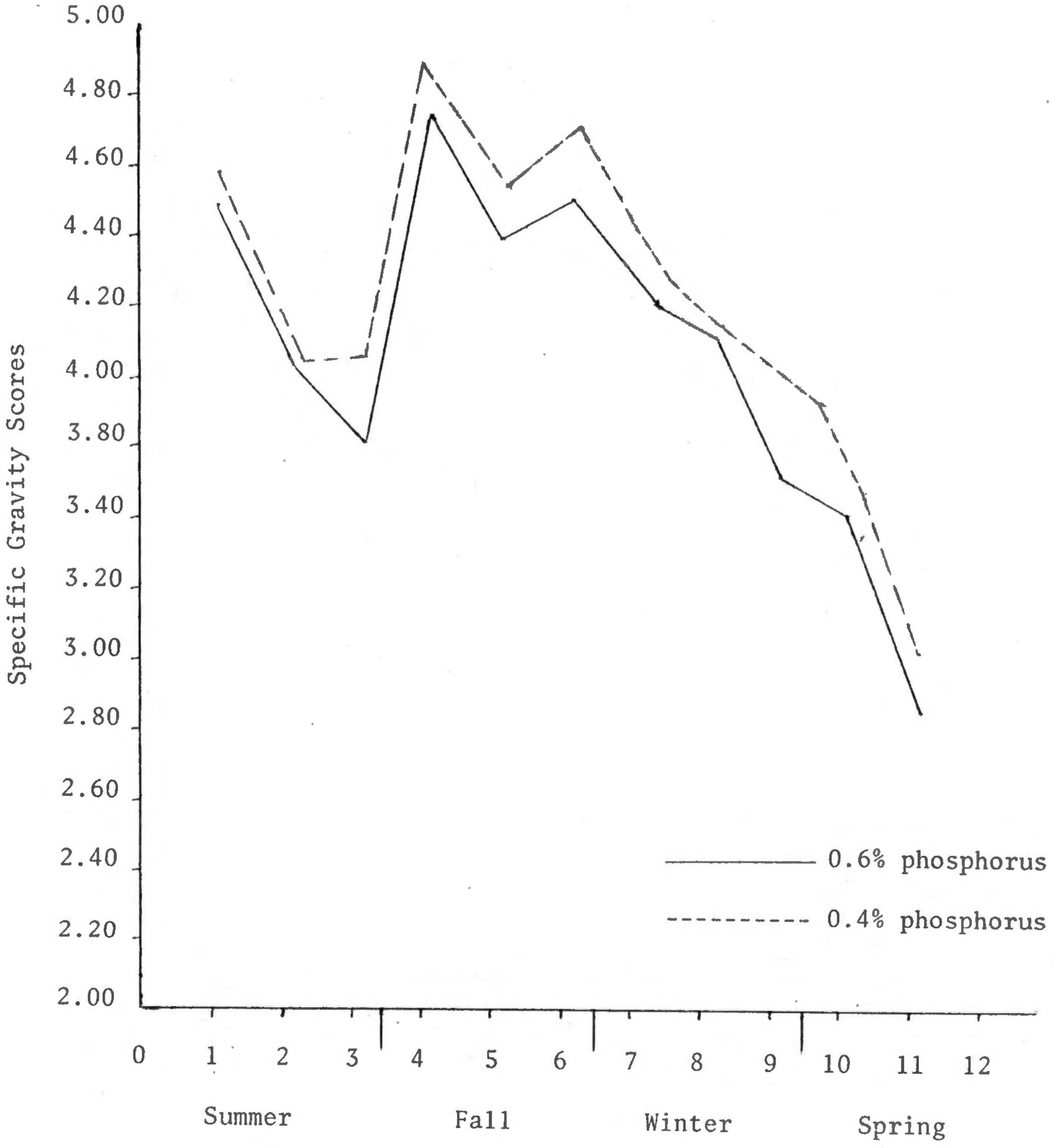

Figure II. Average specific gravities by periods of eggs of hens fed two levels of phosphorus.

Egg shell quality improved during the fourth period when lower ambient temperature prevailed and then declined for the remainder of the production period. Wolford and Tanka (1970) in a review of various factors influencing egg shell quality stated that egg shell quality declines with length of lay.

Roland (1976) observed that as eggs become larger the percent of shell decreases but that the actual amount of shell remains constant. This observation might explain why specific gravity decreased with the length of lay.

IV. FEED CONSUMPTION

The effect of different levels of dietary phosphorus on feed consumption of layers has not been extensively studied.

In this study feed consumption is reported in two ways—feed per hen and feed per dozen eggs. Feed consumption data are summarized in Table IV. The analysis of variance of the two parameters revealed that there were no significant differences between the two dietary phosphorus levels on the response of any one strain of layers, between strains or between diets. Ingram (1976) reported significant differences in feed consumed per hen with strains 1 and 2 consuming significantly more feed than strains 3 and 4. He also reported significant differences in feed consumed per dozen eggs. He found that the layers of strain 2 required significantly more feed per dozen eggs than those of strains 3 and 4 and that those of strain 3 required significantly less feed per dozen eggs than those of any of the other strains. In this experiment the rank of strains 2 and 3 by total feed consumed was the same as reported by

TABLE IV

EFFECT OF STRAIN AND DIET ON FEED CONSUMPTION AND MORTALITY*

Strain	Diet (% P)	Feed/Hen (kilograms)	Feed/Doz. (kilograms)	Mortality (percent)
Diet within strains				
1	0.4	31.48^{bc}	1.66^{a}	7.50^{a}
	0.6	32.30^{ab}	1.71^{a}	8.34^{a}
2	0.4	32.87^{a}	1.71^{a}	6.67^{a}
	0.6	32.93^{a}	1.69^{a}	10.00^{a}
3	0.4	30.79^{c}	1.63^{a}	5.83^{a}
	0.6	31.63^{bc}	1.65^{a}	10.00^{a}
4	0.4	31.83^{abc}	1.70^{a}	10.84^{a}
	0.6	32.36^{ab}	1.67^{a}	6.67^{a}
Between strains				
1		31.89^{a}	1.68^{a}	7.92^{a}
2		32.90^{a}	1.70^{a}	8.33^{a}
3		31.21^{a}	1.64^{a}	7.92^{a}
4		32.10^{a}	1.68^{a}	8.75^{a}
Between diets				
	0.4	31.74^{a}	1.67^{a}	7.71^{a}
	0.6	32.31^{a}	1.68^{a}	8.75^{a}

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

Ingram (1976) but strains 1 and 4 were reversed. When the strains were ranked by feed per dozen eggs the rankings were similar to those of Ingram (1976) except that he reported a slightly higher requirement for strain 1 than for strain 4. In both studies strain 2 layers required the most feed and strain 3 the least.

When the data for feed consumed per hen were analyzed to determine the response of the strains of layers to the two dietary phosphorus levels (diet within strains) significant differences between strains were indicated. Why such differences could not be identified when the data were analyzed for between strain differences cannot be explained.

These results were supported by Harms, Damron and Waldroup (1965); Mostert and Swart (1968); Ademosum and Kalango (1973); and Damron, Andrews and Harms (1974) who reported that feeding different levels of phosphorus had no effect on feed consumption.

Hunt and Chancey (1970) and Damron, Eldred and Harms (1974) reported that an improvement in feed consumption was observed when layers were fed a low level of dietery phosphorus. Conversely, Shirley (1974) obtained a lower feed consumption when layers were fed a high level of dietary phosphorus (0.8 vs. 0.35 percent). No explanation is apparent for these contradictions. It is recognized that many factors such as body weight and egg production affect feed consumption.

V. MORTALITY

The percent mortality was analyzed by diet within strains, between strains and between diet (Table IV, p. 29). The analysis of variance of data indicated that there were no significant differences between diets within strains or between strains and between diets; however, a lower percent mortality was observed with 0.4 percent phosphorus as compared to 0.6 percent phosphorus for strains 1, 2, and 3 but not for strain 4. Neither cage layer fatigue nor any other specific diseases could be associated with strains or diets.

VI. BODY WEIGHT

Another parameter studied in this experiment was body weight. It was divided into three parameters initial body weight, final body weight and body weight gain.

The effect of 0.4 and 0.6 percent dietary phosphorus on these parameters for the four strains of layers studied are presented in Table V.

Examination of the initial body weight data indicates that the lots of birds of any one strain assigned to the two experimental diets did not differ significantly at the beginning or end of the experiment or in average body weight gain during the experiment. However, the beginning body weights of strains 1 and 2 were significantly larger than those of strain 3 and 4. Since there were no significant differences in average body weight gain during the experiment, the final body weights of the various strains apparently reflected differences due to initial body weights. It should be noted that the numerical ranking of the strains according to their beginning body weights was identical to that reported by Ingram (1976) but when they were ranked according to final body weight the position of strains 3 and 4 were reversed.

TABLE V

EFFECT OF STRAIN AND DIET ON BODY WEIGHT PARAMETERS*

Strain	Diet (% P)	Avg. initial body wt. (grams)	Avg. final body wt. (grams)	Avg. body wt. gain (grams)
Diet within strains				
1	0.4	1551^{abc}	1662^{abc}	110^{a}
	0.6	1583^{a}	1707^{a}	123^{a}
2	0.4	1571^{a}	1686^{ab}	114^{a}
	0.6	1556^{ab}	1693^{ab}	136^{a}
3	0.4	1481^{d}	1598^{d}	116^{a}
	0.6	1473^{d}	1624^{cd}	150^{a}
4	0.4	1505^{cd}	1645^{bcd}	139^{a}
	0.6	1513^{bcd}	1656^{abc}	142^{a}
Between strains				
1		1567^{a}	1684^{a}	116^{a}
2		1564^{a}	1689^{a}	124^{a}
3		1509^{b}	1611^{b}	101^{a}
4		1477^{b}	1650^{ab}	172^{a}
Between diets				
	0.4	1527^{a}	1648^{a}	120^{a}
	0.6	1531^{a}	1670^{a}	138^{a}

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

Ingram (1976) obtained significant ($P < 0.05$) differences in the average body weight gains of the strains studied and found that the layers fed the 0.6 percent phosphorus diet gained significantly more body weight than those fed the 0.4 percent phosphorus diet.

In this experiment the layers fed the 0.6 percent diet gained more body weight than those fed the 0.4 percent phosphorus diet but the differences were not significant. The same was true in Ingram's (1976) research.

These results are in agreement with the work of Walter and Aitken (1962) and Ademosun and Kalango (1973). Hunt and Chancey (1970) demonstrated that a dietary phosphorus level ranging from 0.38 to 0.72 percent had no effect on final body weight or weight gain. Similarly, Pepper et al. (1959) and Hinners, Gholson and Ritchason (1963) reported no effect of different levels of dietary phosphorus on body weight.

VII. SHELL COLOR OBSERVATIONS

Any egg not chalk white as observed under a fluorescent lamp was considered to be a tinted egg. Data were obtained by observing the number of tinted eggs among the eggs used to determine egg weight and specific gravity. The summary of these observations are presented in Table VI. The analysis of variance of the data revealed that strain 2 layers fed the 0.4 percent phosphorus diet produced a significantly ($P < 0.05$) higher percentage of eggs with tinted shells than they did when fed the 0.6 percent phosphorus diet. Strains 1 and 3 responded in a manner similar to strain 2 but the differences were not significant. There were significant differences between strains with strain 4

TABLE VI

EFFECT OF STRAIN AND DIET ON
PERCENT TINTED EGGS*

Strain	Diet (% P)	Percent Tints
Diets within strains		
1	0.4	1.98^{cd}
	0.6	1.05^{d}
2	0.4	2.83^{bc}
	0.6	0.95^{d}
3	0.4	4.40^{b}
	0.6	2.58^{bc}
4	0.4	7.15^{a}
	0.6	7.68^{a}
Between strains		
1		1.52^{c}
2		1.89^{c}
3		3.49^{b}
4		7.42^{a}
Between diets		
	0.4	4.09^{a}
	0.6	3.07^{a}

*Values under each subheading within each column with different superscript are significantly different ($P < 0.05$).

producing the highest percentage of tinted eggs followed in order by strain 3, 2, and 1.

When the data were analyzed for diet effects the differences were non-significant. However, there was a tendency for hens fed the 0.4 percent phosphorus diet to lay a higher percentage of tinted eggs.

No observations were found in the literature concerning the effect of dietary phosphorus on the color of white shelled eggs.

VIII. SPECIFIC GRAVITY AS RELATED TO THE TIME OF OVIPOSITION

The primary objective of the time of oviposition study was to determine the effect of time of oviposition on egg specific gravity including the variability among the eggs gathered at any one time. This was done by collecting the eggs at 7:30 p.m., 6:30 a.m., 8:00 a.m., 10:15 a.m., 1:00 p.m. and 4:00 p.m. for 4 days. Specific gravity scores for only three time periods when eggs were collected are listed in Table VII. Data for the collections at the 7:30 p.m., 6:30 a.m., and 8:00 a.m. times were not included in this table because the number of eggs that were collected at those times was so small that it appeared to be impractical to collect eggs at those times for egg quality studies.

The analysis of variance of the data revealed that there were no significant differences between diets within strains on the specific gravity score of eggs laid between 8:00 to 10:15 a.m., 10:15 a.m. to 1:00 p.m. or 1:00 to 4:00 p.m.

The analysis of data between strains indicated that there was a significant difference ($P < 0.05$) between strains on the specific gravity

TABLE VII

EFFECT OF STRAIN AND DIET ON THE RELATIONSHIP BETWEEN TIME OF OVIPOSITION AND SPECIFIC GRAVITY*

Strain	Diet (% P)	Time of Oviposition 8:00-10:15 a.m.	10:15-1:00 a.m. p.m.	1:00-4:00 p.m.
Diet within strains				
1	0.4	2.81^{ab}	2.68^{a}	3.45^{a}
	0.6	3.02^{a}	2.83^{a}	3.91^{a}
2	0.4	2.95^{a}	3.07^{a}	3.93^{a}
	0.6	2.81^{ab}	2.63^{a}	3.28^{a}
3	0.4	3.31^{a}	3.52^{a}	4.23^{a}
	0.6	3.07^{a}	3.17^{a}	3.93^{a}
4	0.4	2.79^{ab}	3.14^{a}	4.10^{a}
	0.6	2.42^{b}	2.84^{a}	3.33^{a}
Between strains				
1		2.92^{ab}	2.76^{a}	3.68^{a}
2		2.88^{ab}	2.85^{a}	3.61^{a}
3		3.19^{a}	3.35^{a}	4.10^{a}
4		2.61^{b}	2.99^{a}	3.72^{a}
Between diets				
	0.4	2.98^{a}	3.10^{a}	3.93^{a}
	0.6	2.83^{a}	2.87^{a}	3.61^{a}

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

scores of eggs laid from 8:00 to 10:15 a.m. but none of the strains showed any significant differences either in specific gravity scores of eggs collected at 1:00 p.m. or at 4:00 p.m.

In general there was a tendency for eggs laid between 10:15 a.m. to 4:00 p.m. and collected at 1:00 p.m. and 4:00 p.m. to have higher specific gravity scores than eggs laid between 8:00 a.m. to 10:15 a.m. and collected at 10:15 a.m. The eggs collected at 4:00 p.m. had significantly larger specific gravity scores than eggs collected at 10:15 a.m. or 1:00 p.m.

These results were supported by the work of Roland, Sloan and Harms (1973); Roland and Harms (1974), and Washburn and Potts (1975) who observed that eggs of the afternoon collection had a higher specific gravity than morning laid eggs.

The coefficient of variation of the specific gravity scores of eggs collected at 7:30 p.m., 6:30 a.m., 8:00 a.m., 10:15 a.m., 1:00 p.m., and 4:00 p.m. are presented in Table VIII. The range in the coefficient of variation of the specific gravity scores was lowest for the eggs collected at 1:00 p.m. for four days of collection.

Variation in the range of the coefficients of variation at 10:15 a.m. was next smallest to that observed at the 1:00 p.m. collection. While further study is needed, these data suggest that more consistant specific gravity data may be obtained by using only those eggs laid between 10:15 a.m. and 1:00 p.m.

TABLE VIII

COEFFICIENTS OF VARIATION OF SPECIFIC GRAVITY SCORES OF EGGS BY DAYS AND TIME OF DAY

Day	Time of egg collection					
	p.m. 7:30	a.m. 6:30	a.m. 8:00	a.m. 10:15	p.m. 1:00	p.m. 4:00
1	33.66	89.00	41.00	48.00	42.00	37.00
2	32.54	16.11	25.00	42.00	43.91	30.00
3	37.66	23.71	28.13	42.64	43.82	37.91
4	29.27	35.40	35.50	42.47	40.94	32.91
Range	8.39	72.89	16.00	6.00	2.97	7.91
Average	33.28	41.06	32.41	43.78	42.67	34.46

IX. GENERAL

Ingram (1976) worked with June hatched layers of the same strains studied in this research. He concluded that a dietary phosphorus level of 0.4 percent, when compared with 0.6 percent, significantly improved average egg specific gravity, but decreased average final body weight and average body weight gain. The only strain responses to diet differences were in egg production and final body weights.

In this experiment, January hatched birds were used, and there was no significant effect of diets for any of the parameters studied. Dietary phosphorus level had no significant effect on the egg production of any of the strains. However, when one of the strains was fed the 0.4 percent phosphorus diet egg specific gravity was significantly improved.

This strongly suggests that the time of the year the chicks are hatched may have some effect on the phosphorus requirement of layers. No observations on this point have been found in the literature that was reviewed.

The characteristics of the strains as observed by Ingram (1976) and in this research were quite similar in many respects and different in others. Ingram observed that strain 4 laid at a significantly lower rate than the other strains. In this study strain 4 laid as well as any of the strains. Ingram (1976) reported significant differences in the specific gravity scores, pounds of feed consumed per hen, feed per dozen eggs, mortality, and in average body weight gains of the various strains.

Significant differences for these characteristics were not found in this study but the numerical ranking of the strains was similar to that reported by Ingram (1976) except in the mortality comparisons. This suggests the possibility of differences in strain laying house performance due to the time of the year the chicks are hatched.

X. CONCLUSION

The results of this experiment indicate that January hatched pullets of the strains studied need no more than 0.4 percent total dietary phosphorus for maximum laying house performance. The four strains of layers exhibited differences in response to dietary phosphorus levels in two of the parameters studied which strongly suggests differences in the phosphorus requirements of layers of different genetic background. Eggs laid after 1:00 p.m. had higher specific gravity scores than those laid earlier. The coefficient of variation was highest for those eggs laid between 8:00 a.m. and 10:15 a.m. and lowest for eggs laid between 6:30 a.m. and 8:00 a.m.

Additional data are needed to determine a preferred time for collecting eggs for specific gravity data.

CHAPTER V

SUMMARY

An experiment was conducted to determine the response of four strains of high producing Single Comb White Leghorn—type hens to dietary phosphorus levels of 0.4 and 0.6 percent as measured by egg production, egg specific gravity, egg weight, feed efficiency, mortality, body weight, and the percentage of eggs having a tinted shell and to study the effect of time of oviposition on egg specific gravity.

A 44-week study was conducted using eight treatments-four strains of layers and two levels of phosphorus (0.4 and 0.6 percent). Each treatment group consisted of 4 replicate lots of 30 birds each housed at the rate of two birds per 20.3 cm. wide cage. Specific gravity, egg weight and tinted shell measurements were taken on a weekly basis. The results of the study are summarized as follows:

1. The response of the four strains of layers to the two dietary levels of phosphorus was identical except that one strain had significantly ($P < 0.05$) improved egg specific gravity and another strain an increase in the percentage of tinted eggs when fed the 0.4 percent phosphorus diet.

2. The strains studied had similar egg production but differed in average egg weight, initial and final body weights, and in the percentage of tinted eggs produced.

3. No significant ($P < 0.05$) differences for the production parameters studied were attributable due to dietary phosphorus levels.

4. Eggs laid late in the day have the highest specific gravity, while those laid between 8:00 a.m. and 10:15 a.m. and between 10:15 a.m. and 1:00 p.m. have the highest coefficients of variation but appeared to vary the least from day to day.

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