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Influence of Diet on the Characteristics of Eggs and Growth of Progeny in Single Comb White Leghorn Pullets

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To the Graduate Council:

I am submitting herewith a thesis written by Poonamalle Kothandaraman entitled "Influence of Diet on the Characteristics of Eggs and Growth of Progeny in Single Comb White Leghorn Pullets." 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.

J. K. Bletner, Major Professor

We have read this thesis and recommend its acceptance:

Don O. Richardson, O. E. Goff

Accepted for the Council:
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(Original signatures are on file with official student records.)

December 10, 1963

To the Graduate Council:

I am submitting herewith a thesis written by Poonamalle Kothandaraman entitled "Influence of Diet on the Characteristics of Eggs and Growth of Progeny in Single Comb White Leghorn Pullets". I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Poultry.

J. K. Bletner
Major Professor

We have read this thesis and recommend its acceptance:

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INFLUENCE OF DIET ON THE CHARACTERISTICS OF EGGS AND GROWTH OF PROGENY IN SINGLE COMB WHITE LEGHORN PULLETS

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Poonamalle Kothandaraman

December 1963

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INTRODUCTION

Poultry husbandry as one of the sectors of the broad field of Agriculture has attained industrial proportions and in many respects is pacing the advancement of other phases of Agriculture. With the development of high producing flocks, through improved breeding, feeding, housing, disease control and management practices, the poultrymen at present enjoy a favorable postion with respect to income and profit. To maintain the status thus far achieved and to promote the interests of the people actively engaged in the poulty industry, more and more research is undertaken to explore ways and means to ensure a steady and lasting progress, which will result in desirable economic returns on the investments made in the enterprise.

Chicken eggs have played a vital role in the nutrition of people, and, at the present time, provide a means for many biological investigations. The consumer acceptance and preference of quality eggs have engaged the attention of many for some time. Periodical surveys and reports indicate that the purchaser buys eggs based on quality, convenience and price. Though it has been shown that variation in egg quality may be due to an individual hen's inherited characteristics, research has also shown the influence of nutrition and environment on egg quality, egg size and egg production.

Quality factors of the egg include both exterior quality factors which may be apparent from external observation and interior quality factors which involve the contents of the shell. According to Hauver et al. (1961), "Quality may be defined as the inherent properties of a product which determine its degree of excellence. Those conditions and characteristics which consumers want and for which they are willing to pay are in a broad sense factors of quality." For the purposes of this study egg weight has also been included under the caption "egg quality characteristics."

No single problem of the poultry industry seems to have aroused the interest of the investigators of all disciplines as has the egg quality problem. Producers, consumers, wholesalers and retailers are also equally interested in egg quality characteristics.

Candling of eggs is one means of determining the quality grade. However, the need for more objective measures has been given serious consideration in recent years. The Fresh Fancy Quality egg program (Anonymous, 1963) is gaining acceptance. The sampling technique used to determine egg quality of the different flocks along with the candling procedures have ensured a better check on quality now than was true a few years ago.

High energy diets are being used more widely and frequently now than ever before. Birds eat to satisfy their energy requirements. This must be considered in diet formulation with regard to proteins, minerals, vitamins and other known

essential nutrients to ensure normal and healthy metabolic activities. The effects of energy and fat supplementation levels as well as protein levels in the diets have been investigated in terms of egg size, rate of production, feed efficiency, fertility, hatchability and with due regard to the interior quality of the eggs thus produced. The hatchability of eggs and subsequent growth rate of the chicks as well as mortality rate have also been considered to add to the economic value of such diets fed. The shell quality is of major concern from the standpoint of marketing and hatchability. The yolk and albumen quality must be considered because these characteristics largely determine the interior quality of the egg.

The changing management practices, the change in feed ingredients and diet formulations, the new strains of birds, the advent of mechanization, the methods of processing feed, the blending of the various ingredients and the medication practices have an impact upon the performance of layers, and perhaps upon the quality and functional properties of the egg produced.

The influence of diet upon egg quality and egg size as well as the influence of these factors upon fertility, hatchability and resultant chick performance needs further elucidation.

OBJECTIVES

The objectives of this study were:

1. To determine the effects of feeding 13 percent protein diets, with varying energy levels, to Single Comb White Leghorn pullets, upon certain egg quality characteristics, hatchability, chick growth and mortality.

2. To determine the effect of egg size on hatching, two, and four-week body weights of Single Comb White Leghorn chicks hatched from the eggs of pullets fed 13 percent protein diets with varying energy levels.

REVIEW OF LITERATURE

Factors Affecting Egg Quality

Interrelationships of Egg Components Contributing to Quality

Jull (1924), working with Barred Rocks reported the following:

> Albumen weight is more highly correlated with egg weight than is yolk weight. Yolk weight is more highly correlated with egg weight than is shell weight.
>
> Shell weight is most variable. Egg weight is less variable than the albumen weight.
>
> The component parts of the egg contribute in different degrees at different times of the year toward the total egg weight.
>
> The percentage of albumen, yolk and shell of total egg weight varies from time to time throughout the year and is influenced by the rate of production.

Bennion and Warren (1933) found that shell and albumen decreased more than the yolk in proportion to their weight in the egg, due to high environmental temperatures. They indicated that the oviduct is more sensitive to high environmental temperature than the ovary. They also found that the 12 percent decrease in feed intake due to hot weather was not the cause for the reduced egg size.

Knox and Godfrey (1934) reported that egg weight was highly correlated with the total weight of the thick white in both White Leghorn and Rhode Island Red eggs.

Knox and Godfrey (1938) found that neither egg production nor egg weight was significantly correlated with the percentage of thick albumen and that there was a significant difference between the percentage of thick albumen of eggs laid during four week periods and among four week periods indicating a seasonal effect upon the percentage of thick albumen.

Pyke and Johnson (1941) found that the volume and the tensile strength of cakes were related positively to the quality of the eggs, and that the length of the storage period, percentage weight of the initial weight of eggs, height of firm albumen and yolk index were all measures which might serve as an indicator of egg quality. They also found that the length of storage period was negatively correlated with the cake quality measures of volume and tensile strength.

King and Hall (1955) found no relationship between shell thickness and albumen quality nor between shell thickness and shape index.

Johnson and Merrit (1955) found that egg production was significantly correlated with both albumen quality and shell strength although at different levels for the White Leghorn and Barred Plymouth Rock eggs.

Spencer et al. (1956) found that the albumen quality, measured in terms of Haugh units, declined linearly with the logarithm of elapsed time from breakout of the egg. The rate

of loss was influenced by the hen and age of the egg.

Baker and Curtiss (1958) found that internal quality was not significantly correlated to either whole egg specific gravity or shell thickness of the egg.

May and Stadelman (1960) reported that the strain of hen significantly influenced percentage moisture, protein of the fresh egg and protein of the dry egg and that the age of the hen and season significanlty influenced the egg contents, weight, albumen height, Haugh units and grams protein per egg. Different strains of the White Leghorn and New Hampshire breeds of birds were used in the experiment.

Huston and Carmon (1961) found that eggs obtained from hens held at a controlled temperature of 90° F. had a lower specific gravity than eggs from hens held under variable temperature conditions. The decline was related to the environmental temperature and age of the hen. They found no difference in Haugh unit scores between the treatment groups.

Skala and Swanson (1962) reported that higher quality eggs were heavier and contained a larger amount of total white than did the lower quality eggs in the White Leghorn strains selected for their experiment. The total White of the higher quality eggs contained a significantly higher percentage by weight of middle thick white. There was no difference in yolk weight between the two classes of eggs. It was also suggested that hens producing higher quality eggs were slightly but significantly heavier.

Interrelationships of Shell Characteristics

Dunn (1922) reported that the rate of loss in weight is one of the most variable of all the characteristics of egg. He contended, besides morphological causes such as variation in shell and egg envelopes, that physiological variability might also contribute to such loss. He also reported on the marked individuality of fowls in the rate at which their eggs lose weight.

Taylor and Martin (1928) found no significant differences between eggs of different shapes and sizes in thickness of shell.

Stewart (1936) reported a correlation coefficient of 0.509 $\pm$ .028 between shell thickness and breaking strength. He also observed that breaking strength and shell thickness were influenced by the individuality and nutrition of the hen.

Wilhelm (1940) reported that the rate of egg production and shell thickness were independent of each other. He ascribed the seasonal trend to be due to the temperature influencing the dry weight of the shell and percentage shell of total egg weight. He also found that shell thickness was significantly correlated with percentage shell of total egg weight and dry weight of the shell and was not independent of egg weight.

Baker and Curtiss (1958) found that the whole egg specific gravity and shell thickness had a highly significant positive coefficient of correlation.

Egg Weight Unaffected by Diet

Parkhurst (1933) found no significant difference in egg size when birds were fed a 11.75 and 15.75 percent protein diet whether the protein was single or mixed.

Miller et al. (1957) found no definite trend in egg size increase in birds fed different protein levels ranging from 10.1 to 19.2 percent with 640 to 1075 Calories of productive energy per pound.

MacIntyre and Aitken (1957) reported that neither the high energy nor the high protein diet fed to birds influenced their egg weight. Protein levels of 20.1 to 21.3 and 15.4 to 16.5 percent with 700-940 Calories of productive energy per pound were used.

Orr et al. (1958) reported that birds fed a practical ration containing 2 1/2 to 5 percent added animal fat showed no difference in egg weight.

Donaldson and Gordon (1960) found that birds fed 19 percent protein diets with and without 3 percent added stabilized animal fat showed no difference in egg weight.

Heywang and Vavich (1962) found that birds fed Calorie levels of 1150, 1250, 1350, 1450 and 1550 of metabolizable energy per pound of feed in a 16 percent protein diet did not show any difference in weight of eggs laid.

Marion and Edwards (1963) found that egg weight was not significantly affected by the dietary protein level of birds.

Egg Weight Related to Protein of Diet

Byerly *et al*. (1933) reported on the effect of 11.2 to 23.6 percent levels of protein in layer diets with protein supplements of different origin. They found increased egg weight in birds on increased protein levels.

Henderson (1937) reported a highly significant trend between mean annual egg weight of pullets and increased percentage of protein in the diet.

Heuser (1941) reviewed the literature and observed that a 15 to 16 percent protein diet would secure good egg size in birds.

Thornton *et al*. (1958) reported the lowest incidence of small eggs in birds fed a diet containing 15 percent protein. The incidence of small eggs was greater in birds fed 11 percent and 17 percent levels of protein in the diet. DL-methionine was found effective in changing the incidence of small eggs at protein levels ranging from 11 to 17 percent. L-lysine was found effective at protein levels of 11 and 13 percent and detrimental at protein levels of 15 and 17 percent. The combination of DL-methionine and L-lysine was effective at two higher protein levels and proved detrimental and non-effective at the two lower protein levels. They also found efficient utilization of amino acids at 13 percent level and concluded that the protein level required for egg production in caged layers may be as low as 13 percent.

Quisenberry and Bradley (1962) reported that egg weights

were significantly improved in the birds with each increase of dietary protein using 13, 15 and 17 percent levels and one percent fat. The effect was found to be more pronounced during the earlier period of egg production.

Egg Weight Related to Energy Content of Diet

Combs et al. (1961) reported that rate of increase in egg size was reduced following energy restriction of heavy type layers.

Harms and Waldroup (1963) found that a diet containing 600 Calories of productive energy per pound of feed could be used to "deplete" hens of egg weight and 1000 Calories of productive energy per pound or 900 Calories of productive energy per pound, with corn as the major source of energy, could be used to "replete" egg weight. They reported that animal fat, corn oil, yellow corn or cerelose could be used as egg weight "repletion diets".

Egg Weight Related to Dietary Fat

Treat et al. (1960) reported an egg weight increase in birds fed 2.5 percent or 5 percent added animal fat or a mixture of hydrolyzed animal and vegetable fats.

Shutze et al. (1962) found that a 5 percent corn oil supplemented diet fed to birds improved egg weight during the first 6 to 8 weeks of early egg production, regardless of the cereal used in the diet. They also found that corn oil did not stimulate egg weight significantly when compared to an

isocaloric diet containing tallow.

Marion and Edwards (1962) reported a significant increase in egg weight in birds fed a 10 percent corn oil supplemented diet. They found no difference in dry matter, lipid content or major lipid components in the egg due to the dietary treatments.

Shutze and Jensen (1963) found that the linoleic acid content of natural oils such as corn oil, tall oil, and safflower oil fed to birds at the 5 percent level, significantly improved egg weight. Methyl linoleate and purified linoleic acid supplement (95%), equivalent to the amount of linoleic acid in 5 percent corn oil,was found to significantly improve egg weight.

March and Biely (1963) found that egg size was reduced when birds were fed a diet containing 10 percent added fat without an increase in the energy level. They attributed the size reduction to reduced feed intake.

Marion and Edwards (1963) obtained higher values for egg weight with corn oil supplementation.

Egg Weight Related to Several Dietary Factors

Hochreich *et al*. (1958) found an increase in egg weight when 6.6 percent yellow grease was added to a 17 percent protein layer diet containing 950 Calories of productive energy per pound. They also reported that the level of protein fed had no effect on egg weight.

Combs and Helbacka (1960) reported on their study with 14.6 to 19.1 percent protein diets with 909 to 1096 calories of

productive energy per pound. They found that birds fed diets containing 9 percent animal or vegetable fat or 10 percent animal tallow or corn oil laid significantly heavier eggs than those fed smaller amounts of fat.

Hinners and Wagh (1962) reported that maximum egg weight was obtained in birds fed 19 percent protein and 3 percent of added animal fat. They used protein levels ranging from 11 to 23 percent and fat levels ranging from 0 to 6 percent.

Childs (1963) observed that the protein requirements of layers was both a confusing and a controversial problem. The commonly reported range of 12-18 percent protein in the diet of hens and the variation in the percentage thereof was attributed to geographic location, strain of birds used, calorie content of the diet and whether or not the basal ration was supplemented with any of the amino acids.

He also observed that some factors present in corn oil besides linoleic acid might be responsible for the increase in egg weight and suggested that this factor might also be present in other fats in varying amounts and stated further that energy intake could not be restricted to obtain the full effect of the factor involved in the increase of egg weight.

Albumen Quality Unaffected by Diet

MacIntyre and Aitken (1957) reported that there was no effect on the albumen height of eggs when birds were fed either high energy or high protein levels.

Donaldson and Gordon (1960) found that 3 percent stabilized animal fat fed to layers in a 19 percent protein diet had no effect on the Haugh unit score of eggs.

Combs and Helbacka (1960), Hinners and Wagh (1962) and March and Biely (1963) all agree that the addition of fat to the diet of laying hens failed to influence albumen height.

Albumen Quality Affected by Diet

Mueller (1956) cited work which showed that the energy content of the diet as well as the kind of cereals used caused no or only a small difference in albumen quality. However, using two protein sources with a protein level of 17 percent with 718 to 974 Calories of productive energy, he found that a barley-oats-meat scrap diet fed group of birds, laid eggs with significantly higher Haugh unit values than did those hens fed corn-meat scrap or corn-soybean oil meal or barley-soybean oil meal diets.

Froning and Funk (1958) showed that there was a difference in thick albumen height between caged layers and their sisters maintained on the floor and fed the same diet which contained 16 percent protein and 860 Calories of productive energy per pound of diet.

Harms and Douglas (1960) reported that Haugh unit values of eggs from hens fed a 14.7 percent protein diet were significantly higher than the eggs from hens fed a 16.7 percent protein diet. They attributed this to the lower production rate secured with

the 14.7 percent protein diet and the higher production rate with the 16.7 percent protein diet. The rate of production altered due to dietary treatment of hens had an effect on Haugh unit values.

Harms *et al.* (1962) reported similar findings using protein levels ranging from 9.1 to 17.6 percent and energy levels ranging from 500 to 1000 Calories of productive energy per pound.

Albumen Weight

Byerly *et al.* (1933) found increased albumen weight as a result of increased body weight and yolk weight in birds fed increased protein levels ranging from 11.2 to 23.6 percent in the diet.

Buckner *et al.* (1941) found no difference in the dried weight of the egg white due to treatment effect on layers when pounds of egg produced and pounds of feed consumed were considered. Diets formulated to contain 18.5 percent protein and 4.8 percent fat, 24.4 percent protein and 8.2 percent fat, 30.4 percent protein and 9.2 percent fat and 29.4 percent protein and 6.8 percent fat were used.

Yolk Quality

Sowell and Morgan (1936), Heywang and Titus (1941), Heywang (1943) and Donaldson and Gordon (1960) found no difference in yolk quality of eggs in terms of yolk index or color due to different protein supplements or added fat or the

addition of different levels of vegetable oils to the diets of layers.

Yolk Weight

Buckner *et al*. (1941) Heywang and Titus (1941) and Heywang (1943) reported no difference in yolk weight when birds were fed diets containing different levels of protein or fat. Different vegetable oils fed at different levels were also without effect on the layers in terms of yolk weight of eggs.

Sowell and Morgan (1936), Heywang and Titus (1941) and Heywang (1943) found no difference in yolk weight to egg weight ratio of eggs in birds fed different protein supplements or different vegetable oils at various levels.

Byerly *et al*. (1933) reported that birds fed protein levels ranging from 11.2 to 23.6 percent produced larger eggs due to a direct increase in yolk weight.

Shell Quality and Weight

Buckner *et al*. (1941) reported no difference in dried shell weight of eggs of birds due to the different diet formulations containing different protein supplements and fat levels.

Denton and Titus (1943) reported that the protein of the diet had no significant effect on the loss of weight of eggs or percent of shell. They used 13, 15, 17, 19, 21 and 23 percent protein diets.

Mueller (1956) using 17 percent protein level with

calorie levels ranging from 718-974 Calories of productive energy per pound in the layer diet found no difference in shell thickness or loss of water from eggs during storage.

MacIntyre and Aitken (1951) reported that specific gravity of whole eggs was not altered by high energy or protein diets fed to birds.

However, Hochreich et al. (1958) reported a decrease in the shell thickness of eggs laid by birds fed 6.6 percent yellow grease in a 17 percent protein diet with 950 Caloreis of productive energy per pound as compared with the same diet without the addition of yellow grease. They also found that the protein level of the diet had no influence on the shell thickness of the eggs.

Donaldson and Gordon (1960) found that 19 percent protein diets with and wihtout 3 percent added stabilized animal fat in the layer diet did not influence the shell thickness of the egg.

Combs and Helbacka (1960), and March and Biely (1963) found no difference in shell thickness of eggs from birds fed fat levels of up to 10 percent in the diet.

Hatchability of Eggs in Relation to Dietary Protein Energy and Fat

Rosedale (1923) according to Hays and Sumbardo (1927) reported that the percentage of protein fed to hens was not a factor affecting hatchability.

Hochreich *et al*. (1958), Frank and Waibel (1960), and Heywang and Vavich (1962) found that neither the protein levels, calorie levels, nor added fat levels of the layer diets influenced the hatchability of fertile eggs.

Hendricks (1934) found that the trend in hatchability was parallel to egg production and egg weight during the first year on a low protein diet but with a normal protein diet, the hatchability was highest during the early part of the laying year. There was no agreement between the trend in hatchability and the trend in egg production and egg weight during the remainder of the laying year. Protein levels of 11.5 and 20.6 percent were used.

Heuser (1941) reviewed earlier work and observed that a protein level of 15 to 16 percent in the diet of hens resulted in good hatchability.

Ringrose *et al*. (1941) reported that a 3.6 percent cottonseed oil supplemented diet when fed to birds reduced hatchability from approximately 80 percent to less than 30 percent. Wesson oil and crude soybean oil at 3.6 percent level and crude peanut oil at 7 percent level did not affect hatchability of eggs.

Heywang (1942) found that 2, 4 or 8 percent corn oil supplemented diet fed to hens produced no significant difference in the hatchability of their eggs or on the time of occurence of embryo mortality.

Creger and Couch (1961) presented evidence to show that the addition of corn and soybean oil meal singly or in combination

to a synthetic diet for laying hens produced marked improvement in fertility and hatchability of fertile eggs.

Marion and Edwards (1962) found that hatchability of fertile eggs was significantly increased when 10 percent corn oil was added to a 19 percent protein diet in birds raised to maturity on low fat diets.

Growth Rate of Chicks in Relation to Maternal Diets

In working with soybean oil meal diets for breeders Bird *et al*. (1946) found that the diet of the breeders was a factor which affected the viability of resultant chicks. Poor hatchability and marked increases in the first week mortality in chicks from hens fed soybean oil meal diets were favorably altered by suitably modifying the soybean diet of the hens. The parallelism between hatchability of eggs and viability of chicks suggested that the factor(s) essential for good hatchability were transmitted from the hen through the egg to the chicks.

Bethke *et al*. (1947) reported the earlier work of investigators on the relationship between vitamin content of the diet of the hens and the vitamin content of the eggs laid by them and that the vitamins present in the chicks at hatching time could have an important influence on their subsequent growth and mortality. They found that the hen diet containing fish meal in addition to soybean oil meal furnished growth factors to the chicks hatched from them.

Wiese *et al*. (1948) found that fish meal supplementation

of their pea meal-meat scrap diet for hens influenced the growth and mortality rate of chicks hatched from the eggs laid by the hens. They found a good growth rate and reduced mortality rate in chicks from hens fed fish meal supplement, despite the fact the chicks were subsequently fed a growth factor deficient diet.

Miller _et_ _al_. (1957) reported that neither the level of energy nor the protein level of the hen's diet had an effect on the growth rate of chicks in their experiment. They used protein levels ranging from 10.1 to 19.2 percent and energy levels ranging from 640 to 1075 Calories of productive energy per pound.

Frank and Waibel (1960) reported no growth difference in chicks from 0-4 weeks of age due to maternal dietary treatments. They used protein levels ranging from 10.2 to 29.9 percent and energy levels ranging from 634 to 1220 Caloreis of productive energy per pound.

Marion and Edwards (1962) found that the progeny growth rate was significantly increased when a 19 percent protein diet of layers raised to maturity on low fat diet was supplemented with 10 percent corn oil.

Relationship Between Egg Size and Chick Size

Halbersleben and Mussehl (1922) and Upp (1928) found that chick weight was 64-68 percent of the weight of the egg set. Halbersleben and Mussehl found that the initial weight difference between chicks from large and small chicks was largely overcome

by thirty-five days of age. Upp reported that, although the egg weight influenced the hatching weight, the hatching weight was found to be an unreliable index of body weight of chicks when, two, four or twelve weeks of age.

Funk et al. (1930), Callenbach (1934), Wiley (1950b), and Kosin et al. (1952) also found that the mean growth rate of chicks from large and small eggs showed on the whole a slight advantage for the former, which was largely overcome during the postnatal growth period of chicks.

Penquite and Milby (1941) reported that chicks from hens fed high levels of protein were smaller than would be expected on the basis of egg size and those from hens fed low levels are larger. They found that 12 percent of the variation in chick weight at hatching time was due to factors other than variation in egg weight.

Wiley (1950a) reported that chick size was limited significantly by the space in the egg shell during the last 2 or 3 days of incubation and that the number of cells per field of embryonic tissue was controlled by egg weight but the degree of control diminished as incubation progressed.

Garber and Godbey (1952) concluded that the total gain from hatching to twelve weeks of age was influenced to the greater extent by the date of hatch followed in order by the residual environment, the dam and the sire.

Godfrey and Williams (1955) found that only 5 percent of the total variation in 12 week body weights could be accounted

for by the percent the day old chick was of the original egg weight as observed in their experiment with New Hampshire chicks.

Godfrey _et al_. (1953) working with New Hampshire chicks found that the influence of egg size continued until after two weeks of age when mature body size and age at sexual maturity began to exert an increasingly greater influence. The influence of body size increased faster than the effect of age at sexual maturity. Egg weight at this time exerts very little effect if any on body weight. Thirty-six percent of the variation observed in body weight at 12 weeks was due to the influence of all three factors. At hatching, however, due to the relatively large influence of egg size, these three factors account for about 74 percent of the observed variation in body weight.

O'Neil (1955) concluded that mortality was heavier and occured earlier in chicks which represented a smaller percentage of the setting weight of eggs. Growth and efficiency of feed utilization to 6 weeks of age was not related to the percentage size of the chick.

PROCEDURES

The Layers and Their Experimental Diets

The Single Comb White Leghorn females from which eggs were secured for this study were hatched April 27, 1962. One-half of the pullets had been grown on a "full-feed" progam while the other one-half had been restricted to approximately 12 pounds per 100 pullets per day from about 10 to 24 weeks of age. They were placed in laying pens on full feeding of their respective experimental diets on October 11, 1962, when 24 weeks old. Each pen received 30 pullets. Birds showing iritis, physical defects and evidence of disease were not housed. All birds were debeaked, vaccinated with Newcastle disease and infectious bronchitis vaccine, leg banded and fitted with blinders at time of housing. Since only one lot of pullets had been grown on each growing period treatment, randomization was attempted by placing birds in shipping coops as they were caught and thereafter assigning two coops of birds to each laying pen. Pullets from the restricted group were assigned to pens 1 to 4 and those from the full-fed group were assigned to pens 5 to 8 in each one of the three houses. The same care and mangement were provided for all the birds in these pens. The four dietary treatments used during the laying period were:

(1) Diet LR2 calculated to contain 17.18 percent protein with 970 Calories of productive energy per pound and a

Calorie-protein ratio of 56.5:1.

(2) Diet EL35 calculated to contain 13.06 percent protein with 970 Calories of productive energy per pound and a Calorie-protein ratio of 74.27:1.

(3) Diet EL36 calculated to contain 13.14 percent protein with 1069 Calories of productive energy per pound and a Calorie-protein ratio of 81.35:1.

(4) Diet EL37 calculated to contain 13.11 percent protein with 1179 Calories of productive energy per pound and a Calorie-protein ratio of 89.93:1.

In the calculations of protein percent and energy content of these four diets, the 8 pounds of ground limestone included as a source of calcium in these diets have not been taken into consideration.

Each diet was fed to one pen of pullets from each growing period treatment. The composition of the four diets used are shown in Table I. The vitamin mix and the mineral mix used in these diets are shown in Tables II and III, respectively. Hereinafter these pens will be referred to as maternal pens.

Since the production of these birds under different dietary treatments might influence certain charactersitics which were studied, a summary of the laying house performance of these birds is presented in the Appendix.

Egg production, mortality, feed consumption and egg weight data were obtained from the monthly pen records maintained by the Poultry Department. The initial and final

TABLE I

COMPOSITION AND CALCULATED ANALYSIS OF LAYER DIETS

Feedstuff	Diet number LR2	EL35	EL36	EL37
	Pounds			
Yellow corn	72.0	68.0	78.0	70.0
Alfalfa meal (17% protein, dehydrated)	5.0	5.0	5.0	5.0
Fish meal (Peruvian)	2.5	2.5	2.5	2.5
Vitamin mix 1[1]	0.5	0.5	0.5	0.5
Mineral mix 1[2]	3.0	3.0	3.0	3.0
Soybean oil meal (50% protein)	17.0	6.0	8.0	9.3
Pulverized oats	--	15.0	--	--
Animal fat	--	--	3.0	9.7
Ground limestone	8.0	8.0	8.0	8.0
Total	108.0	108.0	108.0	108.0
Calculated analysis (not considering the 8 pounds of ground limestone):				
Protein percent	17.18	13.06	13.14	13.11
Calories productive energy per pound	970	970	1069	1179
C/P Ratio	56.5	74.27	81.35	89.93

[1]See Table II.

[2]See Table III.

TABLE II

COMPOSITION AND CALCULATED ANALYSIS OF VITAMIN MIX OF LAYER DIETS

Feedstuff	Pounds
Vitamin D supplement (30,000 I.C.U./g.)	4.0
Vitamin A supplement (10,000 I.U./g.)	10.0
Riboflavin supplement (4 g./lb.)	13.8
Vitamin B_{12} supplement (20 mg./lb.)	6.0
Niacin (50%)	2.0
D-Calcium pantothenate (dissolve in not more than 1 pint of water and premix in ground corn)	76 grams
Ground corn	164.2
Total	200.0
Caloulated vitamin content per 0.5 pounds:	
Vitamin D	134,187 I.C.U.
Vitamin A	111,823 I.U.
Riboflavin	134 mg.
Vitamin B_{12}	0.295 mg.
Niacin	1.097 g.
Pantothenic acid	191 mg.

TABLE III

COMPOSITION AND CALCULATED ANALYSIS OF MINERAL MIX OF LAYER DIETS

Feedstuff	Pounds
Rock phosphate, defluorinated	150
Limestone	100
Salt	50
Manganese sulphate	2.5
Total	302.5

Calculated minerals supplied per pound:

Calcium	0.29 pounds
Phosphorus (inorganic)	0.084 pounds
Salt	0.165 pounds
Manganese	1215 mg.

body weights were recorded for each bird at time of housing and at the end of the 11 month production period. From these the average gain in body weight per hen for the 11 month period was calculated. Egg weights in ounces per dozen were also recorded for all the eggs laid on three consecutive days during the fourth week in each month. The average for the 11 month period was calculated for each pen.

Eggs were used from these pens for the egg quality characteristics study or hatchability and subsequant growth rate study during the months of February, March, April, June, July and August.

Egg Quality Characteristics Study

Experiments I to IV were designed to obtain data for determining the egg quality charactersitics of these birds due to the four dietary treatments. These experiments were conducted during the months of February, April, June and July. The time interval between two consecutive experiments was approximately seven weeks.

Experiment I

The eggs for this experiment were obtained from the 8 pens of house 2 only. All eggs laid on the day of collection by birds in each pen were held overnight in walk-in cooler operated at approximately 55° F. and 70 percent relative humidity. These eggs were used for the break out study on the

following morning. They were cleaned if necessary with a dry paper towel and marked with an identifying number on both the large and small end to facilitate later shell measurements. A sufficient number of eggs were broken until a complete set of data was obtained for each of a total of 10 eggs in each pen. Thus, in this study complete data on 80 eggs were obtained. The following measurements were made and recorded with respect to each egg:

Egg weight. Each egg was weighed in ounces per dozen and also to the nearest one-hundreth of a gram. A triple beam balance was used for taking the gram weight of each egg.

Whole egg specific gravity. A series of salt solutions ranging in specific gravity from 1.060 to 1.100 (with a difference of 0.005 in specific gravity between any two solutions in this range) were kept in wide mouth glass quart jars. Each weighed egg was placed in the salt solutions by means of a wire loop, working from solutions of lower to higher specific gravity. The specific gravity of the solution in which the egg first floated was noted as the specific gravity.

Haugh units. The eggs were next broken out, as nearly as possible into two halves by the knife edge of the egg breaking tray and the contents placed on the flat surface of the egg breaking table. The albumen height was measured with the Ames tripod micrometer as described by Haugh (1937). By using the standard slide rule calculator, Haugh units were determined and recorded.

Yolk weight. The whole content of each egg devoid of

the shell was transferred to a petri dish and the chalazae were carefully separated from the yolk with the aid of scissors and forceps. The yolk was lifted from the petri dish in the fingers and was transferred after allowing all the albumen to run off to a watch glass smeared with glycerin. The yolk weight was obtained directly to the nearest one-hundreth gram on the triple beam balance.

Yolk specific gravity. The yolk was immediately transferred with scrupulous care from the watch glass to a tea strainer which was used to suspend the yolk in the salt solutions which ranged in specific gravity from 1.010 to 1.055 (with a specific gravity difference of 0.005 between two solutions in this range.) The yolk was first suspended in a solution of lower specific gravity and then in the solution of the next higher concentration until the yolk floated. The specific gravity was recorded.

Shell weight. As soon as the eggs were broken out, the shell halves were carefully washed to remove adhering albumen, and allowed to drain on filler flats. They were grouped according to pen and numerical series and dried overnight in the hot air oven. The following day the shell quality and weight measurements were made. Each shell was weighed individually on the triple beam balance to the nearest one-hundreth of a gram and recorded.

Shell thickness. Measurements were taken at three points; one at the equatorial region, one at the large end and one at the small end. The average of these three measurements was

considered to be the shell thickness which was subsequently calculated and recorded. The same spot in each region was used uniformly for all eggs. A micrometer graduated in thousandths of an inch was used.

Shell specific gravity. The egg shell was crushed into fine pieces and carefully transferred into a 10 milliliters graduated cylinder into which 5 milliliters of water had been pipetted. With the help of a stiff wire, the shell pieces were completely immersed in the water with the exclusion of air bubbles. The reading of the graduated cylinder due to the displacement of water was recorded. The weight of the shell previously obtained in grams divided by the weight of an equal volume of water displaced by shell in grams was taken as specific gravity of the shell and recorded.

Experiment II

Similar measurements of egg quality characteristics were taken on 80 eggs from the same 8 pens of house 2 during April.

Experiment III

Similar measurements of egg quality characteristics were taken on 240 eggs for all the 24 pens of houses 2, 3 and 4 during June.

Experiment IV

Similar measurements of egg quality characteristics were taken on 240 eggs for all the 24 pens of houses 2, 3 and 4

during July.

Hatchability and Chick Studies

Experiments V to X were designed to obtain data regarding the hatchability of eggs secured from birds in houses 2, 3 and 4 and the subsequent growth rate of chicks to 4 weeks of age. These experiments were also designed to determine the relationship of egg weight and day-old chick body weight and the relationship of 4 weeks weight to diet of the hens.

Two cockerels per layer pen were added on the 1st of February. During Experiment V the cockerels were not rotated. During the Experiments VII and IX the cockerels were rotated between the pens in each house beginning 20 to 30 days prior to the commencement of saving eggs. During April the rotation period lasted for about three weeks and during July and August for a period of about a month.

The hatching experiments were conducted in March, April and August. The incubator or incubators used were operated uniformly for all the three experiments. The eggs from each pen of eaoh treatment group consisting of 6 pens were arranged in a tray. The large eggs (56 grams and above in weight) and small eggs (55 grams and below in weight) were weighed and marked on both ends of the egg with the pen number and weight of the egg prior to setting. Egg groups were hatched separately except in Experiment V. Any egg removed as infertile or dead-in-shell during and on the completion of incubation was duly

recorded to facilitate the calculation of the average egg weight of eggs set which hatched.

Experiment V

The eggs from three dietary treatments LR2, EL35 and EL37 were set on the 6th of March. A total of 1080 eggs were set. Each treatment had a replicated tray of eggs in each of four incubators. The infertiles and dead-in-shell removed on the 18th day and on the completion of incubation were recorded with their initial weights. The chicks were removed on the 22nd day and sexed. The pullet chicks for Experiment VI were wingbanded, weighed and vaccinated with Newcastle disease and infectious bronchitis vaccine and put into the brooder house on the 29th of March.

Experiment VI

All the pullet chicks with the exclusion of weaklings hatched in Experiment V were used in this experiment. Sixty-five and 71 chicks of the LR2 fed groups, 74 and 64 chicks of the EL35 fed groups and 26 and 35 chicks of the EL37 fed groups as obtained from the six trays set were randomly assigned according to treatment to each of two blocks of brooder house pens. Thus, each pen of chicks had a replicate lot in another pen across the alleyway of the house. The chicks had access to feed and water at all times. Peat moss was used as litter material. The temperature and ventilation were controlled by three roof exhaust fans working on a thermostat and an automatic

time clock. The chicks were brooded under infra-red lamp brooders. The same care and management was provided for all the pens. Pen records were posted at each pen daily for the duration of the experiment. The chicks were individually weighed at two and four weeks of age.

Experiment VII

The eggs from all the four treatments were used in this experiment. A total of 1440 eggs were set on the 23rd of April with 360 eggs from each treatment. Of these 45 were large and 15 were small eggs from each replicate pen of a treatment. The eggs of each treatment were distributed in two trays and hatched separately. The eggs were candled during the first week, second week and on the 18th and 22nd day of incubation. The infertiles and dead-in-shell eggs were removed and initial egg weights recorded. The chicks were removed on the 22nd day and were sexed. On the 16th of May, the pullet chicks to be used for Experiment VIII were wingbanded, weighed and vaccinated with Newcastle and infectious bronchitis vaccine and placed in the brooder house.

Experiment VIII

All the pullet chicks hatched with the exception of weaklings from Experiment VII were used in this experiment. The chicks obtained from the large as well as small eggs in each tray were equally distributed by treatments at random to four floor pens. A total of 175 chicks were placed in the

first pen and 174 chicks were assigned to each of the other three pens. Wood shavings were used as litter material. The feed, water, ventilation and temperature were frequently checked and the chicks were cared for similarly up to four weeks. Pen records were maintained. Individual body weights at two and four weeks of age were taken and recorded.

Experiment IX

Eggs from all four treatments, totalling 2000, were set on the 7th of August. Of these 1292 were large eggs and 708 were small eggs. From the LR2 fed groups, 360 large and 180 small eggs; from the EL35 fed groups, 351 large and 180 small eggs; from the EL36 fed groups, 286 large and 180 small eggs; and from the EL37 groups 295 large and 168 small eggs were set. The eggs were candled on the 7th, 18th and 22nd day of incubation and the weights of eggs removed were recorded. The chicks were removed and sexed on 22nd day and the pullet chicks to be used for Experiment X were wingbanded, weighed and vaccinated with Newcastle disease and infectious bronchitis vaccine and housed in battery brooders on the 30th of August.

Experiment X

Five hundred eighty-eight pullet chicks were taken at random for this experiment from Experiment IX. Twenty-one chicks were randomly assigned to 28 pens of the three battery brooders in one of the rooms of the nutrition laboratory. Fourteen of the chicks were from large eggs and seven were

from small eggs. Each treatment had seven replicated groups. The temperature of the battery brooders was maintained at 95° F. during the first week, at 90° F. during the second week and at 80° F. during the third and fourth weeks. The room temperature was maintained as comfortable as possible by adjusting the inlets and by an exhaust fan. The birds had access to feed and water at all times. The log book was maintained to record the daily observations. The body weights were taken at two and four weeks of age.

The composition and the calculated analysis of the starter diet used in these three experiments are included in Table IV. The vitamin mix and mineral mix used in the chick diet have been respectively included in Tables V and VI. Amprol was not included in the chick diet for Experiment X.

TABLE IV

COMPOSITION AND CALCULATED ANALYSIS OF CHICK DIET. EXPERIMENTS VI, VIII AND X

Feedstuff	Pounds
Yellow corn	636
Fish meal (Peruvian)	25
Alfalfa meal (dehydrated 17% protein)	25
Vitamin Mix 6[1]	6
Mineral Mix 2[2]	28
Amprol premix 3	25
Soybean oil meal (50% protein)	255
Total	1000

Calculated analysis:

Crude protein	21.67 percent
Productive energy	938.5 Calories per pound
C/P ratio	43.3:1

[1]See Table V.

[2]See Table VI.

[3]4.25 pounds of "Amprol, 25%" in 200 pounds of soybean oil meal. "Amprol, 25%" is a product of Merck and Company, Rahway, N. J., which contains 25% amprolium. As used this diet contains 0.013% amprolium.

TABLE V

COMPOSITION AND CALCULATED ANALYSIS OF VITAMIN MIX OF CHICK DIET. EXPERIMENTS VI, VIII AND X

Feedstuff	Pounds
Vitamin D supplement (30,000 I.C.U./g.	0.6
Vitamin A supplement (10,000 I.U./g.)	10.0
Riboflavin supplement (4 g./lb.)	12.9
Vitamin B_{12} supplement (20 mg./lb.)	6.0
Aureomycin supplement (10 g./lb.)	13.0
Choline Chloride (25%)	45.0
Niacin (50%)	2.0
D-Calcium panthothenate (100% - in water)	76 g.
Corn	54.4
Total	143.9

Calculated vitamin and non-nutritive additive content per 0.6 pounds:

Vitamin D	34,000 I.C.U.
Vitamin A	189,167 I.U.
Riboflavin	215 mg.
Vitamin B_{12}	0.498 mg.
Choline	18.42 g.
Niacin	1.828 g.
Pantothenic acid	318 mg.
Aureomycin	0.54 g.

TABLE VI

COMPOSITION AND CALCULATED ANALYSIS OF MINERAL MIX OF CHICK DIET. EXPERIMENTS VI, VIII AND X

Feedstuff	Pounds
Rook phosphate, defluorinated	62.5
Limestone	75.0
Salt	30.0
Manganese sulphate	1.0
Total	168.5

Calculated minerals supplied per pound:

Calcium	0.291 pounds
Phosphorus (inorganic)	0.063 pounds
Manganese	727 mg.
Salt	0.178 pounds

RESULTS AND DISCUSSION

Egg Quality Characteristics Study

The results of this study are summarized in Tables VII to XV. Each egg quality characteristic is individually grouped combining the four experiments with eggs from house 2, and two experiments with eggs from houses 2, 3 and 4. Data were analyzed by the analysis of variance technique for a split block design. Experiments I to IV were similar except for the difference in season of the year. The same measurements were made in all the experiments.

Experiments I to IV

Egg weight. The results are summarized in Table VII. The average egg weights of hens fed diets LR2 (17.18 percent protein and 970 Calories of productive energy per pound), EL35 (13.06 percent protein and 970 Calories of productive energy per pound), EL36 (13.14 percent protein and 1069 Calories productive energy per pound) and EL37 (13.11 percent protein and 1179 Calories of productive energy per pound) did not differ significantly, in all the experiments.

The results tended to be in agreement with the findings of Miller *et al.* (1957) and Orr *et al.* (1958). Since the egg sample size involved in these experiments was relatively small and the weights highly variable, it was difficult to draw any valid conclusion and to gainsay the work of other

TABLE VII

AVERAGE WEIGHT OF EGGS USED IN EGG QUALITY STUDIES. EXPERIMENTS I TO IV

		Diet number							
		LR2		EL35		EL36		EL37	
		House numbers							
Trial number	Month	2	2,3,4	2	2,3,4	2	2,3,4	2	2,3,4
		grams							
I	February	57.63	--	57.35	--	56.90	--	55.55	--
II	April	56.83	--	57.77	--	58.27	--	58.20	--
III	June	56.96	58.48	56.68	57.90	58.58	57.74	58.85	57.08
IV	July	56.63	57.86	57.40	57.58	58.68	57.56	57.12	57.45

investigators referred to in the literature who have reported increased egg weight due to increased protein, fat or energy levels. Again the metastatic nature of the results noticed between houses, trials and treatments suggest the possibility of differential response to the seasonal and environmental factors besides the possible dietary effects.

Whole egg specific gravity. The results are summarized in Table VIII. Dietary treatments failed to significantly affect whole egg specific gravity. However, for the house 2 comparisons the replicates x trials x treatment interactions were significant at the 1 percent level of probability. Significant differences were noted in the house 2, 3 and 4 comparisons between trials at the 1 percent level of probability and the treatment x replicate interaction at the 5 percent level of probability. Since the objectives of the study involved only treatment effects, no critical study of the trial and replicate (block) differences was made.

The significance between the tirals might be attributed to the seasonal change and temperature effects during June and July. Again the treatment x replicate interaction and treatment x replicate x trial interaction might be due to the individuality of the birds. These results seem to be in partial agreement with the findings of MacIntyre and Aitken (1957). Huston and Carmon (1961) reported a decline in specific gravity of eggs to environmental temperatures and age

TABLE VIII

AVERAGE WHOLE EGG SPECIFIC GRAVITY. EXPERIMENTS I TO IV

		Diet number							
		LR2		EL35		EL36		EL37	
		House numbers							
Trial number	Month	2	2,3,4	2	2,3,4	2	2,3,4	2	2,3,4
I	February	1.089	--	1.089	--	1.086	--	1.091	--
II	April	1.086	--	1.086	--	1.084	--	1.085	--
III	June	1.085	1.083	1.087	1.085	1.084	1.085	1.084	1.085
IV	July	1.082	1.08.	1.082	1.083	1.082	1.080	1.079	1.080

of the hen. The seasonal effect was marked during July, 1963; however, age might also be a factor since the values for earlier trials tended to be higher.

Haugh units. The results are summarized in Table IX. The treatment differences were not significant. However, significant differences were obtained in the treatment x replicate interaction at the 5 percent level and between trials at the 1 percent level of probability for the house 2 comparisons and treatment x replicate interaction at the 1 percent level, trials at the 1 percent level and treatment x trial interaction at the 5 percent level of probability for the house 2, 3 and 4 comparisons.

The results tended to be in partial agreement with the findings of Harms and Douglas (1960) and Harms et al. (1962) who found that dietary treatments which influence the higher rate of production might also be a factor in lowered Haugh unit values. This seems to be the case with the LR2 and EL35 fed groups which had nearly 65 and 60 percent production, respectively, and which had lesser Haugh unit values than EL36 and EL37 fed groups (with 54 and 53 percent production) in three out of four trials in the house 2 comparisons. In the house 2, 3, 4 group the results were not quite consistent. In general, the lower Haugh unit values during June and July suggest seasonal effect. Knox and Godfrey (1938) found significant differences between the percentage of thick albumen of eggs

TABLE IX

AVERAGE HAUGH UNITS OF EGGS. EXPERIMENTS I TO IV

		Diet number							
		LR2		EL35		EL36		EL37	
		House numbers							
Trial number	Month	2	2,3,4	2	2,3,4	2	2,3,4	2	2,3,4
I	February	83	--	79	--	85	--	82	--
II	April	80	--	84	--	86	--	85	--
III	June	80	79	77	79	77	78	76	81
IV	July	72	73	74	75	75	75	74	75

laid during the four week periods and among four week periods indicating a seasonal effect upon the percentage of thick albumen. Again age and season might have been a factor affecting Haugh units besides the strain of birds as reported by May and Stadelman (1960).

Yolk weight. The results are summarized in Table X. The treatment effects were not significantly different. However, significant differences were obtained between trials at the 1 percent level of probability and for the treatment x replicate interaction at the same level of probability for house 2 only. The values for June and July tended to be higher than for February and April. The maturity of the birds and the proportionate increase in yolk weight of their eggs might have contributed to the difference between trials. Again despite the fact that shell specific gravity was reduced, the yolk weight tended to be nearly constant indicative of lack of temperature effect. Bennion and Warren (1933) found that shell and albumen decreased more than yolk in proportion to the weight of the egg due to high environmental temperatures. They indicated that the oviduct is more sensitive than ovaries to high environmental temperatures. Byerly *et al*. (1933) found increased body weight and concomittant yolk and albumen weight increase in their protein level studies.

Yolk specific gravity. The results are summarized in Table XI. While the primary analysis of variance indicated

TABLE X

AVERAGE YOLK WEIGHT OF EGGS. EXPERIMENTS I TO IV

		Diet number							
		LR2		EL35		EL36		EL37	
		House numbers							
Trial number	Month	2	2,3,4	2	2,3,4	2	2,3,4	2	2,3,4
		grams							
I	February	16.60	--	16.66	--	16.30	--	16.03	--
II	April	16.77	--	16.92	--	17.17	--	17.50	--
III	June	17.28	17.68	16.91	17.09	17.18	17.07	17.67	17.27
IV	July	17.62	17.45	17.37	17.12	17.46	17.72	17.17	17.55

TABLE XI

AVERAGE YOLK SPECIFIC GRAVITY OF EGGS. EXPERIMENTS I TO IV

		Diet number							
		LR2		EL35		EL36		EL37	
		House numbers							
Trial number	Month	2	2,3,4	2	2,3,4	2	2,3,4	2	2,3,4
		grams							
I	February	1.036	--	1.033	--	1.036	--	1.039	--
II	April	1.036	--	1.035	--	1.035	--	1.034	--
III	June	1.033	1.034	1.033	1.033	1.034	1.034	1.034	1.033
IV	July	1.033	1.035	1.033	1.033	1.032	1.032	1.033	1.034

a significant difference for treatments ($P < 0.05$) for the house 2 comparisons, Duncan's multiple range test failed to identify such differences. The primary analysis also indicated significant differences for trials, trials x treatment, and trials x replicates x treatment interactions at the 1 percent level of probability. With 2, 3 and 4 house comparisons, treatment effects were not significantly different. However, treatment x replicate, treatment x trials and replicate x treatment x trial interaction were significant at the 1 percent level of probability.

The results secured from house 2 tended to show that EL35 fed groups had lower values than the other three groups, with exceptions in EL36 group during July trial and EL37 group during April trial. The highest value of 1.039 and the lowest value of 1.032 with a difference of only 0.007 suggests that yolk specific gravity might be more precisely measured by using specific gravity solutions with differences of less than 0.005.

Shell weight. The results are summarized in Table XII. The results were not significantly different between the eggs of the four treatment froups. The results tended to be in agreement with the findings of Buckner et al. (1941). However, there was a downward trend in shell weight in the latter experiments in almost all the experimental groups suggesting a seasonal effect and tended to be in agreement with the

TABLE XII

AVERAGE DRY SHELL WEIGHT OF EGGS. EXPERIMENT I TO IV

		Diet number							
		LR2		EL35		EL36		EL37	
		House numbers							
Trial number	Month	2	2,3,4	2	2,3,4	2	2,3,4	2	2,3,4
		grams							
I	February	5.32	--	5.48	--	5.14	--	5.24	--
II	April	4.99	--	5.12	--	5.03	--	5.10	--
III	June	4.92	4.89	5.13	5.04	4.93	4.96	4.97	4.87
IV	July	4.88	4.88	4.89	5.02	5.00	4.84	4.74	4.81

observations of Wilhelm (1940). He ascribed the seasonal trend to be due to temperature influencing the dry weight of the shell and that dry weight of the shell was not independent of the egg weight. Egg weights also tended to be low with exceptions denoting the individuality of the birds constituting a group in such cases.

Shell thickness. The results are summarized in Table XIII. Treatment differences were not significant. However, the trials differences were significant at the 1 percent level of probability in the house 2 comparisons. The results tended to be in agreement with the findings of Combs and Helbacka (1960) and March and Biely (1963). This could be concommittant with altered metabolism of the hen due to the temperature effects and the physiological funcitoning of the oviduct (Bennion and Warren 1933). Results obtained clearly indicate in almost all cases a downward trend in shell thickness during June and July trials. Again the EL35 fed group tended to show more moderate results than the other groups and, this again might be attributed to an adequate intake of calcium and its utilization on a comparable basis. The reduction in shell thickness was also gradual over the four experimental periods. Stewart (1936) reported that shell thickness was influenced by the individuality and nutrition of the hen. Wilhelm (1940) reported that the rate of egg production and shell thickness were independent of each other.

TABLE XIII

AVERAGE SHELL THICKNESS OF EGGS. EXPERIMENTS I TO IV

		Diet number							
		LR2		EL35		EL36		EL37	
		House numbers							
Trial number	Month	2	2,3,4	2	2,3,4	2	2,3,4	2	2,3,4
		0.001 inches							
I	February	13.43	--	13.94	--	13.37	--	13.63	--
II	April	12.46	--	12.41	--	12.20	--	12.52	--
III	June	11.78	11.67	12.39	12.07	11.71	11.90	11.67	11.77
IV	July	11.78	11.65	11.90	12.01	11.79	11.59	11.38	11.51

Shell specific gravity. The results are summarized in Table XIV. The results did not differ significantly between treatments. However, significant F values were obtained for treatment x replicate interaction at the 5 percent level, trials at the 1 percent, replicates x trials at the 5 percent and replicates x trials x treatment at the 1 percent levels of probability in the house 2 comparisons and treatment x replicate at the 5 percent level, trials at the 1 percent level and replicate x treatment at the 5 percent levels of probability for the house 2, 3 and 4 comparisons.

The results tended to fluctutate between treatments, between houses and between trials. Again the interaction significances obtained may be suggestive of seasonal influence and individuality of hens in response to treatment and seasonal effect.

Albumen weight. The results are summarized in Table XV. The results were not significantly different between treatments.

Fluctuations between trials and between treatments are noticeable. This could not be accounted for fully. Jull (1924) stated that albumen weight is the least variable of all the parts and that the component parts of the egg contribute in different degrees at different times of the year toward the total weight and that the independent variation of the parts of the egg is probably caused by the underlying physiological processes. The percentage of albumen, yolk and shell of the

TABLE XIV

AVERAGE SHELL SPECIFIC GRAVITY OF EGGS. EXPERIMENTS I TO IV

		Diet number							
		LR2		EL35		EL36		EL37	
		House numbers							
Trial number	Month	2	2,3,4	2	2,3,4	2	2,3,4	2	2,3,4
I	February	1.881	--	2.071	--	1.781	--	1.888	--
II	April	2.002	--	2.016	--	2.014	--	2.057	--
III	June	1.988	1.976	2.046	2.022	2.001	2.005	2.009	1.994
IV	July	2.010	2.009	1.978	2.032	1.996	2.018	2.009	2.005

TABLE XV

AVERAGE ALBUMEN WEIGHT OF EGGS. EXPERIMENTS I TO IV

Trial number	Month	LR2 2	LR2 2,3,4	EL35 2	EL35 2,3,4	EL36 2	EL36 2,3,4	EL37 2	EL37 2,3,4
		Diet number / House numbers							
		grams							
I	February	35.71	--	35.21	--	35.46	--	34.28	--
II	April	35.07	--	35.73	--	36.07	--	35.60	--
III	June	34.76	35.91	34.64	35.77	36.47	35.71	36.20	34.94
IV	July	34.13	35.53	35.13	35.45	36.22	34.99	35.21	35.08

total egg varies from time to time throughout the year and is influenced by the rate of production.

The results of egg quality characteristics of experiments I to IV were not significantly different due to the dietary treatments. Sample size, seasonal effect, age and individuality of the birds seems to have had a bearing on the results. Larger samples might enhance the value of the experiment. The growing period treatments to which the layers had been subjected might have had some effects on the egg weight and indirectly on some of the quality characteristics as indicated by the number of significant interactions involving replicates.

Hatchability Study

Experiment V

The results are summarized in Table XVI. EL37 fed group was significantly different from EL35 and LR2 fed groups in respect to hatchability of fertile eggs at the 1 percent level of probability. However, the infertility rates were not significantly different.

Though the significant difference indicates treatment effect, the failure of males to provide for fertile hatchable eggs needs to be considered. Pens on the same treatment varied greatly in fertility. The non-significance of the infertility rate and high incidence of infertile eggs and dead-in-shell eggs replicate pens of all three treatments used in this experiment

TABLE XVI

PERCENTAGE OF FERTILITY AND HATCHABILITY OF FERTILE EGGS. EXPERIMENT V, MARCH, 1963 HOUSE 2, 3 AND 4

Diet number	Eggs set	Fertility	Hatchability of fertile eggs[1]
		percent	percent
LR2	360	81.94[a]	86.44[a]
EL35	360	85.56[a]	92.86[a]
EL37	360	68.89[a]	52.02[b]

[1]Means with different superscripts are significantly different at the 1 percent level of probability as calculated by Duncan's Multiple Range Test.

suggest the male effect. This was untrue in two other latter trials when males were rotated in each house between pens prior to saving of eggs.

Experiments VII and IX

The results are summarized in Tables XVII and XVIII. No significant differences were found in these two experiments either with percentage fertility or with the hatchability of fertile eggs. Again there was no difference between large and small eggs in these two characteristics.

Results tend to agree with the findings of Hochreich et al. (1958), Frank and Waibel (1960) and Heywang and Vavich (1962).

The results of hatchability trials tend to show no significant differences due to dietary effect on fertility rate or hatchability of fertile eggs. However, results of Experiment V could not be fully explained except to point to the effect of male infertility and to the possibility of a toxic dietary effect which could have been associated with the high fat level used in diet EL37 in the first trial.

Chick Growth and Egg Size-Chick Size Study

The results of Experiments VI, VIII and X which constituted this study are summarized in Tables XIX and XX. The average weight of eggs which hatched, the average chick weight at hatching and average chick weight as percent of egg

TABLE XVII

PERCENTAGE OF FERTILITY AND HATCHABILITY OF FERTILE EGGS. EXPERIMENT VII, APRIL, 1963, HOUSE 2, 3 AND 4

Diet number	Eggs set	Size	Fertility	Hatchability of fertile eggs
			percent	percent
LR2	270	large	96.30	92.31
	90	small	96.67	96.55
EL35	270	large	96.67	91.19
	90	small	94.44	94.12
EL36	270	large	97.04	95.04
	90	small	95.56	88.37
EL37	270	large	95.56	93.41
	90	small	98.89	89.89

TABLE XVIII

PERCENTAGE OF FERTILITY AND HATCHABILITY OF FERTILE EGGS. EXPERIMENT IX, AUGUST, 1963, HOUSE 2, 3 AND 4

Diet number	Egg size	Size	Fertility	Hatchability of fertile eggs
			percent	percent
LR2	360	large	93.33	89.58
	180	small	94.44	90.00
EL35	351	large	96.30	90.24
	180	small	96.67	86.78
EL36	286	large	95.10	91.18
	180	small	93.89	91.72
EL37	295	large	98.31	92.76
	168	small	91.67	87.01

weight are summarized in Table XIX. The pullet chick weights at hatching, two weeks and four weeks in these experiments are summarized in Table XX. The eggs for Experiment VI were not set separately as large and small eggs as was done for Experiments VIII and X.

Experiment VI

The chick weights at hatching as percent of egg weight ranged from 60.65 to 61.71 percent. The body weights of chicks at two and four weeks were not significantly different between those from the EL35 and LR2 fed groups. However, chicks from EL37 fed groups were significantly smaller than chicks from EL35 fed group at two and four weeks of age. ($P < 0.01$ and $P < 0.05$, respectively).

Experiment VIII

The chick weight at hatching as percent of egg weight ranged from 62.93 to 64.59. These results tended to be in agreement with the findings of Halbersleben and Mussehl (1922) who obtained a value of 64 percent in their experiment.

The intital difference in chick weights between chicks hatched from small and large eggs continued through the four week growth period. The body weights were significantly different at two weeks at the 1 percent level of probability and at four weeks at the 5 percent level of probability. The maternal treatments did not significantly affect body weight at two and four weeks of age. At four weeks there were

TABLE XIX

AVERAGE EGG WEIGHT, DAY-OLD CHICK WEIGHT, AND PERCENTAGE OF CHICK WEIGHT TO EGG WEIGHT. EXPERIMENTS VI, VIII AND X, HOUSE 2, 3 AND 4

Diet number	Egg size	Average weight of eggs hatched			Average chick weight			Chick weight percent of egg weight		
		Experiment numbers								
		VI	VIII	X	VI	VIII	X	VI	VIII[1]	X[1]
		grams			grams			grams		
LR2	Large	--	60	60	--	39	36	--	64.76	59.20
	Small	--	53	53	--	34	31	--	63.58	58.85
	All eggs	58	--	--	35	--	--	60.65	--	--
EL35	Large	--	59	59	--	38	35	--	64.39	59.01
	Small	--	53	52	--	34	31	--	64.59	59.65
	All eggs	58	--	--	35	--	--	51.02	--	--
EL36	Large	--	60	59	--	38	36	--	63.92	59.84
	Small	--	53	52	--	34	31	--	63.97	59.12
	All eggs	--	--	--	--	--	--	--	--	--
EL37	Large	--	60	60	--	39	36	--	64.31	60.27
	Small	--	53	52	--	33	31	--	62.93	60.22
	All eggs	56	--	--	34	--	--	61.71	--	--

[1]The percent values for Experiments VIII and X differed significantly at the 1 percent level of probability.

TABLE XX

AVERAGE PULLET CHICK WEIGHTS AT HATCHING, TWO AND FOUR WEEKS OF AGE. EXPERIMENTS VI, VIII AND X

Diet number	Egg size	Average hatching weight			Average two week weight			Average four week weight		
		Experiment numbers								
		VI	VIII	X	VI	VIII[1]	X[1]	VI	VIII[2]	X[1]
			grams			grams			grams	
LR2	Large	--	39	35	--	88	123	--	201	280
	Small	--	34	31	--	83	116	--	197	270
	All eggs	35	--	--	97	--	--	217	--	--
EL35	Large	--	38	35	--	90	121	--	203	278
	Small	--	34	32	--	84	118	--	201	270
	All eggs	35	--	--	100	--	--	222	--	--
EL36	Large	--	38	36	--	91	123	--	205	282
	Small	--	34	31	--	81	120	--	183	275
	All eggs	--	--	--	--	--	--	--	--	--
EL37	Large	--	39	36	--	92	123	--	205	282
	Small	--	33	31	--	84	114	--	199	261
	All eggs	35	--	--	87	--	--	202	--	--

[1]The average weights of the chicks from the large and small eggs were significantly different at the 1 percent level of probability.

[2]The average weights of the chicks from the large and small eggs were significantly different at the 5 percent level of probability.

significant differences between replicates at the 5 percent level of probability. There was also significant treatment x size interaction at the 5 percent level of probability at four weeks of age.

The lower level of significance at four weeks of age suggests the possibility of diminishing influence of egg weight at this age. Again the differences between replicates and treatment x size interaction suggest individual variation in response during post natal growth despite the initial weight of hatching egg. This tended to be in agreement with the report of Garber and Godbey (1952) and Godfrey *et al.* (1953).

Experiment X

The chick weight at hatching as percent of egg weight ranged from 58.85 to 60.27. No effect of maternal diet or hatching egg size could be noted for this characteristic. The initial difference in egg size continued to significantly affect the chick weights at two and four weeks of age at the 1 percent level of probability. Chick weights did not differ significantly, due to maternal dietary treatments, at two and four weeks of age. Chick weights at four weeks of age showed significant differences between replicates at the 1 percent level of probability. Replicate x treatment interaction and treatment x size interactions were also significant at the 1 percent level of probability. These data suggest the variability of response of chicks to the diminishing influence of egg weight

on subsequent growth rate. However, the replicate x treatment interaction could not be fully explained.

The apparent significant effect of a maternal diet upon the subsequent growth of progeny obtained in Experiment VI and the failure to obtain such a response in Experiments VIII and X suggests that one or more feedstuffs used in diet EL37 prior to setting of the eggs for Experiment VI chicks might have been responsible for such a response.

Bird et al.(1964) reported that the parallelism between hatchability of eggs and viability of chicks suggested that the factors essential for good hatchability were transferred from the hen through the egg to the chicks.

The results obtained in Experiment VI suggesting a significant maternal dietary effect upon chick weight does not permit the drawing of defininte conclusions since Experiments VIII and X failed to indicate such treatment effect.

Chick weight as percent of egg weight obtained in Experiments VIII and X showed no significant differences due to treatment effect. However, between these experiments the chick weight as percent of egg weight differed significantly at the 1 percent level of probability. This suggests the possible influence of season and the influence of temperature and relative humidity of the incubators and/or holding room on the percent weight of chicks of hatching egg weight.

The chick mortality observed during the growth studies was small and did not appear to be associated with maternal diets.

SUMMARY AND CONCLUSIONS

Data have been presented on the egg quality characteristics, hatchability of eggs and subsequent growth rate of chicks and also on the relationship of egg size to chick size from hatching to four weeks of age. Eggs for this study were obtained from about 720 Single Comb White Leghorn pullets which were maintained in floor pens in three houses of similar construction, under four dietary treatments for an 11 month laying period. A 17 percent protein diet with 970 Calories of productive energy per pound was used to compare the results of 13 percent protein diet with 970 Calories of productive energy per pound of feed which in turn served as an additional control for the 13 percent protein diets with 1069 and 1179 Calories of productive energy per pound. The high energy diets had, respectively, 3 and 9.7 percent added animal fat.

A total of 640 eggs were broken for the egg quality characteristics study. The data were obtained during the months of February, April, June and July. No significant differences due to dietary treatment of the dams were obtained for egg weight, whole egg specific gravity, Haugh units, yolk weight, yolk specific gravity, shell weight, shell thickness, shell specific gravity and albumen weight. However, the significant differences obtained between trials for whole egg specific gravity, shell thickness, shell specific gravity, yolk weight and yolk specific gravity were suggestive of the

seasonal and/or age effects on egg quality characteristics.

A total of 4520 eggs were set to secure data on the hatchability of eggs from these pullets and to study the effects of the four dietary treatments. Three experiments were conducted. In the first experiment, started during March, significant differences were found in hatchability of fertile eggs due to maternal diets while no significant differences were found in the two latter experiments, started during April and August. The fertility rate was not significantly altered in any of the three experiments. In the two latter experiments large and small eggs were hatched separately. There was a marked difference in chick weights at hatching due to the initial difference in hatching egg weight. The chick weight as percent of egg weight at hatching differed significantly between hatches.

A total of 1616 pullet chicks obtained from the three hatchability experiments were used for studying the effect of maternal dietary treatments on the subsequent progeny growth to four weeks of age. In the first two experiments the chicks were reared in floor pens and in the last experiment in battery brooders. Body weights were recorded at hatching and when the chicks were two weeks and four weeks of age. No significant differences were found in chick weights associated with maternal diets in the two latter experiments either at hatching, two weeks or at four weeks of age although significant differences

were found in the first experiment. The initial chick weight difference due to initial difference in hatching egg weight continued through four weeks of age. The mortality rate was comparable for treatments and trials and was not suggestive of treatment differences.

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APPENDIX

TABLE XXI

SUMMARY OF PRODUCTION PERFORMANCE OF SINGLE COMB WHITE LEGHORN PULLETS. FOR 11 MONTHS

House and pen No.	Mortality	Production	Average egg weight	Average gain in body weight	Feed per dozen eggs	Feed per hen
	percent	percent	oz./doz.	oz.	lbs.	lbs.
Diet LR2, 17.18% protein, 970 Calories of productive energy/lb.						
2-4	16.67	68.47	23.60	12.30	4.19	77.24
2-7	30.00	61.90	23.30	12.58	4.56	76.14
3-4	20.00	64.30	24.06	13.54	4.50	78.00
3-7	10.00	66.72	24.06	11.76	4.29	77.30
4-2	30.00	62.23	24.50	17.47	4.58	76.10
4-8	16.67	64.83	24.42	9.13	4.22	73.25
Average	20.56	64.74	23.99	12.80	4.39	76.34
Diet EL35, 13.06% protein, 970 Calories of productive energy/lb.						
2-2	20.00	61.77	23.70	9.51	4.72	78.60
2-8	13.33	60.61	23.33	5.14	4.62	75.61
3-2	16.67	58.85	23.54	7.20	4.72	75.14
3-8	3.33	66.61	23.53	8.89	4.51	82.03
4-3	3.33	63.27	23.56	10.34	4.54	76.93
4-5	16.67	51.74	23.59	7.78	5.31	74.01
Average	12.22	60.48	23.54	8.14	4.74	77.05
Diet EL36, 13.14% protein, 1069 Calories of productive energy/lb.						
2-1	20.00	53.06	24.00	10.26	5.17	74.18
2-6	30.00	55.74	23.40	10.38	5.05	75.82
3-1	30.00	55.81	23.12	7.29	4.58	68.97
3-6	13.33	58.79	23.64	7.66	4.45	70.68
4-4	26.67	51.97	23.69	10.93	5.00	70.31
4-6	13.33	50.49	23.60	7.87	4.93	67.25
Average	22.22	54.31	23.58	9.07	4.86	71.20
Diet EL37, 13.11% protein, 1170 Calories of productive energy/lb.						
2-3	13.33	58.72	23.60	10.55	5.45	70.98
2-5	26.67	57.96	23.71	8.23	4.36	68.05
3-3	23.33	51.35	23.56	9.70	4.79	66.22
3-5	43.33	46.13	23.41	6.36	5.11	63.75
4-1	13.33	50.58	24.18	12.27	5.02	63.84
4-7	16.67	56.03	23.21	9.82	4.41	66.65
Average	22.78	53.46	23.61	9.49	4.86	66.58

TABLE XXII

PRODUCTION PERFORMANCE OF SINGLE COMB WHITE LEGHORN PULLETS.
FEBRUARY-AUGUST 1963 HOUSE 2, 3 AND 4

Month	Production	Average egg weight	Feed per dozen eggs	Feed per hen
	percent	oz./doz.	lbs.	lbs.
Diet LR2, 17.18% protein, 970 Calories of productive energy/lb.				
February	69.16	23.38	4.71	7.59
March	72.92	24.20	4.46	8.40
April	70.67	25.23	4.10	7.25
May	69.78	25.24	4.10	7.39
June	68.32	25.18	4.11	6.99
July	62.48	24.96	4.15	6.68
August	58.76	24.90	4.23	6.39
Diet EL35, 13.06% protein, 970 Calories of productive energy/lb.				
February	66.55	23.06	5.03	7.78
March	71.09	23.87	4.71	8.61
April	70.57	24.48	4.37	7.74
May	67.48	24.73	4.36	7.53
June	60.97	24.89	4.40	6.65
July	56.24	24.24	5.00	6.64
August	53.20	24.50	4.87	6.59
Diet EL36, 13.14% protein, 1069 Calories of productive energy/lb.				
February	59.91	23.08	5.04	7.03
March	64.69	24.01	4.98	8.27
April	67.43	24.70	4.45	7.47
May	65.15	24.96	4.33	7.58
June	54.63	24.92	4.51	6.09
July	45.46	24.29	5.03	5.78
August	44.52	24.29	5.26	5.95
Diet EL37, 13.11% protein, 1179 Calories of productive energy/lb.				
February	60.40	22.98	4.54	6.66
March	61.05	24.10	4.78	7.47
April	62.38	24.63	4.36	6.75
May	59.39	24.91	4.21	4.43
June	52.55	24.85	4.39	5.71
July	46.58	24.33	4.84	5.79
August	41.46	24.56	5.49	5.96