12-1973

Strain differences with respect to economic traits of egg laying chickens entered in the Tennessee Random Sample Laying Test

Shaker Al-Mohammadi

To the Graduate Council:

I am submitting herewith a thesis written by Shaker Al-Mohammadi entitled "Strain differences with respect to economic traits of egg laying chickens entered in the Tennessee Random Sample Laying Test." 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.

H. V. Shirley Jr, Major Professor

We have read this thesis and recommend its acceptance:

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

November 14, 1973

To the Graduate Council:

I am submitting herewith a thesis written by Shaker Al-Mohammadi entitled "Strain Differences with Respect to Economic Traits of Egg Laying Chickens Entered in the Tennessee Random Sample Laying Test." 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 Animal Science.

H. V. Shirley
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We have read this thesis
and recommend its acceptance:

Robert R. Shrode

J. B. McLaren

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STRAIN DIFFERENCES WITH RESPECT TO ECONOMIC TRAITS OF EGG LAYING CHICKENS ENTERED IN THE TENNESSEE RANDOM SAMPLE LAYING TEST

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

Shaker Al-Mohammadi

December 1973

ACKNOWLEDGMENTS

With deep appreciation and thanks, the author wishes to acknowledge the Iraqi Government who supported him during this study and to those who have given their time, efforts and assistance to make this study possible.

Any acknowledgment would be all too inadequate unless special expression first of all the author's gratitude to Dr. H. V. Shirley, Jr., who, as the writer's major professor, has given valuable advice, assistance, guidance and encouragement throughout the course of this study.

High indebtedness is expressed to Dr. R. R. Shrode, for his many helpful suggestions, encouragement, advice, review of the manuscript and for serving on the graduate committee. Without his criticisms and suggestions this thesis would never have been available.

To Dr. J. B. McLaren, for serving on the graduate committee and for his valuable suggestions and encouragement.

To Dr. J. K. Bletner, for his advice and encouragement throughout the course of study.

To Mr. G. McGhee, for his assistance in the collection of data.

To Dr. B. La Berge, assistant director of international student affairs, for his assistance, encouragement and dear friendship.

To Dr. N. T. Kazzal, for his many helpful suggestions, for his help in analyzing the data of this study, for his encouragement during the course of study and for his dear friendship.

To Mr. N. M. Ali, for encouragement during studying together and for his dear friendship.

To Mrs. Mary Mills who assisted in typing and for her understanding during the preparation of this thesis.

Last but not least, regards to the author's parents, brothers, sisters, wife and to his three children, Saad, Afraa and Mohammad, for their encouragement and patience during his stay at the University of Tennessee.

ABSTRACT

Data collected during the Fifteenth Tennessee Random Sample Laying Test (1972) were analyzed statistically using analysis of variance and conventional product-movement coefficients of correlation among most variables studied to determine the magnitude of these correlations in both strain and treatment subclasses. The variables studied were egg production, average egg weight, feed efficiency, mortality, egg quality, income over chick and feed cost, body weight and sexual maturity. The effects assessed were strain (14 strains), feeding period during the growing period (short period = 10 to 20 weeks and long period = 10 to 24 weeks), protein level (low level = 10.2 percent and high level = 17.6 percent) and their interactions.

Strain differences were significant with respect to most traits studied. The other two main effects, feeding period and protein level, were found also to differ, frequently and significantly.

Most of the interactions were observed to be nonsignificant except for some first-order interaction such as strain X protein interactions for percent hen-day egg production after 50 percent of production ($P < 0.05$) and body weight at housing ($P < 0.01$), and feeding period X protein for sexual maturity ($P < 0.05$) and cost per hen ($P < 0.01$), while the second-order interactions were not significant for any trait.

In spite of lack of significance in interactions between variables, there were some interactions which cannot be ignored.

They would undoubtedly be significant with larger sample size and experimental procedures which would permit detection of small differences.

Tests of significance of coefficients of correlation showed that strains differed in sign of correlations rather than in magnitude. Treatments showed significant positive relationships of average egg weight with eggs per hen housed and of profit per hen with both eggs per hen housed and average egg weight, while other relationships with different sign were not significant.

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CHAPTER I

INTRODUCTION

There has been a rapid decline in the number of egg laying strains offered for sale as a result of a decrease in magnitude of differences between strains of laying hens since performance levels have been approaching a plateau.

Strains differ in protein requirement during different phases of the growing-feeding period. Recently, valuable research has been conducted to determine the best level of protein during the growing period and its effect on performance of egg production stocks. Protein level during the growing period has generally been reported to be no more than 15 percent but no less than 11 percent.

Attention has naturally been focused on protein level, since protein is the most costly part of the ration other than energy, but the importance of differences in protein requirements among commercial egg production strains during different periods of feeding rests largely in the possibility of importance of genotype X environmental interactions. Genotype X environment interactions were found to play a large part in reducing poultry industry expenses. Any progress in reducing those expenses will increase interest in studies of genotype-environment interactions in egg laying stocks. Changes in all phases of the poultry industry have been rapid and have led to changes in patterns of breeding programs.

The producers have to provide certain environmental conditions suitable to their strains, or they must use certain strains capable of producing better under their environmental circumstances if genotype-environment interactions are important.

Strains, feeding period, protein level and their interactions have different influences on economic traits in egg laying chickens. Recently, most breeders have been interested in all economically important traits and the genotypic and environmental effects on them.

Correlations between traits make various production traits affect one another through the relationships between them. Therefore, it is very important to know the sign and magnitude of those relationships before planning any breeding program. That is obvious, for example, in the case of negative correlation between two traits each of which needs to be increased. Any improvement in one of them might cause extreme depression in the other trait if the correlation is a large negative one. Most production traits have phenotypic correlations among them which result from genotypic and environmental correlations.

The objective of this study was to evaluate the effect of all possible genotype X environment interactions affecting the individuals of different strains treated in two different feeding periods and fed rations containing two levels of protein, and determination of the sign and magnitude of coefficients of correlation among various economic traits.

CHAPTER II

REVIEW OF LITERATURE

I. PROTEIN IN GROWING RATIONS

The subject of protein in growing rations has been studied by many researchers to determine the requirements of growing pullets and the effect on laying performance. The requirement for specific traits was studied very early. Studies in this subject were conducted by Roberts (1929) who indicated that a medium protein level (4.5 percent of meat scraps added) might be satisfactory for growing pullets from (10 to 23) weeks of age. However, he suggested that 7.5 percent of meat-scrap protein gave somewhat more uniform growth, but 1.5 percent seemed not to be sufficient for maximum growth during that period. Blaylock (1956) stated that the requirement of protein of light-breed growing pullets was as low as 12 percent by 12 weeks of age. Berg and Bearse (1958) reported that the requirement for Single Comb White Leghorns (S.C.W.L.) was no more than 15 percent from 8 to 12 weeks, 13 percent from 12 to 16 weeks and 12 percent from 16 to 20 weeks of age. Berg (1959) showed that 13 percent was adequate for W.L. from 8 to 21 weeks, Waldroup and Harms (1962), Waldroup *et al*. (1966) and Lillie and Denton (1966) stated that 11 to 12 percent protein was adequate for W.L. from 8 to 20 weeks without any adverse effects on the subsequent laying period carried over from the growing period. Costain *et al*. (1970) reported that 12 percent was adequate for birds 6 to 20 weeks of age.

The requirements of protein in a layer ration are affected by such factors as: strain or breed, hen size, egg production, season of the year, cage management or cage density, environmental temperature and poor protein quality (amino-acid content). Sharpe and Morriss (1965) showed that a smaller-type hen such as the Leghorn had a higher protein requirement than did a heavier type during the laying period. Harms and Waldroup (1962) indicated that protein requirement of the laying hen is as high as 17 percent and as low as 11 percent, varying from one strain or breed to another. This report agrees with those of Moreng et al. (1964), Deaton and Quisenberry (1965), Harms et al. (1966) and Wright et al. (1968).

Optimum protein requirement during the laying period was stated to be 13 percent by Thornton et al. (1957), 20 grams/hen/day by Harms and Waldroup (1962) and 14 grams/hen/day by Peterson and Sauter (1969).

Egg Production

Considerable research has been conducted in an attempt to determine the optimum protein requirement during the rearing period and its effect on subsequent egg production. Atwood (1923) reported that a poorly balanced ration, fed to chicks as starter and grower diet until maturity, reduced egg production.

Most reports reviewed stated that there was no significant effect of level of protein during the growing period on egg production. (Sunde and Bird, 1959; Waldroup and Harms, 1962; Lillie and Denton, 1966; Waldroup et al., 1966; Lillie and Denton, 1967; Peacock and

Combs, 1967; Harms et al., 1968; Smith et al., 1970; and Costain et al., 1970.) However, some investigators showed that there was a slight effect, (Hull and Gowe, 1962 and Wright et al., 1968). Some investigators found significant differences between levels of protein during growing period with respect to egg production, (Santana and Quisenberry, 1968 and Wolf et al., 1969).

Restriction of feed intake of growing pullets was reported to decrease egg production by Davis and Watts (1955) and Al-Khazraji (1968), increase egg production by Fuller (1960) and to have no effect on egg production either in chickens by Milby and Sherwood (1956) or in turkeys by Voitle et al. (1971) and Voitle et al. (1973).

The requirement for protein during the laying period has been studied by many investigators, and it was stated to be at least 17 percent of the layer diet by Sharpe and Morris (1965) and Nivas and Sunde (1969), whereas others indicated it to be 15 percent protein of the layer diet (Heywang et al., 1955). In some instances 12.5 to 13 percent gave good egg production (Miller et al., 1957) and even 11 percent was found to be adequate by Thornton et al. (1957), but Butts and Cunningham (1972) stated that a 12 percent protein diet was not sub-optimum for maximum egg production. Petersen and Sauter (1969) reported 14 grams/hen/day to be sufficient for egg production. Gleaves et al. (1968) found 15 grams/hen/day to be a minimum level for egg production. Touchburn and Naber (1962) showed 17 grams/hen/day to be sufficient. Tonkinson et al. (1968) found 17.5 grams/hen/day to be sufficient, and 20 grams/hen/day was sufficient in the work of Harms and Waldroup (1962) and Nivas and Sunde (1969). Harms and

Waldroup (1963), Gleaves *et al*. (1968), Marks *et al*. (1969c), Summers *et al*. (1969) and Gleaves and Dewan (1971) found significant differences in egg production between protein levels fed during the laying period, but data of Thornton *et al*. (1957) indicated that no significant effect of protein level on egg production during laying period.

Egg Weight or Egg Size

Most of the research reported indicated that egg weight or egg size was not affected by protein level during the growing period, while some workers noted that protein level during the growing period had little, if any, effect upon egg weight or egg size. Berg (1959) found no differences between 13, 16 and 19 percent protein level in the diet fed to chickens 8 to 21 weeks of age. Sunde and Bird (1959), Waldroup and Harms (1962), Lillie and Denton (1966, 1967), Peacock and Combs (1967), Harms *et al*. (1968), Wright *et al*. (1968), Summers *et al*. (1969), Costain *et al*. (1970), Ceballos *et al*. (1970) and Voitle *et al*. (1973) reported that there were no significant egg weight or size differences between levels of protein fed during the growing period.

Davis and Watts (1955) stated that restriction of feed intake of New Hampshire pullets during the growing period resulted in slightly larger initial eggs and Al-Khazraji (1968) reported in one experiment, but not in another that as the degree of feed restriction increased, the average egg size decreased and that was reflected in the average egg weight, Milby and Sherwood (1956) and Quisenberry (1959) reported that egg size at any given age was not affected by the feeding program, Santana and Quisenberry (1968) reported that there were differences in egg size due to differences in level of protein (*i.e.*, 12 percent protein level produced smallest eggs, but the 14 percent protein level produced slightly below the highest level for egg size). Voitle *et al*. (1971) reported that eggs laid by birds fed a control diet (21 percent protein level) were too small for setting as compared to eggs produced on low protein level (10.2 percent) and the "skip-a-day" treatment (75 percent of control).

However, egg size or egg weight is more sensitive to level of protein in the layer diet than to level of protein in grower diet. Some investigators found significant or highly significant differences in egg weight between levels of protein in the layer diet (Thornton *et al*., 1957; Moreng *et al*., 1964; Smith, 1967; Marks *et al*., 1969c; Nivas and Sunde, 1969; Mackin, 1970 and Smith *et al*., 1970). However, Hochreich *et al*. (1957) found no differences in egg size between levels of protein fed during the laying period. Smith (1967) stated that 14 percent protein during the laying period was not adequate for optimum egg size but that 16 or 18 percent was. Quisenberry *et al*. (1963) indicated that egg size was improved by increasing the level of protein in layer diet. Balloun and Speers (1969) showed that a small-size strain required less than 10 grams/hen/day to maintain egg size, but that a large-size strain required 18 grams/hen/day with producing a greater mass of eggs than a medium-size strain which also required 18 grams/hen/day. Petersen and Sauter (1969) reported that egg weight was improved with each increase in protein intake up to 18 grams/hen/day, and Butts and Cunningham (1972) showed that 12 percent protein level in a layer diet was not sufficient for production of eggs of maximum size.

With respect to effect of starter diet, Petersen and Sauter (1967) reported no effect in an experiment in which chickens of a commercial strain of White Leghorns were fed different levels of protein, viz., 20, 18, 16, 18 percent + adequate methionine and cystine in the starter diet and 14 percent in the grower diet.

Sexual Maturity

During recent years considerable attention has been given to the possibility of improving egg production or egg weight by delaying sexual maturity of replacement pullets, Bletner (1963) reported improvement but some researchers such as Kennard (1921) showed that delaying sexual maturity was not desirable in pullets of egg production type.

The most effective methods of delaying sexual maturity involve the restriction of total feed intake by limiting feeding time, feeding lower amounts, feeding a high-fiber diet and by feeding an incomplete diet.

Most papers reviewed reported that sexual maturity was significantly affected by reducing the level of protein during the rearing period. Atwood (1923) noted that a poorly balanced ration fed to chicks as a starter and grower diet increased the age at sexual maturity (age at first egg). Waldroup and Harms (1962) reported that using 9 percent protein in a grower diet had significantly delayed sexual maturity. Hull and Gowe (1962) found a very large effect of protein level during rearing. Bletner (1963) reported that delays in sexual maturity of less than 7 days had no effect on subsequent laying performance; while birds experiencing delays of 8 to 21 days generally had higher egg production and larger egg size, but had low mortality during the laying period, and delays of more than 21 days usually increased egg production of heavy breeds but not of Leghorns or Leghorn-type breeds.

Wilson et al. (1964), Harms et al. (1964), Waldroup et al. (1965), Palafox (1965), Waldroup et al. (1966), Jones et al. (1966), Harms et al. (1968), Wilson et al. (1968), Wright et al. (1968), Wolf et al. (1969), Caballos et al. (1970), Costain et al. (1970), Smith et al. (1970), Voitle et al. (1971) and Voitle et al. (1973) stated that feeding low protein levels in the grower diet often significantly delayed sexual maturity as measured by age at 50 percent or 30 percent production or age at first egg. Some investigators found no effect of low level of protein in the grower diet, (Denton and Lillie, 1959; Sunde and Bird, 1959; Lillie and Denton, 1966 and Peacock and Combs, 1967).

Another method of delaying sexual maturity is to give little or no feed on certain days. Luckman et al. (1963) reported that this physical restriction of the amount of feed offered each day or by using fiber in the diet. Singsen et al. (1964) observed that a grower diet deficient in lysine also was effective in delaying sexual maturity of meat type birds, while Petersen and Sauter (1967) showed that starter diet (until 7 weeks) did not affect the sexual maturity (neither age at first egg nor age at 50 percent of production).

Body Weight and Feed Efficiency

Considerable research has been done to determine the effect of protein level on body weight and feed efficiency in pullets of egg production type but this subject has greater importance in broilers than in egg production stocks.

One would expect body weight and feed efficiency or feed conversion to be affected by level of protein during the growing period, and that effect was significant in some experiments. Atwood (1923) indicated that a poorly balanced ration fed during the growing period reduced the weight of mature females. Kondra and Hodgson (1961), in two experiments, found significant ration differences in weight gain and feed efficiency at some ages, ($P < .05$, $P < .01$). One experiment was with a hybrid egg production stock, and the other was with broilers. Effects were nonsignificant at some ages, but body weight and feed efficiency were usually improved as the protein level in the ration was increased. Hull and Gowe (1962) found a very large effect of growing diet level of protein on body weight. Siegel and Wisman (1962) observed significant body weight and feed conversion differences ($P < .01$) between rations at all ages. Wilson *et al.* (1963, 1964) noted that low protein caused very small body weight gains at 20 weeks of age but no differences in final body weight. Essary *et al.* (1964) stated that live weight and feed conversion differences were in favor of birds fed the higher level of protein.

Jones *et al*. (1966) observed that a low protein grower diet caused small body weight gain in cockerels. Lillie and Denton (1966) reported that at 20 and 64 weeks of age there were significant body weight differences ($P < .01$) between grower diet protein levels, but there were no significant differences in feed consumption/dozen of eggs. Waldroup *et al*. (1966) concluded that body weight gain could be reduced during both the growing and laying periods by feeding a low-protein diet without adversely affecting performance factors. Lillie and Denton (1967) observed significant 20-week body weight differences ($P < .01$) between grower diet levels of protein. Peacock and Combs (1967), Harms *et al*. (1968), Wilson *et al*. (1968), Wright *et al*. (1968), Marks *et al*. (1969b), Summers *et al*. (1969), Wolf *et al*. (1969), Costain *et al*. (1970), Smith *et al*. (1970), Voitle *et al*. (1971) and Voitle *et al*. (1973) reported significant body weight and feed conversion differences between levels of protein during the growing period.

Some investigators observed no significant body weight, feed consumption, feed/dozen of eggs, feed/kg of eggs or final body weight differences between levels of protein (Berg, 1959; Ceballos *et al*., 1970 and Layfield *et al*., 1971). The protein-level requirement during the growing period was shown in experiments conducted by Sunde and Bird (1959) to be 15 percent to allow normal weight gains. Holmquist and Carlson (1972) reported that birds receiving low protein-low energy starting rations required less feed per dozen of eggs than others after 8 weeks of production. Petersen and Sauter (1967) showed that protein level did not affect body weight at 20 weeks of age, but Summers et al. (1969) reported a significant decrease in body weight, daily feed consumtion and an increase in feed-to-gain ratio on 14 percent protein as compared to 20 percent during the first eight weeks.

Mortality

Most workers reported that, with respect to mortality during either the growing or laying periods, there was no significant difference between levels of protein during the growing period (Sunde and Bird, 1959; Waldroup et al., 1966; Harms et al., 1968; Wright et al., 1968; Summers et al., 1969; Ceballos et al., 1970; Costain et al., 1970; Smith et al., 1970). However, Holmquist and Carlson (1972) reported that mortality was less in a group fed 10 percent protein than in those fed 12 percent and 16 percent during the laying period, but there were no differences in mortality during the growing period between levels of protein.

Mortality was affected significantly by level of protein fed during laying period according to Gleaves and Dewan (1971).

Egg Quality

Egg quality refers to such traits as incidence of blood spots and meat spots, Haugh units and specific gravity.

Bearse et al. (1962) conducted 4 experiments to determine the effect of protein level during the laying period on blood spot incidence in White Leghorn hens, feeding different levels of protein in each experiment. They reported that there were significant ($P < .01$) differences in spots between levels of protein, with 14 percent producing the lowest blood spot incidence after 9-28 days of egg production, Mackin (1970) reported that there were no significant egg quality differences between laying-period protein levels. The egg quality traits measured in his study of 5 Tennessee Random Sample Laying Tests were incidence of blood and meat spots, Haugh units and specific gravity. Smith *et al*. (1970) stated that there were no significant shell thickness or Haugh units differences between levels of protein fed during the laying period, but Moreng *et al*. (1963) found significant ($P < .01$) differences Haugh units between levels of protein in the layer diet. Moreng *et al* (1964) reported that there were significant ($P < .05$) shell thickness differences between levels of protein.

Income Over Chick and Feed Cost

With respect to this variable, Mackin (1970) found a significant effect of protein level during the laying period. Apparently, few, if any, other workers included this variable in their studies of effect of protein level.

II. STRAIN DIFFERENCES

There have been many experiments conducted to determine strains or breed differences in most economic traits under different environmental conditions. Most workers found significant ($P < .05$ or $P < .01$) strain differences in most of the traits studied (Abplanalp *et al*., 1962; Mackin, 1970; Marks *et al*., 1970; Aitken *et al*., 1972 and Srinivasan, 1972).

Balloun and Speers (1969) stated that 14.9 grams/hen/day was adequate protein for Hy-Line chickens for highest production and best feed conversion efficiency. They indicated also that hens of small size strains need less than 10 grams protein daily to maximize their production rate, egg size and feed efficiency. Birds of medium-size strains need 18 grams, and those of large-size strains need 18 grams also but produce a greater mass of eggs daily than do those of medium-size strains. Harms and Waldroup (1962), Moreng et al. (1964), Deaton and Quisenberry (1965), Harms et al. (1966) and Wright et al. (1968) reported that a small-size strain or breed needs protein to be fed a ration with a higher percentage than do the larger ones.

Egg Production

Egg production was found to be significantly ($P < .05$ or $P < .01$) affected by strain and breed in most of the research reported (Owings, 1964; Lillie and Denton, 1967; Tindell et al, 1967a; Kondra et al., 1968; Marks et al., 1969c; Marks et al., 1969a; Adams and Jackson, 1970; Mather and Gleaves, 1970). However, cook and Dembnicki (1966) reported that there were no significant hen-day production differences between stocks. Smith et al. (1970) found no differences between two commercial strains of White Leghorns.

Egg Weight and Egg Size

Egg weight and egg size were significantly affected by strain in many experiments (Moreng et al., 1963; Moreng et al., 1964, $P < .01$; Owings, 1964, $P < .05$; Lillie and Denton 1967; Tindell et al., 1967a, $P < .05$; Kondra et al., 1968, $P < .05$; Marks et al., 1969c, $P < .05$; Marks et al., 1969a, $P < .05$; Adams and Jackson, 1970, $P < .05$; Holmquist and Carlson, 1972, slight different in egg size).

However, some research workers found there were no significant differences between strains, with respect to either egg weight or egg size (Mather and Gleaver, 1970 and Smith et al., 1970).

Body Weight and Feed Efficiency

Many investigators observed significant (P < .05 or P < .01) differences between strains (Johnson, 1960) in fryer stocks with respect to both weight at 8 weeks and bird-day feed consumption; Kondra and Hodgson, 1961, P < .01 for weight gain in egg-type stocks but nonsignificant in broilers and P < .01 for feed conversion in both types; Chamberlain et al., 1962, P < .01 for strain differences in weight gain in one breed of turkeys but not in another; Siegel and Wisman, 1962, P < .01 for both body weight gain and feed conversion; Touchburn et al., 1963, P < .01; Owings, 1964, P < .05; Lillie and Denton, 1967, P < .01 at 8 weeks of age but not at 20 weeks of age; Tindell et al., 1967b, P < .01, in broiler-type, both males and females; Tindell et al., 1967a, P < .05 for differences among 10 stocks of egg-production type breeders; Kondra et al., 1968, P < .05 for both body weight and feed utilization calculated as grams feed/grams egg; Tindell et al., 1968a, P < .01 for differences between broiler stocks at most of measurement periods; Tindell et al., 1968b, P < .01 for differences between parent stocks in broilers; Marks et al., 1969c, P < .05 and Marks et al., 1969b, P < .05 for body weight differences between parent stocks in broilers).

However, Cooke and Dembnicki (1966), Mather and Gleaves (1970) and Smith et al. (1970) observed no significant body weight or feed conversion differences between strains or stocks.

Egg Quality Factors

Breed and strain differences have been found with respect to egg quality (albumen quality, measured by Haugh units; shell thickness, measured by specific gravity and incidence of blood and meat spots). Van Wagenen et al. (1937) observed significant albumen firmness differences between breeds. Hall (1939) reported no significant differences between breeds White Wyandottes, Barred Plymouth Rocks, Rhode Island Reds and White Leghorns with respect to total weight of egg white and height of albumen. Brant et al. (1953) found small albumen quality and shell thickness differences between breeds. King and Hall (1955) reported significant ($P < .01$) albumen quality differences between breeds. Within breed differences between strains of White Leghorns and Rhode Island Reds were significant, but these were not significant in other breeds. White Leghorns had a higher incidence of blood spots than did birds of the heavy breeds. Strains of White Leghorn and Rhode Island Red differed significantly in this respect, but strains of other breeds did not. With respect to shell thickness there were significant differences between breeds but not between strains within breeds. However, Petersen et al. (1960) found large specific gravity differences between strains of White Leghorn, Ward and Schaible (1961) found strain differences in incidence of blood spots in White Leghorn, and Adams and Skinner (1963) reported significant ($P < .01$) differences between strains for interior quality (Haugh units). Moreng et al. (1963) found significant ($P < .01$) differences in Haugh units and shell thickness. Kidwell et al. (1964) found significant ($P < .01$) differences in fresh Haugh units and significant

(P < .05) differences in Haugh units after a 7-day storage period but nonsignificant differences with respect to loss Haugh units. Moreng *et al*. (1964) reported significant (P < .05) differences in shell thickness and Haugh units; and Owings (1964) found significant (P < .05) differences in albumen height and specific gravity, while Cooke and Dembnicki (1966) found no significant differences between stocks with respect to specific gravity but highly significant (P < .01) differences in incidence of blood spots in research with Rhode Island Reds and six White Leghorn strains. Tindell *et al*. (1967a) found no significant Haugh units or blood and/or meat spots differences among ten stocks of egg-production type breeders. Marks *et al*. (1969c) reported no significant stock differences with respect to albumen height, Haugh units or specific gravity, but there were significant (P < .05) stock differences with respect to incidence of meat and blood spots. Marks *et al*. (1969a) found no significant stock differences with respect to most egg quality traits, but they found significant differences in 200-day albumen height in the second year and in specific gravity at 350-days in the first year. Adams and Jackson (1970) observed significant strain differences with respect to Haugh units in two experiments. Mather and Gleaves (1970) stated that egg characteristics were not influenced by stock differences, and Smith *et al*. (1970) reported that Haugh units and shell thickness were not affected by strain differences.

Mortality

Reports concering strain differences in mortality differed considerably also. Some workers found significant mortality differences between strains, and others reported finding no strain differences. Among those reporting significant strain differences were Cook and Dembnicki (1966), $P < .05$ and Marks *et al*. (1969a), $P < .05$, for rearing mortality, but laying mortality differences were significant only in the second year and Marks *et al*. (1969b), $P < .05$ between parent stocks in one of the above-mentioned traits but not in the other. Adams and Jackson (1970) and Holmquist and Carlson (1972), reported that there were significant ($P < .05$) strain or stock differences in mortality. However, others reported no significant differences between strains or stocks (Tindell *et al*., 1968a; Tindell *et al*., 1968b between parent stocks after removing first week mortality; Marks et al., 1969c and Mather and Gleaves, 1970).

Sexual Maturity

Some investigators reported significant strain or stock differences in sexual maturity (Marks *et al*., 1969c, $P < .05$; Marks *et al*., 1969a, $P < .01$; Adams and Jackson, 1970, $P < .05$).

Income Over Chick and Feed Cost

Mackin (1970) observed highly significant ($P < .01$) strain differences in income over chick and feed cost in his study of 5 Tennessee Random Sample Laying Tests, using 10 to 16 strains.

III. GENOTYPE-ENVIRONMENT INTERACTION

It is important for the poultry breeder to know whether or not the particular genetic strains in which he is interested are adaptable to a wide variety of environments or to only a particular set of environmental circumstances.

Genotype-environment interactions have been discussed by many poultry breeders during the last 25 years (e.g., Lerner, 1950, Johnson, 1960 and Mackin, 1970). Numerous reports involving genotype-environment interactions in egg production stocks of chickens were summarized by Harms and Waldroup (1962), Deaton and Quisenberry (1964) and Aitken *et al.*, (1972), especially genotype x diet interaction.

Some workers found no interactions in any traits (Thornton and Whittet, 1960; Siegel and Wisman, 1962; Lillie and Denton, 1967; Aitken *et al.*, 1969; Marks *et al.*, 1969c and 1969b).

Egg Production and Sexual Maturity

Egg production is more important than other traits. Hence, much research has been directed toward determining optimum conditions for maximum egg production.

Some workers found with respect to hen-day production significant interaction between genotype and level of protein (Harms and Waldroup, 1962; Moreng *et al.*, 1963; Deaton and Quisenberry, 1964, $P < .01$; Deaton and Quisenberry, 1965, $P < .001$; Harms *et al.*, 1966, $P < .05$ and Krueger *et al.*, 1969 in turnkey strains).

However, others found no significant interaction, with respect to egg production between genotype by level of protein (Moreng *et al.*, 1964; Mackin, 1970 and Aitken *et al.*, 1972).

With respect to sexual maturity, Hull and Gowe (1962) found significant ($P < .05$) interactions between strain and diet.

Egg Weight

Most of the available data regarding the influence of interactions strain between stock and protein indicate significant influences on egg weight (Harms and Waldroup, 1962, $P < .05$; Moreng et al., 1964, $P < .01$; Deaton and Quisenberry, 1964 and 1965, $P < .01$; Mackin, 1970, $P < .01$, and Aitken et al., 1972, $P < .01$).

However, Harms et al. (1966) found no significant strain-by-protein level interactions with respect to egg weight in an experiment using 6 strains fed different levels of protein, viz., 11, 13, 15 and 17 percent.

Body Weight and Feed Efficiency

All reported evidence concerning interactions of stock or strain with protein level show that body weight and feed efficiency were significantly affected by such interactions (Johnson, 1960, $P < .05$, for pullets live weight but nonsignificant for weight of cockerels; Harms and Waldroup, 1962, $P < .05$, for body weight at 21 weeks of age; Touchburn et al., 1963, $P < .01$, for weight gain; Deaton and Quisenberry, 1964, $P < .01$, for both average body weight and feed efficiency; Owing, 1964, $P < .05$; Deaton and Quisenberry, 1965, $P < .01$, for both traits; Harms et al., 1966, $P < .05$, for body weight but nonsignificant for feed efficiency and Aitken et al. 1972, $P < .05$, for feed consumption).

Mackin (1970) reported no significant interaction between strain and protein level with respect to yearly feed efficiency as measured by pounds of feed per hen housed, per pound of eggs or per average number of hens, but for quarterly feed efficiency he found highly significant ($P < .01$) interactions for pounds of feed per hen housed and significant ($P < .05$) interactions for pounds of feed per hen housed and significant ($P < .05$) interactions for pounds of feed per average number of hens and nonsignificant interactions for pounds of feed per pound of eggs.

Egg Quality, Mortality and Income Over Chick and Feed Cost

Egg quality measured by Haugh units, incidence of blood and meat spots and specific gravity were found to be significantly affected by interaction of strain or stock with protein level in many experiments, but such interactions were nonsignificant in some experiments. Moreng et al. (1964) found such interaction to be significant ($P < .05$) for Haugh units but nonsignificant for shell thickness. Deaton and Quisenberry (1964 and 1965) found significant ($P < .01$) interactions for both of the aforementioned traits, and Aitken et al. (1972) found significant ($P < .01$) interactions for albumen quality but nonsignificant interactions for specific gravity and mortality.

However, Mackin (1970) observed no significant strain by protein interactions for Haugh units, specific gravity or income over chick and feed cost but significant ($P < .05$) interactions for blood spot incidence and highly significant ($P < .01$) interactions for meat spot incidence.

IV. CORRELATION BETWEEN VARIABLES

Economic production traits of laying stocks and correlations among them have been discussed by numerous investigators (Atwood, 1923; Hays, 1944; Brant et al., 1953). No attempt will be made here to present an exhaustive review of the work of these authors, but attention will be concentrated on egg production variables and their correlations which are of interest to poultry breeders.

Egg Production and Egg Weight

Several researchers observed positive correlations between egg production and egg weight (Hogsett and Nordskog, 1958; Nordskog, 1960 in Leghorns, but negative correlations in heavy breeds; Kinder and Kobayashi, 1969 and Srinivasan, 1972). King (1961) found negative correlations between these traits. Birds with very high and very low rates of production laying small eggs make for a nonlinear or zero relationship of these traits (Marble, 1930 and Farnsworth and Nordskog, 1955).

Egg Production and Egg Quality

The improvement in egg quality is receiving increasing attention. Numerous investigators have studied the relationship between egg production and egg quality, some of them observing significant negative correlations between these traits (Brant *et al*., 1953, $P < .01$ and Srinivasan, 1972 nonsignificant). However, Knox and Godfrey (1938) found no relationship between them, but Farnsworth and Nordskog (1955) found positive correlations between egg production and blood spots. Perek and Snapir (1970) found a nonsignificant correlation between egg production and shell quality.

Egg Production and Body Weight

Many researchers found negative correlation between egg production and body weight Hogsett and Nordskog (1958). Nordskog (1960) found no relationship in the Leghorn breed but highly significant negative correlations in heavy-breed chickens, as found also by Kondra et al. (1968), but Kinder and Kobayashi (1969) found no relationship between these two traits. However, King (1961) found positive correlations between them.

Egg Production and Other Traits

Other traits such as age at sexual maturity, mortality and feed consumption and efficiency have some relationship with egg production. Farnsworth and Nordskog (1955) and King (1961) observed that early sexual maturity was accompanied by increased egg production, but Harms et al. (1968) observed the opposite relationship. Certain reports concerning sexual maturity have been reviewed earlier in the section on protein level. Fernandez et al. (1973) observed a negative relationship between egg production and mortality. Gleaves et al. (1968) and Kinder and Kobayashi (1969) found a positive correlation between egg production and feed consumption.

Egg Weight and Body Weight

Most reported research showed a positive correlation between egg weight and body weight, either in egg-production type pullets or in broilers (Hogsett and Nordskog, 1958; Nordskog, 1960; King, 1961; Tindell and Morris, 1964; Kinder and Kobayashi, 1969). Marble (1930) and Farnsworth and Nordskog (1955) reported that the relationship was close to zero, slightly positive or even curvilinear. O'Nell (1955) and Kondra et al. (1968) found no relationship between body weight at 6 weeks and annual egg weight.

Egg Weight and Other Traits

Farnsworth and Nordskog (1955) reported no relationship between egg weight and egg quality but a negative relationship of egg weight with age at sexual maturity. A positive correlation between egg size and feed efficiency was observed by Kinder and Kobayashi (1969). The correlation between egg weight and shell quality was significant and negative as observed by Perek and Snapir (1970), a positive relationship between egg weight and Haugh units was found by King (1961) and negative but nonsignificant correlation between egg weight and Haugh units was reported by Srinivasan (1972).

Body Weight and Other Traits

Many workers have reported research concerning the relationship between body weight and other traits. O'Nell (1955) observed a negative correlation between body weight and mortality at hatching time, but Kinder and Kobayashi (1969) observed a positive correlation between the same traits. Kondra and Hodgson (1961), Kondra *et al*. (1968) and Kinder and Kobayashi (1969) found a positive correlation between body weight and feed efficiency. King (1961) stated that there was positive correlation between body weight and age at sexual maturity, but a negative correlation between these traits was reported by Kinder and Kobayashi (1969).

Income and Other Triats

Some studies regarding correlations between income over feed and chick cost and other economic traits have been conducted. Nordskog (1960) found a highly significant positive correlation between income and egg production in Leghorns and in heavy breeds and with egg weight in Leghorns, but the correlation of income with body weight was negative and highly significant in boty light and heavy breeds. Strain and Nordskog (1962) observed positive correlations of income with 8-week body weight and feed conversion in broilers, but Srinivasan (1972) reported that there were significant and nonsignificant positive and negative correlations of income over feed and chick cost with all other common economic traits when the correlations were calculated separately for each strain used in three Tennessee Random Sample Laying Tests (*viz*., 12th 13th and 14th tests).

CHAPTER III

EXPERIMENTAL PROCEDURE

I. SOURCE AND DESCRIPTION OF DATA

Data used in this study were collected in the Fifteenth Tennessee Random Sample Laying Test.

The test was started by securing hatching eggs of each entry (strain) to be entered. Breeder farms supplied three cases of hatching eggs of each strain to the representative of the test management. Approximately 72 dozen eggs from each strain were set. The eggs of each strain were incubated in five incubators. All entries remained under uniform management practices during the incubation and laying period. The chicks were removed from the incubators on March 31, 1971. At that time, when the chicks were one day old, they were sexed, and 300 female chicks of each strain, where available, were selected at random. They were wingbanded, dubbed and vaccinated against Newcastle disease, infectious bronchitis and Marek's disease. The chicks of each strain were divided into two pens in the brooder house where infrared heat lamps served as the source of heat during the first 10 weeks. Chicks were fed a starter diet containing 22 percent protein until 10 weeks of age (Table 1). At 10 weeks of age all the pullets of each strain were moved to a grower shelter, and were divided into four pens. Two pens of each strain were placed on grower diet containing 17.6 percent protein while the other two pens of each strain were placed on grower diet containing 10.2 percent protein

TABLE 1

STARTER AND LAYER DIETS

Feedstuffs	Starter BR1*	Layer
	lbs.	lbs.
Yellow corn	638.00	669.75
Alfalfa meal, 17%	25.00	50.00
Fish meal	25.00	25.00
Vitamin mix*	6.00	5.00
Defluorinated rock phosphate	15.00	15.00
Ground limestone	6.00	60.00
Salt	4.80	5.00
Manganese sulfate	0.20	0.25
Soybean oil meal, 50%	255.00	170.00
Coccidiostat premix	25.00	-
	1000.00	1000.00
Calculated to contain:		
Crude protein, %	21.95	17.11
Productive energy, C/lb.	957	911
C/P (Calorie: protein ratio)	43.60	53.24
Metabolizable energy C/lb.	1365	1305
Metabolizable energy C/P ratio	62.19	76.27
Methionine, %	.3629	.3006
Cystine, %	.3287	.2580
Lysine, %	1.2511	.9122
Calcium, %	.894	2.957
Phosphorus, %	.6812	.6226
Available phosphorus, %	.4353	.4177
Manganese, mg./lb.	32.21	36.95
Vitamine A, I.U./lb.	5349	7123
Vitamin D, I.C.U./lb.	340	1342
Riboflavin, mg./lb.	3.05	2.90
Niacin, mg./lb.	28.44	20.68
Pantothenic acid, mg./lb.	6.71	5.44
Choline, mg./lb.	761.02	658.24

*Mineral and vitamin content calculated to equal or exceed requirements given by National Research Council.

(Table 2). At that time (10 weeks of age) all pullets were revaccinated against Newcastle and infectious bronchitis. When the pullets were 20 weeks of age, all were debeaked and vaccinated for fowlpox, Newcastle and infectious bronchitis, and 60 pullets from each of the two protein-level treatments for each strain were housed in laying cages, while the remaining pullets were continued on the same previous two treatments until they were 24 weeks of age, at which time another 60 pullets of each strain from each of the two protein levels were placed in laying cages. A total of 240 pullets of each strain were placed in the laying house. A cage laying house was employed throughout this test. The pullets were housed in cages 8" x 16" at the rate of two pullets per cage. The 240 pullets of each strain were separated into 8 lots, two lots from each of the four growing treatments. A randomized block design was used in assigning the lots within the laying house. From the time of housing a laying ration containing 17.1 percent protein was fed ad libitum. The layer diet did not contain a coccidiostat, but it was added to starter and grower diets (Table 1, page 27, and Table 2). The diets were calculated to equal or exceed the nutritive requirements for each class of pullets as given by the National Research Council. Flow-trough waterers supplied water continuously. A 14-hour light day was provided throughout the laying period. There were 14 strains used in the test, one of them being the Kentville-Cornell Stock, a control strain included in every test of Tennessee Random Sample Laying Test. The test was terminated when the pullets were 496 days of age on August 9, 1972.

TABLE 2

GROWER DIETS

Feedstuffs	High-Protein Grower GR6*	Low-Protein Grower GR8*
	lbs.	lbs.
Yellow corn	718.75	883.75
Alfalfa meal, 17%	50.00	50.00
Fish meal	25.00	-
Vitamin mix*	6.00	6.00
Defluorinated rock phosphate	15.00	20.00
Ground limestone	10.00	10.00
Salt	5.00	5.00
Manganese sulfate	0.25	0.25
Soybean oil meal, 50%	145.00	145.00
Coccidiostat premix	25.00	25.00
	1000.00	1000.00
Calculated to contain:		
Crude protein, %	17.59	10.18
Productive energy, C/lb.	966	1012
C/P (Calorie: protein ratio)	54.92	99.41
Metabolizable energy C/lb.	1382	1443
Metabolizable energy C/P ratio	78.57	141.75
Methionine, %	.3097	.1942
Cystine, %	.2658	.1720
Lysine, %	.9285	.3771
Calcium, %	1.057	1.1000
Phosphorus, %	.6360	.6126
Available phosphorus, %	.4217	.4358
Manganese, mg./lb.	37.08	34.57
Vitamin A, I.U./lb.	7966	8217
Vitamin D, I.C.U./lb.	340	340
Riboflavin, mg./lb.	3.10	2.90
Niacin, mg./lb.	28.43	27.47
Pantothenic acid, mg./lb.	6.57	5.95
Choline, mg./lb.	654.20	462.80

*Mineral and vitamin content calculated to equal or exceed requirements given by National Research Council.

Description of Variables and Variable Names

The independent variables considered in this study were: Strain (S), feeding period (F) and protein level (P), 10- to 20-week feeding period with 17.6 percent (high) protein growing diet (P_1F_1), 10- to 20-week feeding period with 10.2 percent (low) protein growing diet (P_2F_1), 10- to 24-week feeding period with 17.6 percent (high) protein growing diet (P_1F_2) and 10- to 24-week feeding period with 10.2 percent (low) protein growing diet (P_2F_2).

The dependent variables considered were: eggs-per-hen-housed (EHH), percent hen-housed egg production (HHP), percent hen-day egg production (HDP), percent hen-day egg production after 50 percent of production (HDA), average egg weight (AEW), pounds of feed per pound of eggs (LBE), pounds of feed per dozen of eggs (LBD), percent mortality (MOR), percent spots observed by candling (SPC), percent blood and meat spots (observed in brokenout eggs) (SPOT), specific gravity (SPG), Haugh units (HAUT), income per hen (INCH), cost per hen (COSH), profit per hen (PROH), body weight at housing (WTH), average body weight at end of test (WTD), days to 50 percent of production (sexual maturity) (DAY).

Data Collection and Calculations

Traits considered in this study were measured on a lot basis. Egg production was recorded daily for each lot. Eggs-per-hen-housed was determined as the sum of all eggs laid divided by the total number of birds which were housed. Percent egg production or percent hen-housed production was calculated by multiplying by 100 the ratio of number of eggs laid per pullet housed to the number of days (354) in the laying house. Percent hen-day production was determined by multiplying by 100 the ratio of average number of eggs laid per pullet housed to the average number of days each pullet stayed in the laying house. Percent hen-day production after 50 percent production was determined by calculating percent hen-day production from the time each lot reached 50 percent production.

Feed consumed was determined every month for each lot. The total weight of eggs, in grams, laid on one day each week was recorded for each lot, to permit determining the quantity of the feed required to produce a unit weight of eggs. The eggs used to obtain the above weights were then graded into five size classes: peewee, medium, large and extra large and over in order to obtain the egg size distribution. The weight in ounces per dozen of eggs for each of the above size categories were: under 17, 17-19, 20-22, 23-25, 26 and over, respectively.

The egg quality characteristics such as albumen height, Haugh units, shell thickness and incidence and size of blood and meat spots were recorded for all eggs produced by each lot on one day of each three-month period. Shell thickness was measured by the specific gravity of shell eggs by using ten salt solutions, ranging in specific gravity from 1.068 to 1.100, the difference between each concentration and the next being 0.004. The presence of blood and meat spots were determined by breaking out 10 eggs from each lot at the same time the albumen heights were measured with a tripod micrometer. The Haugh units score was calculated by using the average egg weight and average albumen height of broken-out eggs. Haugh units of 72 or better indicate grade AA eggs, and grade A eggs have a range of 55-72 units.

Body weights of the pullets were recorded at 20 and 24 weeks of age and at the end of the test.

Dead birds were collected daily and necropsies were performed to determine the causes of death. Growing mortality was calculated as percentage of birds that died from one week to 20 weeks of age, while laying mortality was calculated as percentage of birds that died from 20 weeks of age to the end of the test.

The income over chick and feed cost was calculated. The prices of eggs, feed, chicks and market hens used to determine income and costs were local prices and assumed to be representative of the local situation at that particular time. The chick price was obtained from each breeder as the price per chick in lots of 1000 day-old pullet chicks. At the termination of the test, all hens were sold for the market price per pound at that time. Feed consumption during the growing period was determined by multiplying the average weight of pullets at housing by six, the estimated pounds of feed required to produce a pound of live weight of egg-type pullet at 140 days of age. The chick and feed cost was calculated by assuming the cost of feed consumed during the growing period, the cost of feed consumed during laying period and the cost of the day-old chicks.

The income from eggs laid was calculated by using the market price for small, medium and large size eggs quoted on the Chicago market. Prices quoted were those paid to first receiver, 80 percent Grade A. The total number of eggs produced in each size, in dozens, was multiplied by the average price per dozen for the year, to give the income from eggs. Since the market reports did not give a quotation for peewee size eggs, this price was calculated by assuming the average difference between small-size price and medium-size price to be the same as the difference between small-size price and peewee-size price. The income from eggs laid by hens of each stock was calculated by subtracting the percentage of income lost due to all sizes of blood and meat spots from the total calculated income from eggs laid by that stock.

Sexual maturity was defined as the age of the pullets of each replicate lot on the first of 3 consecutive days of lay at the rate of 50 percent.

II. METHODS OF ANALYSIS

Analysis of data in this test were of two kinds. The first was analysis of variance based on a factorial arrangement of stocks, protein levels and feeding period during growing period. The following mathematical model describes the variables studied.

$$Y_{ijkl} = \mu + S_i + F_j + SF_{ij} + P_k + SP_{ik} + FP_{jk} + SFP_{ijk} + e_{ijkl}$$

where: S_i = effect of i^{th} stock, $i = 1, 2, \cdots 14$ stocks

F_j = effect of j^{th} feeding period, $j = 1, 2$ feeding period

P_k = effect of k^{th} level of protein, $k = 1, 2$ levels of protein

$l = 1, 2$ lots per stock in each feeding period fed each protein level.

Y_{ijkl} is the observation of the l^{th} lot fed the k^{th} level of protein in the j^{th} feeding period from the i^{th} stock. The overall mean of the population is symbolized by μ and e_{ijkl} symbolizes random variation among lots of the same entry.

The second kind of analysis consisted of computing coefficients of correlation between production traits of each strain and treatment subclass to determine the magnitude of these relationships.

CHAPTER IV

RESULTS AND DISCUSSION

I. ANALYSIS OF VARIANCE

Results of analysis of variance are presented in Tables 3 through 11 for all traits studied. Mean squares which were found to be significant are denoted in the conventional way.

Egg Production

Strains were found to differ significantly ($P < 0.001$) with respect to all four egg-production traits (Table 3). One strain (no. 2) had the highest average of each egg production trait in all treatments combined, while another strain (no. 16) had the lowest average of nearly all egg production traits (Table 12). These results are in agreement with the results of many investigators; Owings, 1964; Lillie and Denton, 1967; Tindell *et al.*, 1967a; Marks *et al.*, 1969c and 1969a; and Mather and Gleaves, 1970). However, they were in disagreement with the results of Cook and Dembnicki (1966) and Smith *et al.* (1970).

Feeding period had a significant ($P < 0.05$) effect on all egg production traits except eggs per hen-housed.

Protein level had a significant influence on all egg production traits. These results confirm the findings of Santana and Quisenberry (1968) and Wolf *et al.* (1969), but they do not agree with the results of Waldroup and Harms (1962), Lillie and Denton (1966), Waldroup *et al.* (1966), Harms *et al.* (1968) and Smith *et al.* (1970).

TABLE 3

ANALYSIS OF VARIANCE OF EGG PRODUCTION

Source	Degrees of Freedom	Mean Square			
		Eggs Per Hen-Housed	% Hen-Housed Egg Production	% Hen-Day Egg Production	% Hen-Day Egg Production After 50% of Production
Strains (S)	13	2124.952***	155.730***	155.174***	151.046***
Feeding Period (F)	1	423.738	61.450*	60.226*	54.433*
SF	13	46.309	5.199	5.799	9.265
Protein (P)	1	1272.040*	46.595*	44.819*	196.683***
SP	13	188.920	10.772	10.553	26.897*
FP	1	188.965	0.911	0.650	9.606
SFP	13	101.542	7.170	7.076	11.435
Error	56	188.821	9.070	8.799	13.078
Total	111				

*Significant ($P < 0.05$).

***Significant ($P < 0.001$).

TABLE 4

ANALYSIS OF VARIANCE OF AVERAGE EGG WEIGHT

Source	Degrees of Freedom	Mean Square
Strain (S)	13	9.003***
Feeding Period (F)	1	24.722***
SF	13	0.520
Protein (P)	1	12.744***
SP	13	0.556
FP	1	1.993
SFP	13	0.637
Error	56	0.660
Total	111	

***Significant ($P < 0.001$).

TABLE 5

ANALYSIS OF VARIANCE OF EGG QUALITY CHARACTERISTICS

Source	Degrees of Freedom	Mean Square		
		Haugh Units	Specific Gravity	% Spots Candling
Strain (S)	13	50.826***	1.290***	0.114*
Feeding Period (F)	1	0.262	0.219*	0.012
SF	13	5.817	0.095	0.032
Protein (P)	1	51.192**	0.870***	0.009
SP	13	4.408	0.047	0.046
FP	1	4.488	0.147	0.052
SFP	13	3.483	0.048	0.026
Error	56	4.777	0.054	0.052.
Total	111			

*Significant ($P < 0.05$).

**Significant ($P < 0.01$).

***Significant ($P < 0.001$).

TABLE 6

ANALYSIS OF VARIANCE OF PERCENT OF BLOOD AND MEAT SPOTS (BROKENOUT)

Source	Degrees of Freedom	Mean Square % of Blood and Meat Spots (Brokenout)
Strain (S)	13	7.026
Feeding Period (F)	1	0.121
SF	13	6.847
Protein (P)	1	3.111
SP	13	2.061
FP	1	1.578
SFP	13	5.546
Total	55	

TABLE 7

ANALYSIS OF VARIANCE OF INCOME OVER CHICK AND FEED COST

Source	Degrees of Freedom	Mean Square		
		Income Per Hen	Cost Per Hen	Profit Per Hen
Strain (S)	13	1.783***	0.143***	1.384***
Feeding Period (F)	1	0.106	0.056*	0.360*
SF	13	0.028	0.007	0.018
Protein (P)	1	1.676***	0.008	2.049***
SP	13	0.086	0.004	0.070
FP	1	0.001	0.071**	0.057
SFP	13	0.067	0.006	0.053
Error	56	0.125	0.010	
Total	111			

*Significant ($P < 0.05$).

**Significant ($P < 0.01$).

***Significant ($P < 0.001$).

TABLE 8

ANALYSIS OF VARIANCE OF BODY WEIGHT

Source	Degrees of Freedom	Mean Square Body Weight At Housing	Mean Square Body Weight At the End of the Test
Strain (S)	13	0.368***	0.487***
Feeding Period (F)	1	1.440***	0.386*
SF	13	0.005	0.054
Protein (P)	1	2.632***	0.020
SP	13	0.016**	0.023
FP	1	0.0001	0.004
SFP	13	0.004	0.073
Total	55		

*Significant ($P < 0.05$).

**Significant ($P < 0.01$).

***Significant ($P < 0.001$).

TABLE 9

ANALYSIS OF VARIANCE OF FEED EFFICIENCY

Source	Degrees of Freedom	Mean Square Pounds of Feed Per Pound of Eggs	Mean Square Pounds of Feed Per Dozen of Eggs
Strain (S)	13	0.287***	0.566***
Feeding Period (F)	1	0.413***	0.480**
SF	13	0.007	0.018
Protein (P)	1	0.085*	0.039
SP	13	0.016	0.055
FP	1	0.010	0.044
SFP	13	0.014	0.042
Error	56	0.016	0.043
Total	111		

*Significant ($P < 0.05$).

**Significant ($P < 0.01$).

***Significant ($P < 0.001$).

TABLE 10

ANALYSIS OF VARIANCE OF SEXUAL MATURITY

Source	Degrees of Freedom	Mean Square Days to 50% Production
Strain (S)	13	54.412***
Feeding Period (F)	1	1501.786***
SF	13	13.853
Protein (P)	1	480.286***
SP	13	8.449
FP	1	54.018*
SFP	13	7.893
Total	55	

*Significant ($P < 0.05$).

***Significant ($P < 0.001$).

TABLE 11

ANALYSIS OF VARIANCE OF MORTALITY

Source	Degrees of Freedom	Mean Square
Strain (S)	13	181.378***
Feeding Period (F)	1	9.149
SF	13	38.034
Protein (P)	1	51.721
SP	13	24.796
FP	1	26.940
SFP	13	27.431
Error	56	43.842
Total	111	

***Significant ($P < 0.001$).

TABLE 12

STRAIN MEANS AND STANDARD ERRORS OF EGG PRODUCTION AND FEED EFFICIENCY TRAITS

Strain	Eggs-Per-Hen Housed	%-Hen-Housed Egg Production	%-Hen-Day Egg Production	%-Hen-Day Egg Production After 50% Production	Average Egg Weight	Lbs. Feed/lb of Eggs	Lbs. Feed/Doz of Eggs
1	229.71± 7.04	66.54±1.62	66.78±1.57	73.64±1.74	60.52±1.24	2.50±0.12	4.00±0.19
2	248.64±12.61	71.80±2.85	72.01±2.88	77.64±2.29	60.73±0.77	2.35±0.08	3.78±0.12
3	214.55± 7.72	62.40±2.38	62.55±2.40	67.54±2.46	59.41±1.66	2.60±0.14	4.05±0.26
6	218.09± 8.27	63.76±2.00	64.02±2.06	69.52±3.13	59.10±1.03	2.62±0.13	4.09±0.16
9	231.46± 5.04	66.84±1.81	67.08±1.86	73.79±3.11	61.70±0.92	2.48±0.08	4.04±0.12
10	216.69±14.86	61.82±4.47	61.97±4.48	66.47±5.07	59.83±0.89	2.64±0.14	4.18±0.21
14	227.61±13.07	64.64±3.04	64.80±2.94	70.77±3.50	61.16±0.87	2.55±0.15	4.14±0.23
16	188.79±14.97	57.48±3.18	58.01±3.20	63.51±3.92	58.20±0.38	2.84±0.16	4.37±0.23
17	224.42±24.68	66.67±4.90	67.06±4.63	72.76±5.35	60.95±1.12	2.52±0.25	4.07±0.38
20	214.16±12.31	62.75±3.17	63.00±3.17	68.82±4.07	60.60±1.17	2.64±0.12	4.23±0.17
22	198.48±16.20	57.66±2.97	57.89±2.83	63.96±3.70	58.86±0.74	2.96±0.18	4.60±0.26
23	237.45±15.82	69.68±2.25	69.97±2.24	75.40±2.08	61.76±0.68	2.39±0.11	3.86±0.17
26	232.38± 7.05	68.06±3.97	68.33±4.11	69.67±8.68	60.23±0.85	2.46±0.09	3.91±0.16
28	201.11± 9.71	58.48±2.08	58.65±2.10	65.15±2.18	60.64±1.14	2.95±0.12	4.73±0.18
Overall Means	220.25	64.18	64.44	69.90	60.26	2.61	4.15

There were no significant interactions except for the strain-by-protein interaction effect on percent hen-day egg production after 50 percent of production. That interaction is of considerable interest. Some strains of hens had a higher average percent of hen-day production after 50 percent production on the 17.6 percent protein level (P_1), while others had a higher average percent of hen-day production after 50 percent production on the 10.2 percent protein level (P_2). These results agree generally with those of Moreng _et al_. (1964), Mackin (1970) and Aitken _et al_. (1972), but they are contradicted by the results of Harms and Waldroup (1962), Moreng _et al_. (1963), Deaton and Quisenberry (1964), Harms _et al_. (1966) and Krueger _et al_. (1969).

Egg Weight

Strains were found to differ very significantly ($P < 0.001$) with respect to average egg weight (Table 4, page 37). One strain (no. 23) had the highest average on all treatments combined and also had the highest average on each treatment except the first treatment (P_1F_1, 17.6 percent protein level during 10-20-week feeding period), while another strain (no. 16) had the lowest average on all treatments combined and had also the lowest average on each treatment except the first treatment (P_1F_1) (Table 12). Apparently, the reason for this is the positive coefficients of correlation between egg production traits and average egg weight since the strain with the highest average egg weight was the second highest in egg production and the strain with the lowest average egg weight was the strain with the lowest egg production. These results agree with results obtained by Moreng *et al.* (1964), Owings (1964), Lillie and Denton (1967), Tindell *et al.* (1967a), Kondra *et al.* (1968) and Marks *et al.* (1960c), but they contradict the findings of Mather and Gleaves (1970) and Smith *et al.* (1970).

Protein level also had a highly significant effect on average egg weight. This result is in agreement with those of Santana and Quisenberry (1968) and Voitle *et al.* (1971) but is in disagreement with the results of Sunde and Bird (1959), Waldroup and Harms (1962), Harms *et al.* (1968) and Voitle *et al.* (1973).

None of the interaction between the variables was found to be significant with respect to average egg weight. Perhaps this is simply a consequence of the large magnitude of all main effects. These results are similar to those of Harms *et al.* (1966), but they disagree with those of Harms and Waldroup (1962), Mackin (1970) and Aitken *et al.* (1972).

Egg Quality Characteristics

There were significant strain differences with respect to Haugh units, specific gravity and percent spots observed by candling, but strain differences were nonsignificant with respect to percent blood and meat spots in brokenout eggs (Tables 5 and 6, pages 38 and 39). One strain (no. 17) had the lowest average Haugh units on all treatments combined and the lowest average on each treatment except the first, (P_1F_1, 17.6 percent protein level during the 10 to 20 weeks feeding period), while another strain (no. 26) had the highest average Haugh units on all treatments combined but only one treatment P_2F_2 (10.2 percent protein level during the 10 to 24 weeks feeding period) gave the highest average among the four treatments for that strain (Table 13). With respect to shell quality, one strain (no. 6) had the highest average on all treatments combined and also on each treatment alone, while another strain (no. 1) had the lowest average on all treatments combined and also on each treatment alone except for the second treatment (P_1F_2, 17.6 percent protein during 10 to 24 weeks feeding period). For percent blood and meat spots observed by candling, one strain (no. 20) had the highest average on all treatments combined, but it had the highest single-treatment average in only one treatment (P_2F_2, 10.2 percent protein level during 10 to 24 weeks feeding period), while another strain (no. 6) had the lowest average on all treatments combined but it had the lowest average on only the first two treatments (P_1F_1 and P_1F_2, 17.6 percent protein level during the 10 to 20, 10 to 24 weeks feeding period). For percent blood and meat spots (brokenout) one strain (no. 2) had the highest average on all treatments combined and on each treatment alone, while another strain (no. 26) had the lowest average on all treatments combined, but it had the lowest average on only one treatment (Table 14). These results confirm the findings of King and Hall (1955) with respect to albumen quality and incidence of blood spots, Petersen et al. (1960), with respect to specific gravity, Ward and Schaible (1961), with respect to blood spots, Adams and Skinner (1963) with respect to Haugh units, Moreng et al. (1963, 1964), with respect to Haugh units and shell thickness, Owings (1964), with respect to specific gravity and Adams and Jackson (1970), with respect to Haugh units, but they

TABLE 13

STRAIN MEANS AND STANDARD ERRORS OF CERTAIN EGG QUALITY TRAITS AND INCOME INDEXES

Strain	% Mortality	% Spots Candling	Specific Gravity	Haugh Units	Income Per Hen	Cost Per Hen	Profit Per Hen
1	9.85±3.94	0.18±0.20	2.80±0.37	79.09±2.00	5.62±0.19	3.64±0.06	1.99±0.19
2	6.43±5.07	0.23±0.28	3.42±0.18	74.61±1.74	6.09±0.33	3.66±0.10	2.43±0.29
3	8.56±4.21	0.28±0.22	3.93±0.19	75.42±2.36	5.12±0.25	3.49±0.15	1.64±0.23
6	9.02±4.23	0.02±0.07	4.33±0.32	78.65±1.75	5.20±0.26	3.54±0.07	1.65±0.26
9	7.26±4.30	0.10±0.19	3.58±0.25	79.53±1.81	5.81±0.15	3.75±0.08	2.06±0.15
10	4.64±4.45	0.18±0.23	3.20±0.19	74.52±3.52	5.22±0.38	3.56±0.11	1.67±0.37
14	5.10±6.08	0.05±0.10	3.62±0.23	79.94±2.04	5.67±0.33	3.75±0.06	1.03±0.32
16	23.60±8.44	0.08±0.11	2.92±0.30	79.83±2.54	4.43±0.37	3.31±0.11	1.12±0.33
17	14.59±9.26	0.19±0.24	3.42±0.26	72.97±2.43	5.55±0.60	3.60±0.11	1.95±0.51
20	11.68±5.32	0.45±0.40	3.38±0.22	79.17±1.26	5.24±0.30	3.60±0.13	1.64±0.25
22	10.07±7.52	0.16±0.25	3.53±0.22	76.54±1.20	4.72±0.38	3.61±0.11	1.12±0.33
23	10.90±8.72	0.34±0.19	3.40±0.41	74.37±2.51	5.98±0.47	3.65±0.10	2.27±0.31
26	8.55±5.22	0.10±0.11	3.97±0.22	80.36±3.12	5.67±0.21	3.60±0.06	2.08±0.16
28	7.29±5.76	0.08±0.11	3.48±0.19	77.54±2.20	5.04±0.22	3.89±0.05	1.15±0.22
Overall Mean	9.82	0.18	3.50	77.32	5.38	3.62	1.76

TABLE 14

STRAIN MEANS AND STANDARD ERRORS OF THE REMAINING TRAITS STUDIED

Strain	Body Weight at Housing	Average Body Weight at End of Test	Days to 50% of Production	% of Blood and Meat Spots (Brokenout)
1	2.82±0.29	4.15±0.08	175.50± 8.77	4.38±3.26
2	2.74±0.22	4.10±0.17	172.13±10.84	4.96±3.06
3	2.65±0.26	4.06±0.14	172.00± 7.22	4.05±1.20
6	2.90±0.36	4.30±0.06	173.13± 5.45	1.83±1.25
9	2.82±0.28	4.40±0.26	175.50± 8.38	3.10±1.63
10	2.68±0.35	4.20±0.19	168.63± 5.12	4.73±1.26
14	2.90±0.43	4.40±0.25	176.88± 7.12	1.55±1.20
16	2.48±0.36	4.39±0.19	175.75± 8.01	4.75±2.58
17	3.07±0.28	4.68±0.16	173.13± 3.84	2.20±0.67
20	2.76±0.30	4.26±0.16	175.63± 8.04	4.70±2.80
22	2.61±0.31	4.21±0.12	180.38± 5.23	4.73±2.56
23	2.82±0.28	4.35±0.35	169.63± 6.65	4.68±3.12
26	2.68±0.33	4.19±0.14	172.63±10.46	1.58±0.62
28	3.76±0.42	5.45±0.56	181.88± 7.86	4.18±2.00
Overall Means	2.83	4.37	174.48	3.67

are contradicted by the results of Tindell et al. (1967a), with respect to Haugh units and percent of blood and/or meat spots, Marks et al. (1969a,c) with respect to Haugh units and specific gravity, Mather and Gleaves (1970) with respect to all egg characteristics and Smith et al. (1970), with respect to Haugh units and shell thickness.

Feeding period was found to have a significant ($P < 0.05$) effect on only specific gravity, but it has nonsignificant effects on Haugh units and percent blood and meat spots observed by candling or in brokenout eggs.

Protein level was significant with respect to specific gravity and Haugh units, but it was nonsignificant with respect to percent of blood and meat spots observed by candling and in brokenout eggs.

None of the first- and second-order interactions were significant with respect to egg quality characteristics. These findings generally agree with those of Moreng et al. (1964), with respect to shell thickness, Mackin (1970), with respect to Haugh units and specific gravity and Aitken et al. (1972) with respect to specific gravity. However, different from those of Moreng et al. (1964) with respect to Haugh units, Deaton and Quisenberry (1964 and 1965) with respect to Haugh units and specific gravity, Mackin (1970) with respect to incidence of blood and meat spots and Aitken et al. (1972) with respect to albumen quality.

Income Over Chick and Feed Cost

Table 7 (page 40) contains the analysis of variance of income over chick and feed costs or profit per hen (PROH) which was obtained by substracting the cost per hen from income per hen.

Strains differences were significant with respect to all accounting variables. One strain (no. 2) had the highest income per hen on all treatments combined (Table 13, page 49) even though it had the second lowest average body weight at the end of the test, giving it the second lowest income from market hens. This is obviously a result of that strain having had the highest average with respect to all egg-production traits studied. The same strain (viz., no. 2) had the low average cost per hen, giving it the highest average income over chick and feed costs on all treatments combined, while another strain (no. 14) had the lowest average income over chick and feed cost on all treatments together because it had low income per hen and high average cost per hen, relatively. These results are in agreement with those obtained by Mackin (1970).

Feeding period differences were significant ($P < 0.05$) in cost per hen and profit per hen, as expected, simply because of the differences in amounts of feed consumed during different periods of feeding; but there was no significant feeding-period difference in income per hen. This is logical also because of the lack of influence of feeding period on income per hen.

Protein levels were found to differ significantly from each other with respect to income per hen and profit per hen, apparently because of the significant differences between levels of protein with respect to egg-production traits and nonsignificant protein-level differences in cost per hen. Mackin (1970) also found a significant effect of protein level during the laying period on income over chick and feed cost.

The only significant interaction was feeding period by protein level in cost per hen. This is simply because of differences in cost of feed resulting from consumption of different amounts of protein during different feeding periods. These results supported the finding of Mackin (1970).

Body Weight

Strains differed significantly with respect to body weight both at housing and at the end of the test (Table 8, page 41). One strain (no. 28) had the highest body weight at housing on every treatment (Table 14, page 50) and it also had the highest average feed consumption on each treatment during the growing period, while another strain (no. 16) had the lowest body weight on every treatment except the second (P_1F_2, 17.6 percent protein level during the 10 to 24 weeks feeding period) and had the second lowest body weight, having had the lowest average feed consumption on each treatment during the growing period. For body weight at end of the test one strain (no. 28) had the highest average on all treatments combined and also on each treatment except the fourth treatment (P_2F_2, 10.2 percent protein during the 10 to 24 weeks feeding period), while another strain (no. 3) had the lowest average on all treatments combined but did not have the lowest average on each treatment. These results confirm the results of Kondra and Hodgson (1961), Siegel and Wisman (1962), Tindell *et al*. (1967a) and Marks *et al*. (1969b), while they contradicted those of Cook and Dembnicki (1966), Mather and Gleaves (1970) and Smith *et al*. (1970).

Feeding periods were found to differ significantly with respect to body weight at housing and at the end of the test.

Protein level had a significant effect on body weight at housing but a nonsignificant effect on body weight at the end of the test, simply because of the different amounts of feed consumed during the growing period. These results supported those of Wilson et al. (1963, 1964) and Lillie and Denton (1966, 1967) but are in disagreement with those of Siegel and Wisman (1962) and Lillie and Denton (1966) with respect to final body weight.

The only significant interaction found was between strain and protein level with respect to body weight at housing. Other interactions were nonsignificant. These results agree with the finding of Hamrs and Waldroup (1962).

Feed Efficiency

Mean squares of pounds of feed per pound of eggs and per dozen of eggs are presented in Table 9 (page 42).

Strains were found to differ significantly with respect to both feed efficiency traits, *viz.*, pounds of feed per pound of eggs and pounds of feed per dozen eggs. One strain (no. 2) had the highest feed efficiency or the lowest average amount of feed per dozen of eggs or per pound of eggs on all treatments combined on most of the treatments alone (Table 12, page 45), and this was the same strain which had the highest egg production in each egg production trait on all treatments combined and on each treatment alone. These results support those of Kondra and Hodgson (1961), Siegel and Wisman (1962), Kondra *et al*. (1968) and Mackin (1970), but they are in disagreement with those of Cook and Dembnicki (1966), Mather and Gleaves (1970) and Smith et al. (1970).

Feeding periods also were found to deffer significantly with respect to pounds of feed per pound of eggs and pounds of feed per dozen eggs.

Protein levels were significantly different only with respect to pounds of feed per pound of eggs. These results are in agreement with those of Lillie and Denton (1966), Santana and Quisenberry (1968), Summers et al. (1969) and Costain et al. (1970) for feed per dozen of eggs, but they are in disagreement with results of Wright et al. (1968) with respect to feed per dozen eggs and of Mackin (1970) with respect to pounds of feed per pound of eggs.

First- and second-order interactions exhibited no sign of significance in either feed efficiency trait. These results confirm those of Harms et al. (1966) and Mackin (1970) but contradict those of Deaton and Quisenberry (1964 and 1965) and Aitken et al. (1972).

Sexual Maturity

Sexual maturity measured as number of days of pullet age at 50 percent of production, was analyzed and its mean squares are tabulated in Table 10, page 43).

Strains were observed to differ significantly from each other. These results generally confirm the results of Marks et al. (1969a, 1969c) and Adams and Jackson (1970).

Feeding period also had a significant effect on sexual maturity, which was significantly delayed by the longer feeding period as compared to the shorter feeding period.

Protein-level differences were significant with respect to sexual maturity. The low protein level produced significantly later sexual maturity than did the high protein level. These results support those of Atwood (1923), Waldroup and Harms (1962, 1966), Harms et al. (1964, 1968), Ceballos et al. (1970) and Voitle et al. (1971, 1973), but do not support results of Denton and Lillie (1959) and Peacock and Combs (1967).

Protein-feeding period interaction was found to affect sexual maturity significantly, while other interactions were not significant. This is expected since we know that the relative magnitudes of the protein-level effects differed between the short and long feeding period.

Mortality

Strains differed significantly with respect to mortality (Table 11, page 44). One strain (no. 16) had the highest average mortality on all treatments combined and also on each treatment alone except for the first treatment (P_1F_1, 17.6 percent protein level during the 10 to 20 weeks feeding period) (Table 13, page 49), while another strain (no. 10) had the lowest overall average though it was not the lowest on each treatment alone. These results confirm those of Cook and Dembnicki (1966), Adams and Jackson (1970) and Holmquist and Carlson (1972), but they contradict those of Tindell et al. (1968a, 1968b) and Marks et al. (1969c).

Neither feeding period nor protein level were significant in effect on this trait. These results are in agreement with most research reports (Waldroup et al., 1966; Harms et al., 1968; Wright et al., 1968; Costain et al., 1970 and Smith et al., 1970), but they are in disagreement with the results of Holmquist and Carlson (1972).

There were no significant interactions with respect to this trait. There results confirm the results obtained by Aitken et al. (1972).

II. COEFFICIENTS OF CORRELATION

Table 15 represents a classification of strains based upon coefficients of correlation among production traits. Coefficients of correlation are presented in Tables 16, 17 and 18.

Egg Production and Average Egg Weight

Strains differed from one another with respect to relationships between these two traits, but those differences were not significant (Table 15). Some interesting results were obtained. For example, strains 16 and 28 were from the same breeder farm, but they were found to have respectively, positive and negative coefficients of correlation between EHH and AEW. Strain 28 was the heaviest strain at housing, while strain 16 was the lightest strain at housing. With respect to average body weight at the end of the test, strain 28 was the heaviest strain, while strain 3 was the lightest strain, but both of them had negative coefficients of correlation between EHH and AEW.

Coefficients of correlation between EHH and AEW by treatments with all strains combined were significantly positive (Table 16) Although analysis of variance showed that strains had significant

TABLE 15

CLASSIFICATION OF STRAINS BASED UPON COEFFICIENTS OF CORRELATION AMONG PRODUCTION TRAITS

Traits Correlated	Strains Identified by Types of Correlations*				
	Very Highly Significant ($P < 0.001$)	Highly Significant ($P < 0.01$)	Significant ($0.01 < P < 0.05$)	Positive ($P > 0.05$)	Negative ($P > 0.05$)
WTH and DAY[a]				10, 14, 22	1, 2, 3, 6, 9, 16, 17, 20, 23, 26, 28
WTH and SPOT[b]			23	3, 6, 16, 17, 20, 22, 28	1, 2, 9, 10, 14, 26
EHH and AEW[c]				2, 6, 16, 22, 23	1, 3, 9, 10, 14, 17, 20, 26, 28
EHH and HAUT[d]			26 (-)	2, 3, 9, 10, 14, 16, 20, 22, 23	1, 6, 17, 28
EHH and PROH[e]	10, 14, 17	16, 20, 22, 23, 26	2, 3, 6, 28	1, 9	
AEW and HAUT[f]		1, 28	3	2, 6, 9, 14, 17, 20, 22, 26	10, 16, 23
AEW and PROH[g]		6		1, 2, 3, 9, 10, 14, 16, 17, 20, 22, 23, 26, 28	

TABLE 15 (continued)

[*] Sign of coefficient of correlation is in parentheses.

[a] Body weight at housing and days to 50% production.

[b] Body weight at housing and % blood and meat spots (brokenout).

[c] Eggs per hen housed and average egg weight.

[d] Eggs per hen housed and Haugh units.

[e] Eggs per hen housed and profit per hen.

[f] Average egg weight and Haugh Units.

[g] Average egg weight and profit per hen.

TABLE 16

COEFFICIENTS OF CORRELATION AMONG ECONOMIC TRAITS BY TREATMENTS WITH ALL STRAINS COMBINED

Traits	P_1F_1[a]	P_1F_2[b]	P_2F_1[c]	P_2F_2[d]	P_1F_1[a]	P_1F_2[b]	P_2F_1[c]	P_2F_2[d]
Eggs per Hen Housed					Average Egg Weight			
Average egg weight	0.377*	0.391*	0.568***	0.423*				
Haugh units	0.061	-0.288	0.109	-0.353	0.031	0.121	0.159	-0.072
Profit per hen	0.961***	0.973***	0.970***	0.962***	0.475**	0.440**	0.651***	0.467**
Days to 50% Production					% Blood and Meat Spots (Brokenout)			
Body weight at housing	0.365	0.140	0.427	0.383	0.498	-0.045	0.124	0.185
Body weight at the end of the test	0.456	0.355	0.359	0.271	-0.025	0.194	0.006	0.004

[a]17.6% protein laying diet during 10-20 weeks of age.

[b]17.6% protein laying diet during 10-24 weeks of age.

[c]10.2% protein laying diet during 10-20 weeks of age.

[d]10.2% protein laying diet during 10-24 weeks of age.

*Significant ($P < 0.05$).

**Significant ($P < 0.01$).

***Significant ($P < 0.001$).

TABLE 17

SIMPLE CORRELATIONS AMONG CERTAIN OF THE TRAITS STUDIED

Traits	HHP	HDP	HDA	AEW	LBE	LBD	MOR	SPC	SPG	HAUT	INCH	COSH	PROH
EHH	0.935***	0.924***	0.814***	0.397***	-0.842***	-0.811***	-0.566***	0.024	0.164	-0.064	0.955***	0.406***	0.938***
HHP		0.999***	0.788***	0.362***	-0.842***	-0.824***	-0.309***	0.082	0.129	-0.121	0.882***	0.267**	0.904***
HDP			0.780***	0.359***	-0.840***	-0.822***	-0.276**	0.084	0.122	-0.123	0.871***	0.249**	0.897***
HDA				0.447***	-0.809***	-0.763***	-0.281**	0.081	0.118	-0.056	0.820***	0.228**	0.851***
AEW					-0.491***	-0.252**	-0.255**	0.019	0.052	0.109	0.621***	0.469***	0.550***
LBE						0.959***	0.293**	-0.065	-0.170	0.042	-0.847***	-0.041	-0.941***
LBD							0.243**	-0.085	-0.180*	0.089	-0.750***	0.094	-0.875***
MOR								0.024	-0.239**	-0.030	-0.549***	-0.618**	-0.416***
SPC									-0.070	-0.155	-0.016	-0.106	0.015
SPG										0.128	0.147	0.046	0.165
HAUT											-0.012	0.057	-0.033
INCH												0.495***	0.955***
COSH													0.228**

*Significant ($P < 0.05$).

**Significant ($P < 0.01$).

***Significant ($P < 0.001$).

TABLE 18

SIMPLE CORRELATIONS AMONG THE REMAINING TRAITS STUDIED

Traits	Days to 50% Production	% Blood and Meat Spots (Brokeout)	Average Body Weight at the End of the Test
Body weight at housing	0.079	-0.0008	0.617***
Days to 50% production		0.065	0.034
% Blood and Meat spots (brokenout)			0.038

***Significant ($P < 0.001$).

differences with respect to both eggs per hen housed and average egg weight (Table 3, page 36, and Table 4, page 37, respectively). Simple coefficients of correlation of average egg weight with all egg production traits studied were positive and very highly significant ($P < 0.001$) (Table 17, page 61).

These results confirm the finding of Hogsett and Nordskog (1958) and Srinivasan (1972), but they differed from the results of King (1961).

Egg Production and Haugh Units

Some positive and some negative coefficients of correlation were observed between EHH and HAUT.

Strain 26 had significant ($P < 0.05$) negative coefficients of correlation between EHH and HAUT (Table 15, page 58). Again, strains 16 and 28 had correlations opposite in sign even though they were from the same breeder farm. Strain 16 had positive correlations between EHH and HAUT as with EHH with AEW, while strain 28 exhibited negative correlations of EHH with HAUT and of EHH with AEW. These results indicate that strain 16 had higher Haugh units as egg production increased or it produced more large eggs with increased Haugh units, but strain 28 had higher Haugh units as egg production decreased or it produced more small eggs with high Haugh units.

Unexpected positive relationships between EHH and HAUT were observed (Table 16, page 60) in the first and third treatment, P_1F_1 and P_2F_1, respectively, (short feeding period with different levels of protein), while the other two treatments P_1F_2 and P_2F_2 (long feeding period with different levels of protein) had expected negative relationships.

Simple correlations (Table 17, page 61) showed expected negative but nonsignificant correlations between Haugh units and all egg production traits studied. This study indicated that strains and treatments differed in sign and magnitude of the coefficients of correlation between these traits.

The negative relationships observed were supported by results of Brant *et al*. (1953) and Srinivasan (1972); however, Knox and Godfrey (1938) found no relation between EHH and HAUT.

Egg Production and Income Over Chick and Feed Cost

All strains were found to have positive coefficients of correlation between EHH and PROH, as expected (Table 15, page 58), but they differed in levels of significance. Strains 10, 14 and 17 had very highly significant ($P < 0.001$) coefficients of correlation. Strains 16, 20, 22, 23 and 26 had highly significant ($P < 0.01$) and strains 2, 3, 6 and 28 had significant ($P < 0.05$) relationships, but those in strains 1 and 9 were not significant.

Simple correlations of PROH with all egg-production traits studied (EHH, HHP, HDP and HDA) showed very highly significant ($P < 0.001$) and positive coefficients of correlation (Table 17, page 61) these results also were as expected.

Table 16, page 60, indicates also very highly significant ($P < 0.001$) and positive coefficients of correlation between these two traits in each treatment with all strains combined together.

These results supported the results of Nordskog (1960) and Srinivasan (1972).

Average Egg Weight and Haugh Units

Strains were found to differ from one another in sign and magnitude of coefficients of correlation between these two traits. Strains 1 and 28 showed highly significant ($P < 0.01$) positive relationships and strain 3 exhibited significant ($P < 0.05$) positive relationships, while other strains showed nonsignificant positive and negative coefficients of correlation (Table 15, page 58). Again, strains 16 and 28 which were from the same breeder farm contradicted each other in their coefficients of correlation between these two traits. Strain 28 showed positive relationships for these traits, while strain 16 showed negative relationships. Another interesting result was obtained in strain 16 in that it had positive relationships between EHH and AEW and between EHH and HAUT. Thus, one would expect it to have positive relationships between AEW and HAUT, but the opposite was observed which is difficult to explain.

Coefficients of correlation between these two traits by treatments with all strains combined show positive relationships except in treatment four (P_2F_2), but the values observed were nonsignificant in all treatments (Table 16, page 60).

Simple correlations between these traits when all strains and treatments were combined were positive but nonsignificant. These results supported the finding of King (1961) but disagrees with that of Srinivasan (1972).

Average Egg Weight and Income Over Chick and Feed Cost

As expected, all strains had positive coefficients of correlation between AEW and PROH (Table 15, page 58). Strain 6 had highly significant ($P < 0.01$) correlations between these two traits, but other strains were found to have nonsignificant relationships. Similar relationships were found between egg production and income over chick and feed cost but of greater magnitude.

Coefficients of correlation between these traits by treatments with all strains combined are presented in Table 16, page 60. The values tabulated there are positive and highly significant ($P < 0.01$) in all treatments.

Table 17, page 61, contains simple correlations between most of traits studied. AEW was found to have very highly significant ($P < 0.001$) positive coefficients of correlation not only with PROH, but with all accounting variables, viz., INCH, COSH and PROH.

These results are in agreement with findings of Nordskog (1960) and Srinivasan (1972).

Body Weight and Sexual Maturity

Strains differed from one another in the sign of their correlations of body weight at housing (WTH) with age at 50 percent production (DAY), but they did not differ in magnitude. All strains had negative correlations except three which had positive correlations between these two traits (Table 15).

Table 16 contains coefficients of correlation of body weight at housing (WTH) and of body weight at the end of the test (WTD) with sexual maturity (DAY) by treatments when all strains were combined. The table shows positive but nonsignificant coefficients of correlation in all treatments.

Simple correlations between these traits are shown in Table 18, page 62, which also shows positive but nonsignificant relationships.

These results are similar to the results of King (1961) but dissimilar to those of Kinder and Kobayashi (1969).

Body Weight and Incidence of Spots

Strains were found to differ from one another in the sign of their relationships between body weight at housing (WTH) and percent of blood and meat spots (brokenout) (SPOT) (Table 15, page 58). All strains showed nonsignificant correlations except strain 23 which had significant ($P < 0.05$) relationships between these two traits.

Coefficients of correlation of body weight at housing (WTH) and at the end of the test (WTD) with percent of blood and meat spots (SPOT) are presented in Table 16 (page 60) by treatments with all strains combined. All treatments were found to have positive relationships except the second treatment (P_1F_2) which had negative relationships between (WTH) and (SPOT), and the first treatment (P_1F_1) which had negative correlations between (WTD) and (SPOT). Yet there were no significant mean differences between treatments.

Simple correlations between WTH and SPOT were negative (Table 18, page 62), while they were positive between WTD and SPOT, but none of them was significant.

Egg Production and Some Other Traits

All egg production traits had significant ($P < 0.001$) negative relationships with feed efficiency traits [pounds of feed per pound of eggs (LBE) and pounds of feed per dozen eggs (LED)] (Table 17, page 61). This means that higher egg production results in less feed consumption for dozen of eggs produced.

Mortality had highly significant ($P < 0.01$) negative relationships with all egg production traits, EHH, HHP, HDP and HDA, which confirmed the finding of Fernandez et al. (1973), and they were logical results.

Percent spots observed by candling was found to have positive but nonsignificant correlation with all egg production traits.

Coefficients of correlation of egg production traits with income per hen (INCH) and cost per hen (COSH) were highly significant. These results were logical.

Average Egg Weight and Other Traits

Average egg weight (AEW) was significantly ($P < 0.001$) correlated negatively with pounds of feed per pound of eggs (LBE) (Table 17, page 61), and significant ($P < 0.01$) negative relationships with pounds of feed per dozen eggs. These results confirmed the results of Perek and Snapir (1970) but contradicted those of Kinder and Kobayashi (1969).

Positive but nonsignificant coefficients of correlation of average egg weight with percent spots observed by candling (SPC) and specific gravity (SPG) (Table 17, page 61). These results were logical.

CHAPTER V

SUMMARY

Data collected during the Fifteenth Tennessee Random Sample Laying Test (1972) were analyzed statistically using analysis of variance and conventional product-movement coefficients of correlation among most variables studied to determine the magnitude of these correlations in both strain and treatment subclasses. The variables studied were egg production, average egg weight, feed efficiency, mortality, egg quality, income over chick and feed cost, body weight and sexual maturity. The effects assessed were strain (14 strains), feeding period during the growing period (short period = 10 to 20 weeks and long period = 10 to 24 weeks), protein level (low level = 10.2 percent and high level = 17.6 percent) and their interactions.

Strain differences were significant with respect to most traits studied. The other two main effects, feeding period and protein level, were found also to differ, frequently and significantly.

Most of the interactions were observed to be nonsignificant except for some first-order interaction such as strain X protein interactions for percent hen-day egg production after 50 percent of production ($P < 0.05$) and body weight at housing ($P < 0.01$), and feeding period X protein for sexual maturity ($P < 0.05$) and cost per hen ($P < 0.01$), while the second-order interactions were not significant for any trait.

In spite of lack of significance in interactions between variables, there were some interactions which cannot be ignored.

They would undoubtedly be significant with larger sample size and experimental procedures which would permit detection of small differences.

Tests of significance of coefficients of correlation showed that strains differed in sign of correlations rather than in magnitude. Treatments showed significant positive relationships of average egg weight with eggs per hen housed and of profit per hen with both eggs per hen housed and average egg weight, while other relationships with different sign were not significant.

Sign and magnitude of correlations between the variables and interactions between main effects might be of considerable value as a guide to poultrymen in their business.

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VITA

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He was married in October 1967. He is a father of three children, two boys, Saad and Mohammad and one girl, Afraa.