MANAGEMENT AND NUTRITIONAL TECHNIQUES
TO INCREASE EGG PRODUCTION

by

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ABSTRACT

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Four experiments were conducted to test a combination of several dietary treatments to determine which factors might be utilized to increase egg production of one of the major egg laying strains used by Michigan commercial poultrymen. In the first experiment a series of four dietary treatments using methionine and protein standards used in British egg production rations, were compared under the prevailing Michigan conditions. All of the four diets are isocaloric and contain varying levels of methionine and protein. In the second experiment a typical egg laying hen ration used in Michigan was compared with another diet which contained an equal amount of protein and methionine and had a similar ration composition. The two rations were different in their metabolizable energy content. This was to compare the caloric differences found in British rations and Michigan egg laying hen rations. The third experiment was to compare the ration composition differences found in British rations and Michigan egg laying hen rations. The fourth experiment was

to compare different cage densities. Two birds and three birds per cage were compared.

The trial utilized twenty-two week old Dekalb 231 Pullets and consisted of seven experimental treatments with four replicates in each. Each experimental group was composed of eight birds maintained in 20 Cm. x 40 Cm. cage, two birds per cage, except that in experimental group "H" each group was composed of twelve birds, confined three birds per 20 Cm. x 40 Cm. cage. The experiment was performed in order to investigate the effect of the different experimental diets and cage densities upon egg production, feed intake, feed conversion, daily protein and metabolizable energy intake, body weight gain, egg weight and egg quality, number of lost eggs and mortality. At the end of the experimental period, data obtained were subjected to statistical analysis.

From the studies reported herein, neither the high protein and methionine levels used in certain European standard diets nor the high metabolizable energy level used in one of U.S. egg laying rations would explain the differences in egg production performance found between Michigan and European commercial laying hens. However, when the diet had a high metabolizable energy content or a high protein level, the birds tended to consume more feed and gained more weight. It had also been shown that the different ration composition used in the experiment did not influence the rate of egg production or exterior and interior egg quality. Under the conditions of the experiment, a 16.94 percent protein and 0.36 percent methionine levels and 2838 Kcal of metabolizable energy per Kg. of diet were sufficient to support highest rate of egg production and best feed conversion. On the other hand, two birds per cage had a better rate of lay and lower body weight gain than three birds confined in the same size.

To the People of My Country

and my Parents

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INTRODUCTION

In all the modern breeds and strains of egg production chickens, there has been marked increase in egg production during the last 75 years. The conditions which have been responsible for this have been the following:

a) selection and breeding,

b) supplying nutritious feed,

c) comfortable housing,

d) improved management, and

e) preventive disease control.

In 1937, there began a steady and almost continuous increase in egg production, which by 1969 had added 100 eggs to the average, to bring the total to 220 eggs per layer during a normal production cycle [U.S. Department of Agriculture, 1969]. On the other hand, continued selection and breeding for high rate of lay, together with improved feeding, housing and management have made it possible for large commercial egg farms in the U.S. and Europe to count on annual yields of 240 to 250 eggs per hen.

It has been realized for some time that the egg production achieved by U.S. producers is much less than the genetic potential. It has been suggested that many European producers are more nearly achieving the maximum genetically attainable egg numbers during a normal production cycle. In a letter dated November 22, 1976 which had been sent to Dr. C. C. Sheppard by the U.K. Ministry of Agriculture, Fisheries and Food, it was mentioned that many U.K. egg producers were getting 280 eggs in 52 weeks. It has also been reported that U.S. egg producers were getting only 240 eggs during the same production cycle [Flegal, 1977].

Speculations as to the possible reasons for increased production in the U.K. are as follows:

1) The simple corn/soya diet used in the U.S. may not provide the same nutritional standard as the more complex ones used in more European poultry diets.

2) Animal protein, fish meal, and meat meal make up a substantial portion of most European poultry rations.

3) Methionine levels used are higher in European poultry rations.

4) U.S. poultry rations contain more energy per pound of ration than their European counterparts.

5) U.S. rearing diets may be high in their energy content due to the use of corn, whereas European rearing diets contain a large proportion of barley.

6) Stocking densities per cage are much higher in the U.S.

7) Others: small flocks, different climate, different strains, etc.

If any of these aforementioned factors can be shown to improve egg production of U.S. birds when compared to typical conditions used in the U.S., more efficiency in the poultry industry could be expected.

The purpose of the studies reported herein was to test several dietary factors used by European commercial poultrymen and various cage densities to determine which factors might be utilized to increase egg production of one of the major egg laying strains used by Michigan commercial poultrymen. The factors tested were:

a) methionine level,

b) protein level,

c) energy level,

d) ration composition, and

e) cage densities.

These studies were conducted May 27, 1977 through May 27, 1978 at the Michigan State University Poultry Science Department Research and Teaching Center.

REVIEW OF LITERATURE

It has been known for a long time that the energy and protein, content of the diet, the rate of feeding, the environmental temperature and the characteristics of the animal itself all affect the performance of the animal.

Energy Level of Poultry Rations

Most investigators have agreed that there is a direct relationship between the energy content of the diet and daily intake. Hill [1962] pointed out that chickens tend to eat less as the energy content of the diet is increased. Morris [1958] reported that the dietary energy level has influence on the voluntary caloric intake of laying birds, DeWar and Gleaves [1969] have shown that the level of energy and protein in a given diet influence feed intake. Guenthner et al. [1972] reported that increasing the level of dietary energy from 2,500 to 3,300 calories of metabloizable energy per kg of diet significantly decreased feed consumption and improved feed conversion. Lillie et al. [1976] demonstrated an inverse relationship of dietary metabolizable energy level and feed intake at 29.5, 21.5 and 13.0 Centigrade. In respect to egg production, it appears there is a controversy among many investigators as to whether it is increased, decreased, or not changed when the energy content of the diet is increased. Heuser and co-workers [1945] were among the first to show that rations low in fiber content supported a higher rate of egg production than similar rations high in fiber content. Bird and Whitson [1946] studied layer rations of high and low fiber content with respect to productive efficiency and showed that efficiency was related conversely to fiber content. Quisenberry et al. [1949] present evidence that increased egg production and improved feed efficiency could be obtained through the use of high energy diets. Skinner et al. [1951] found that higher egg production, greater feed efficiency and larger eggs were obtained on a higher efficiency ration than on a conventional breeder mash. Lillie et al. [1952] observed that a marked increase in efficiency of egg production resulted from incorporation of lard in the laying hens' diet. Singsen et al. [1952] reported that hens fed a high corn diet (61.25%) required as much as 13% less feed per dozen eggs, were slightly heavier in body weight, and tended to have a higher rate of egg production than hens fed a corn-oat-middling ration. Hill et al. [1956] reported that the rate of egg production was increased as the dietary energy level was increased during the months of cold weather. Hill [1956] reported that feeding hens a constant protein level of 17.5% of the diet showed that the relationship between energy level and relative efficiency was linear within the range of 740 to 1030 calories of productive energy per pound of diet. Harms et al. [1957] obtained a significant improvement in egg production, in addition to feed efficiency and body weight gains with White Rocks, White Leghorns, and New Hampshires, when hens were fed a high energy ration compared to a low energy ration. Peterson et al. [1960] reported that egg production of hens fed a low energy ration was not equal to that obtained from hens fed a high energy ration; on the other hand, he observed that feed consumption was significantly increased, while egg weight and albumin quality were not influenced by the high energy ration. Sykes [1972] indicated that egg weight began to fall before egg production was affected and that body weight was also affected following energy restriction. Reid et al. [1977] reported that limiting metabolizable energy intake in laying hen diets reduced both egg weight and hen-day production. Donaldson [1962] indicated that egg production was reduced when a balanced ration which contained 30.4 percent of added fat was fed to leghorn pullets. Goodling et al. [1968] found that increasing the level of dietary energy resulted in lower egg production. Santana and Quisenberry [1968] reported that a high energy level made for larger body weight, lower egg production, higher feed efficiency, but larger egg size except when the protein was 12% or lower. Gleaves et al [1968] reported, as estimated dietary energy was increased, there was a concurrent decrease in body weight gain, egg production and egg weight. Grover et al. [1972] reported that a high energy treatment depressed egg production, increased body weight gain and decreased total feed consumption. Quisenberry et al. [1967] showed that phasing both the protein and energy levels was superior to phasing either alone. Peterson [1971] reported that daily metabolizable energy intake can be reduced to 240 KCal per bird per day without affecting egg output, providing that the daily intake of other nutrients was adequate. Peterson et al. [1973] showed that the mature hen derives more metabolizable energy from several feed ingredients than does a growing chick, indicating that the calculated energy values for laying hen diets may be considerably lower than actually realized in feeding. He also concluded that the constancy of metabolizable energy values makes them a poor criterion for the evaluation of nutrient balance, housing and management. Gerry [1954] noted that neither egg production nor egg size was improved by feeding high efficiency rations as compared with conventional rations. Mueller [1956] found that hens fed a barly-oat ration equaled the production of the birds fed a corn ration. Anderson et al. [1957] obtained increased feed efficiency but not egg production when a ration that contained 884 calories of productive energy per pound was compared to one with 723 PE calories. MacIntyre and Aiken [1957] compared rations that contained 710 and 840 calories productive energy per pound in one experiment and 840 and 900 calories productive energy per pound in another. Rate of egg production was not influenced by energy level although feed intake and feed efficiency were markedly affected. Berg et al. [1956]

found that the rate of lay of leghorns in floor pens was not affected at several levels of metabolizable energy varying from 1100 to 1367 calories productive energy per pound in diets of either 15 or 17 percent protein content. Treat et al. [1960] reported the caloric level of the diet apparently did not affect egg production, since hens that received the basal diet laid at a rate comparable to any of the diets with added fat. On the other hand, he observed an improvement in feed efficiency when fat was added to the basal diet. Gordon et al. [1962] indicated that energy content of the diet had no direct effect on egg production or egg weight; however, he found that increasing the energy content of the diet decreased feed intake, thereby improving the feed efficiency. Hochreich et al. [1958] added 6.6 percent stablized yellow grease to a 950 calorie productive energy ration without effect on egg production. Heywang and Vavich [1962] reported no significant change in egg production as dietary levels increased in the diet. They also found that feed intake decreased progressively as the calorie content of the diets increased. March and Biely [1963] reported that an increased dietary energy level reduced egg weight. Egg production was not affected by high energy level. Bragg and Hodgson [1969] reported no difference in egg production as the dietary energy level was increased. Jones et al. [1976] evaluated the feeding of 2.67, 2.85 and 2.99 KCal metabolizable energy per gram diets at temperatures of 4.5, 21 and 45 centigrade and found that the level of dietary energy had no significant effect on egg production. Hill et al.

[1954 a,b] reported a marked decrease in the amount of feed required per dozen eggs produced when the caloric density of the diet was increased from 746 to 930 calories of productive energy per pound. McDaniel et al. [1957] observed a 12.2 percent increase in feed efficiency, as measured by feed required per dozen eggs produced, with the addition of 88 calories of productive energy per pound to a layer ration that contained 17 percent protein. Price et al. [1957] found that feed required per dozen of eggs was reduced by increasing the energy content of the diet. Speers and Balloun [1967] reported that feed conversion was improved by increasing dietary energy of the diet only when protein intake was adequate. Harms et al. [1962] presented evidence to indicate that hens will over-consume on either protein or energy in an attempt to meet their need for the other nutrient.

Protein Level of Poultry Rations

From a review of the literature, it seems there is controversy among many investigators about the protein level needed in the diet to maintain maximum egg production. A wide range was published which runs from 11 to 21 percent. Heuser et al. [1945] indicated that a 15 percent protein content in the laying hen diet was sufficient to support maximum egg production. The National Research Council [1950] recommended that diets containing 15 percent protein were sufficient to support adequate egg production. Heywang et al. [1955] indicated that pullets may require a protein level of 15 percent in the diet during heat stress. Thornton et al. [1957] reported that 11 percent protein in the diet was adequate for maximum egg production. Berg and Bearse [1957] stated that a 14 percent protein level in a diet that contained 1015 Kcal of productive energy per pound depressed egg production, whereas the same protein level supported better egg production than higher protein levels on a diet that contained 700 Kcal of productive energy per pound. Miller et al. [1957] indicated that they obtained good egg production with diets that contained 12.5 and 13.5 percent protein. Thornton and Whittet [1959] found that a 13 percent protein level in the diet was comparable with higher levels of protein for egg production and feed efficiency. Frank and Waibel [1960] presented data showing that 15 and 14.9 percent protein levels in the diet were sufficient to support egg production. Bray and Gesel [1961] stated that a minimum of 13 to 14 grams of protein a day for a leghorn pullet was adequate for egg production. They also observed that whenever daily protein intake of hens fell below 12 grams, a decreased rate of production occurred, either simultaneously or during the following period. Owings [1964] noted that reducing the protein content of the diet from 17.5 percent to 15.3 or 13.3 had no detrimental effects on egg production, body weight gain, egg size or Haugh Unit scores. He also indicated that feed required to produce a dozen eggs was significantly less on the lower protein levels. Shapiro and Fisher [1965] found that a minimum of 13 to 14 grams daily protein intake supported egg production up to a level of 76 percent. Lillie and Denton [1965] stated that a minimum of 15 grams of protein per leghorn per day appeared to be adequate for egg production, body weight and egg size. Smith [1967] found no difference in egg production when rati were fed which contained protein levels of 11, 15 and 19 percent. Lillie and Denton [1967] compared dietary protein levels of 12, 14 and 16 percent. They found that when the 12 percent protein level was fed, egg production was significantly lower than that obtained with 14 percent protein level, but was equivalent to that obtained with 16 percent proten level. Blaylock et al. [1967] concluded that no more than 14 grams of protein intake per hen per day were required to support egg production up to a level of 80 percent. Shapiro [1968] reported that 13 to 14 grams of protein per hen per day would support 70 percent egg production and satisfactory nitrogen retention of 800 mg per day. Novacek and Carlson [1969] stated that the protein requirement of layer hens was not more than 11.3 grams per day for a 4.4 pound hen at a level of 60 percent egg production. Manoukes and Young [1969] reported that a total intake of 14.4 to 15 grams of protein per hen per day supported optimum egg production. Reid and Weber [1974] found that the feeding of a 14 percent protein diet that contained 0.55 percent total sulfur amino acids supported maximum egg production. Thayer et al. [1974] have evaluated the protein requirement of hybrid pullets to be 14 to 15 grams per hen per day. Reid [1976] found a 14.5 percent dietary protein was adequate to support an egg production rate of 77 percent at an average intake of 16.64 grams per hen per day. Hamilton [1978] reported that productive performance and egg quality of S.C.W.L. hens were not affected when the level of dietary protein was decreased from 17 to 13 percent at 325 days of age or when the birds received a 15 percent protein diet from 143 to 504 days of age. Reid et al. [1951] observed that 18 percent protein in feed was superior to 13 or 15 percent protein in feed when the feed was formulated to contain a relatively high level of energy. Milton and Ingram [1957] found that an 18 percent protein level was superior to a 14 or 16 percent protein level. Hochreich et al. [1958] reported that a level of 17 percent protein in the feed was required to maintain maximum egg production and feed efficiency, when the diet contained at least 950 Kcal productive energy per pound. Quisenberry and Bradley [1962] found that egg production (on a hen-day basis), egg weight and efficiency of feed utilization were significantly improved as dietary protein level was increased from 13 to 17 percent. Touchburn and Naber [1962] stated that a minimum of 17 grams protein intake was required per pullet per day to support 72% egg production. Gordon et al. [1962] indicated that increasing the protein level to 19 percent resulted in improved egg production, egg weight and feed efficiency with no improvement observed from 23 percent protein level. On the other hand, at low energy level, 860 calories of productive energy per pound, 23 percent protein level depressed egg weight, while at high calorie level, 1100 calories of productive energy per pound, it did not. Harms and Waldroup [1963] found that feeding a 11.6 percent protein level significantly reduced the length of the laying cycle, which resulted in a significantly lower rate of egg production compared to birds receiving a 14.3 or 17 percent protein level. Biely and March [1964] reported that hens which received a dietary level of 16 percent protein consistently laid larger eggs than did those which received a dietary level of 14 percent protein. Britzman and Carlson [1965] concluded that a layer ration with a protein content of 11 percent would support egg production for a period of 5 or 6 months, but at a level ten percent below that obtained from hens fed a 16 percent protein. Bray et al. [1965] observed that egg weight increased with an increase in dietary protein level above 14 percent, at a dietary level of 1450 Kcal of metabolizable energy per pound, but was depressed when the 14 percent dietary protein level was fed in combination with a dietary energy level of 1100 carlories productive energy per pound of diet. Tonkinson et al. [1968] set a protein intake requirement of 17.5 grams of protein per hen per day with a daily energy intake of 343 Kcal per hen. Santana and Quisenberry [1968] indicated that a diet that contained 16 percent protein was satisfactory for body weight gain and resulted in the highest egg production. They also found that feed cost was lower per dozen eggs produced and mortality appeared not to be affected. Gleaves et al. [1968] reported that as estimated dietary protein level was increased from 13 to 19 percent in the diet, there was an increase in observed body weight gain, egg production and egg weight. Nivas and Sunde [1969] provided layer hens with protein intakes of 14, 16, and 18 grams per hen per day. They observed that egg production was lower when protein intake was 14 to 16 grams per hen per day compared to an intake of 18 to 20 grams per hen per day. They also noted an increase in body weight gain and egg weight as protein intake was above 14 grams per day per hen. Aiken et al. [1973] evaluated the protein intake and protein source on performance of seven strains of laying hens. Their findings suggested that 17 grams of protein intake per hen per day was adequate for egg production and no significant strain differences in protein need were noted. Deaton and Quisenberry [1965] reported that egg production of laying hens that received 17 or 14 percent protein in their diet was not significantly different. On the other hand, the hens that received 17 percent protein in their diet laid significantly heavier eggs, had significantly better feed efficiency and significantly lower Haugh Unit scores, but no difference in shell thickness. Combs [1962] noted that for a given diet, a decrease in intake would result in a decrease in protein intake per day and performance would fall. Coligado and Quisenberry [1961] found that a gradual decrease in dietary protein level had little or no effect on egg production. Guenthner et al. [1972] reported that a gradual increase of protein level--from 13.9 to 18.3

percent of the diet--did not influence feed intake and feed conversion; although the rate of egg production tended to increase, it was not significantly altered by increase in protein levels. Sharpe et al. [1965] found that decreasing the dietary protein level from 16 to 12 percent at 343 days of age caused a decrease in both feed and protein intake. Reid et al. [1965] assumed that protein requirement will decline with age because of declining egg output, although it has been recognized that seasonal differences in rate of lay and feed consumption may also affect dietary protein requirement. Campbell [1966] concluded that a 13 percent protein diet, while failing to support a maximum peak of production, was equal to 15 or 17 percent protein diets after egg production had declined to a rate of 70 percent. Fisher and Morris [1967] reported that reducing the dietary protein level from 16 to 12 percent and 14.7 and 10.7 percent, respectively at 219 days or 343 days of age caused a decrease in egg production. Jennings et al. [1972] indicated that when comparisons of egg production were made at a given protein intake, the older birds consistently produced some 10 to 13 grams less egg material than the young ones, so more protein was required for older birds for a given level of production. In respect to egg quality, most investigators have agreed that ration composition has no effect on egg quality. Card and Sloan [1935] reported that feeding a high proportion of the common grains, corn, wheat or oats, did not affect interior egg quality. Griminger and Scott [1954] found that the different grains could not be shown to influence egg weight, shell thickness or the standing-up quality of the egg. Orr et al. [1958] reported that the addition of 2.5 and 5.0 percent fat had no effect on egg quality or egg weight. Mueller [1956] indicated that egg weight was affected significantly by the ration composition but not shell thickness nor water loss of eggs during storage. On the other hand, eggs of hens that received a barley-oats-meat scrap diet had significantly higher Haugh Unit scores, compared to the others. Harms and Douglas [1960] observed that dietary changes which resulted in an improved rate of egg production caused the interior egg quality to decrease.

Methionine Levels in Poultry Laying Rations

There is also controversy among investigators about the level of methionine required to support adequate egg production. Titus [1955] indicated that methionine was the first limiting amino acid in a corn-soybean meal diet. Heywang [1956] reported that, when a soybean type diet that contained .28 percent methionine and .56 percent cystine was supplemented with .085 percent DL methionine, the methionine supplementation had no appreciable consistent effect on egg production. Johnson and Fisher [1959] observed that a diet that contained 10.4 percent protein plus. .09 percent added methionine and lysine supported egg production equal to that obtained with a diet that contained 15.7 percent protein. Harms et al. [1962] obtained a significantly improved performance when diets were supplemented with .075 percent methionine (MHA) in the diet, when the protein level in the diet was 14.7 or 15.7 but not when the protein level was 16.7 percent. Quisenberry [1965] presented evidence showing methionine supplementation consistently improved protein conversion in low protein laying hen rations. Fernandez et al. [1973] reported that a diet that contained 13 percent protein supplemented with .05 percent lysine and .05 percent methionine was as effective as diets with 15, 17 or 18 percent protein for supporting egg production and egg size. Damron and Harms [1973] noted that diets supplemented with a .528 percent sulfur amino acid level significantly improved egg production, egg weight and feed conversion. Reid and Weber [1974] found that the feeding of a 14 percent protein diet that contained .55 percent total sulfur amino acids supported maximum egg production. Mehring et al. [1954] found that the addition of .0847 percent methionine to a corn-soybean diet had no statistically significant effect on egg production. The quantity of feed required per dozen eggs or per unit gain in live weight was reduced. The basal diet was estimated to contain about .25 to .31 percent methionine and .26 percent cystine. Bradly and Quisenberry [1961] reported a slight non-significant decrease in egg production of birds fed 16 percent and 18 percent protein diets when these diets were supplemented with lysine and/or methionine. Amino acid supplementation caused increased egg production of hens fed a 14 percent protein diet.

Stangeland and Carlson [1961] observed that supplementation of .15 percent of the diet with methionine alone to a corn-soybean diet containing 11 percent protein did not affect egg production, whereas the combination of methionine and lysine consistently improved egg production and feed efficiency. Egg production and feed efficiency were superior on the positive control diet that contained 16 percent protein. Britzman and Carlson [1965] demonstrated that, when methionine did not show a response, either in egg numbers, egg weight or feed conversion, the protein intake was generally in excess of 16 grams per hen per day. Muller and Balloun [1974] have reported that addition of methionine to a low-protein, corn-soybean meal diet, fed to light weight laying hens may not always increase production performance. Leong and McGinnis [1952] indicated that the level of methionine required for supporting maximum egg production, body weight gain and egg size appeared to be approximately .28 percent in the presence of .25 percent cystine. Ingram and Little [1958] reported that when using a wheat-peanut meal basal diet supplemented with various levels of DL-methionine, the requirement for this amino acid was determined to be .25 percent of the ration. Levels of methionine as low as .225 percent supported egg production; however, egg size and body weight were not maintained, and as amino acid imbalance raised the requirement to .325 percent of the diet. The National Research Council [1960] sets a methionine requirement of either .53 percent of the diet or .28 percent of the diet in the presence of .25 percent of dietary cystine, for a diet containing 1300 Kcal per pound. Combs [1964] indicated that the methionine requirement per hen per day was about 295 mg. Bray [1965] estimated the requirement to be 233 mg. per hen per day. Fisher and Morris [1970] estimated the requirement to be 275 mg. per bird per day for maximum egg yield of pullets during the early stage of lay. The National Research Council [1971] recommends a level of .26 percent methionine and .25 percent cystine in a ration containing 2850 Kcal metabolizable energy per kg. Ingram et al. [1951] concluded that methionine requirement of laying hens was not more than .38 percent of the diet in the presence of .25 percent of the dietary cystine. Combs [indicated that a 2 kg. hen producing 40 grams of egg per day would require 302 mg. methionine per day. Carlson and Guenthner [1969] noted that the methionine requirement for laying hens was in excess of 300 mg. per hen per day for the first four months of production, but between 289 and 328 mg. per hen per day during the later stage of lay.

The Influence of Cage Density on Egg Production

Hartman [1953] indicated that poor air circulation, lack of space for holding the wings away from the body and other factors may increase hot weather hazard for hens. Craig [1969] found a relationship between crowding, aggressiveness and age at sexual maturity. Champion and

Zindel [1968], using 1, 2 and 3 birds in 20.3 cm. x 40.6 cm. cages, 4 birds in 40.6 cm. and 40.6 cm. cages, and 5 birds in 40.6 cm. x 40.6 cm. cages, indicated that egg production declined and mortality increased as the bird density increased; however, they concluded that income per unit of cage space can be maximized by caging layers in multiple cage units in preference to caging layers individually. They argued that whether the commercial egg producer could hold cage birds at a particular density may be dependent in part upon his ability to control cannibalism. Wilson et al. [1967] reported that egg production was significantly less with three birds per cage than with one or two birds per cage. They also noted strain interactions with respect to the effect of bird densities on egg production and egg weight and that egg quality characteristics were affected little by treatment and that major differences were due to strain effects. On the other hand, increasing cage density resulted in smaller body weight and increased mortality. Coligado and Quisenberry [1967] observed that crowding the birds depressed egg production and increased mortality, especially in large cages. No specific effects on body weight and egg size were noted. They also reported that feed efficiency was slightly favored by higher density. Tower et al. [1967] indicated that 10 birds per cage group produced the highest number of eggs per bird, had larger sized eggs, had the best feed conversion and had the lowest mortality compared to 2,5 or 20 birds per cage. Doran et al. [1967]

reported that birds housed individually in 25.4 cm. x 45.0 cm. cages matured two to six days earlier, produced three to eleven more eggs, had a five percent higher survival, required less feed per dozen eggs and were 31.8 grams higher in body weight than two birds housed per cage. Marr et al. [1967] reported that, when given equal floor space, two birds per 25.4 cm. x 40.6 cm. cage produced at a higher rate than did three, four, five or six birds per cage. Owings et al. [1967] stated there was no significant difference in egg production, feed efficiency, or mortality of birds confined two birds per cage or three birds per cage. Magruder and Nelson [1966] observed that two birds housed in a 20.3 cm. x 40.6 cm. cage had better egg production and three percent better livability than when a single layer was housed in the same cage. They also mentioned that there was little influence of density or cage construction regarding interior quality of eggs as measured by Haugh Units and that eggs showed less incidence of heavy staining as density decreased. Bell and Little [1966] reported a significant decrease in egg production an an increase in mortality with increased cage densities. Elmslie et al. [1966] indicated that egg production declined and mortality increased as bird population or bird densities increased. He also reported that a hysterical and featherless condition developed among birds housed 12 to 14 per 41 cm. x 123 cm. cage, but not among birds housed three per 41 cm. x 141 cm. cage. Bramhell et al. [1966] reported that higher population densities per cage generally decreased the number of eggs and increased mortality. Cook and Dembnicki [1966] observed that pullets housed one bird per 25.4 cm. x 45.7 cm. cage were significantly better in egg production than pullets housed in double or colony cages, i.e., two birds in a 25.4 cm. x 45.7 cm. cage, and five birds in a 45.7 cm. x 50.8 cm. cage. Blount [1965] suggested that two birds per cage were always better than one because of their companionship, their supplementary heat in colder weather and stimulus which each may give to the other's appetite. Mor et al. [1965] reported that cage density had a highly significant effect on hen-housed egg production and feed efficiency but no effect on mortality. Two females per cage showed the least cost to produce a dozen eggs. Lowe and Heywang [1964] reported that higher mortality and greater body weight gain in the multiple cage adversely affected egg production. Shupe and Quisenberry [1961] reported that egg production declined and mortality increased if the bird population or density increased. They also observed a significant difference in egg production and mortality between individually caged birds and colony birds; in favor of the individually caged birds. Marr and Green [1970] stated that space per bird was more of an influence on egg production than the number of birds per cage. They also observed that there were no significant differences in egg production among social densities of two, three, four, five, six, or seven hens with comparable space per bird. Adams and Jackson [1970] failed to observe a significant difference in performance or shell qaulity of six strains of White Leghorn type chickens housed at different densities. They also observed that crowding reduces rate of lay. Birds housed at a high density level had higher Haugh Unit scores. Ruszler and Quisenberry [1970] reported that space per bird was more of an influence on egg production than was number of birds per cage. Mather and Gleaves [1970] stated that egg production was significantly influenced by both density and stocks. The egg production decreased as the number of birds per cage was increased. They also observed that there was no stock-density interaction and that there were more bare backs in the cages with six birds density. Grover et al, [1972] reported that greater bird density depressed egg production, increased mortality and depressed body weight gains; however, under the conditions of their study, increasing density from two to three birds per cage failed to significantly depress egg production.

It has been reported by many investigators that energy content of the diet influences the daily feed intake. In respect to egg production, there is a controversy among many investigators as to whether it is increased, decreased or not changed when the metabolizable energy content of the diet is increased. On the other hand, most of the researchers have reported higher body weight gain and improvement in feed efficiency, when hens were fed a high energy ration compared to a low energy ration.

MATERIALS AND METHODS

Four experiments were conducted to test a combination of several dietary treatments to determine which factors might be utilized to increase egg production of one of the major egg laying strains used by Michigan commercial poultrymen. In the first experiment a series of four dietary treatments using methionine and protein standards used in egg production ration [Appendix B, 1, 3, 5, and 7] were compared under the prevailing Michigan conditions. All of the four British rations were isocaloric and calculated to contain 2822 calories M.E. per kg. of diet. The four standard diets which are designated with "A", "B", "C", and "D" contained 17.52, 17.27, 16.94, and 16.27 percent of protein, respectively, and 0.40%, 0.38%, 0.36%, and 0.34% of methionine respectively [Appendix B, 2, 4, 6, and 8]. In the second experiment, a typical egg laying hen ration used in Michigan which is designated with "E", was compared with another diet which is designated with "G" [Appendix B, 9 and 11]. The two rations contained an equal amount of protein and methionine, 16.54 percent of protein and 0.34 percent of methionine and had a similar ration composition. The two rations were different in their metabolizable energy content. Ration "E" contained 2958 Cal metabolizable energy per kg. of diet, whereas ration "G" contained metabolizable energy approximately equal to the British rations [Appendix B, 10 and 12]. This was to compare the calorie differences found in British and Michigan egg laying rations. The third experiment was to compare the British ration "D" with the ration "G". This was to compare the ration composition differences found in British rations and Michigan egg laying rations. The British ration "D" was chosen for this comparison, since it conta an equal amount of methionine and protein as ration "G". The fourth experiment was to compare different cage densities. Two birds and three birds per cage were compared. The two experimental groups received ration "E" [Appendix B, 9]. All of the diets were mixed at the Michigan State University poultry farm.

The trial utilized twenty-two-week-old DeKalb 231 pullets. The trial consisted of seven experimental treatments. There were four replicates of each experimental group. Each experimental group was composed of eight birds, maintained in 20 cm. x 40 cm. cages, two birds per cage, except that in experimental treatment "H" each group was compose of 12 birds, confined three birds per 20 cm. x 40 cm. cage. For the first three months of the experimental period, in the two experimental groups which were used to compare cage densities, any birds which died, were replaced. All experimental groups received feed and water ad libitum and 13.5 hours of light daily for the first three months, the light was increased to 16 hours of light daily for the rest of the experimental period. The different experimental groups and their replicates were randomly assigned to the cages in the environmentally controlled laying house. The different experimental groups were given the same designation as the different experimental diets except for the cage density experimental groups, which were designated with "F" and "H" and received diet "E". The different experimental groups were on test for one production cycle consisting of 365 days.

The following data were collected:

1) Egg Production

Egg production was recorded daily for each experimental group. At the end of the trial, the final average hen-housed and final average hen-day egg production [Table 1, 3, 4, and 5] were calculated and expressed in percent.

2) Feed Intake and Feed Conversion

The amount of the total feed consumed was recorded and at the end of the experimental period, the final average feed intake [Table 1, 3, 4, and 5] for each experimental group was obtained. Next, the final average feed conversion of the different experimental groups was calculated. The feed intake is expressed in kg. and the feed conversion is expressed in kg. of feed per dozen eggs produced.

3) Daily Protein and Metabolizable Energy Intake

Based on calculated analysis, the final average daily protein and metabolizable energy intake of the different experimental groups were obtained [Table 1, 3, 4, and 5]. The average daily protein intake is expressed in gram/bird and the average daily M.E. intake is expressed in cal./bird.

4) Body Weight Gain

The birds were weighed at the beginning and end of the trial. The final average body weight gain [Table 2, 3, 4, and 5] was obtained and expressed in grams. The body weight gain of the birds that died during the trial were excluded.

5) Egg Weight and Egg Quality

The final average egg weight is expressed in grams [Table 2, 3, 4, and 5]. Albumen height was measured by Albumen Height Micrometer, then was converted to Haugh Units [Table 2, 3, 4, and 5] obtained from the Haugh Unit Chart made by the U.S. Department of Agriculture. Shell thickness [Table 2, 3, 4, and 5] was measured by Shell Thickness Gauge and is expressed in mm. Shell thickness and egg quality were measured three consecutive days of each month for the different experimental groups.

6) Number of Lost Eggs

The term "lost eggs" included soft shell eggs, eggs without shells, misshapen eggs and broken eggs. They were recorded daily and the final average number of lost eggs of each experimental group was determined [Table 2, 3, 4, and 5].

7) Mortality

The mortality was recorded daily and at the end of the trial, the final average mortality was obtained for each experimental group and expressed in percent [Table 2, 3, 4, and 5].

Data obtained were subjected to analysis of variance and Tukey's Test [1953] was employed to determine the effect of the different dietary treatments.

TABLE 1

THE EFFECT OF VARIOUS DIETARY TREATMENTS ON EGG PRODUCTION, FEED INTAKE, FEED CONVERSION AND DAILY PROTEIN AND ENERGY INTAKE OF THE EXPERIMENTAL GROUPS A, B, C, AND D

Dietary Treatment	Hen-Housed Egg Production %	Hen-Day Egg Production %	Feed Intake Kg./Bird	Feed Conversion Kg./Dozen Eggs	Daily Average Intake	
					Protein gm.	M.E. cal.
A	64.83^{a}	67.50^{a}	42.26^{a}	2.06^{a}	20.29^{a}	326.29^{a}
B	63.00^{a}	68.11^{a}	$40.79^{a,b}$	$1.98^{a,b}$	19.30^{a}	$316.21^{a,b}$
C	65.52^{a}	72.17^{a}	$40.59^{a,b}$	1.84^{b}	18.84^{a}	$312.72^{a,b}$
D	59.93^{a}	64.33^{a}	38.48^{b}	$2.00^{a,b}$	17.15^{b}	298.08^{b}

^{a,b}Means within a column without a common superscript are significantly different ($P \leq .05$).

TABLE 2

THE EFFECT OF VARIOUS DIETARY TREATMENTS ON BODY WEIGHT, EGG WEIGHT, HAUGH UNIT SCORES, SHELL THICKNESS, NUMBER OF LOST EGGS AND MORTALITY OF THE EXPERIMENTAL GROUPS A, B, C, AND D

Dietary Treatment	Body Weight Gain gm.	Egg Weight gm.	Haugh Unit Scores	Shell Thickness mm./100	Lost Eggs No.	Mortality %
A	208.50^{a}	60.43^{a}	$84.52^{a,b}$	34.67^{a}	25.25^{a}	9.38^{a}
B	$161.32^{a,b}$	60.21^{a}	85.49^{b}	35.24^{a}	22.75^{a}	21.88^{a}
C	117.24^{b}	58.86^{a}	82.24^{a}	35.04^{a}	31.00^{a}	12.50^{a}
D	$159.60^{a,b}$	59.23^{a}	84.94^{b}	34.30^{a}	32.25^{a}	18.75^{a}

[a,b] Means within a column without a common superscript are significantly different ($P \leq .05$).

TABLE 3

THE EFFECT OF VARIOUS DIETARY TREATMENTS ON EGG PRODUCTION FEED INTAKE, FEED CONVERSION DAILY PROTEIN AND ENERGY INTAKE, BODY WEIGHT GAIN, EGG WEIGHT, HAUGH UNIT SCORES, SHELL THICKNESS, NUMBER OF LOST EGGS AND MORTALITY OF THE EXPERIMENTAL GROUPS F AND G*

Dietary Treatments	Hen-Housed Egg Production %	Hen-Day Egg Production %	Feed Intake Kg./Bird	Feed Conversion Kg./Dozen Eggs	Daily Average Intake: Protein gm.	Daily Average Intake: M.E. cal.
F	60.68	63.79	41.70	2.10	18.90	337.98
G	61.84	65.31	40.35	2.00	18.25	313.78

	Body Weight Gain gm.	Egg Weight gm.	Haugh Unit Scores	Shell Thickness mm./100	Lost Eggs No.	Mortality %
F	208.60	60.59	82.26	35.15	20.75	12.50
G	163.78	59.87	84.79	35.09	10.50	15.63

*There were no significant differences at ($P \leq .05$)

TABLE 4

THE EFFECT OF VARIOUS DIETARY TREATMENTS ON EGG PRODUCTION FEED INTAKE, FEED CONVERSION DAILY PROTEIN AND ENERGY INTAKE, BODY WEIGHT GAIN, EGG WEIGHT, HAUGH UNIT SCORES, SHELL THICKNESS, NUMBER OF LOST EGGS AND MORTALITY OF THE EXPERIMENTAL GROUPS D AND G*

Dietary Treatments	Hen-Housed Egg Production %	Hen-Day Egg Production %	Feed Intake Kg./Bird	Feed Conversion Kg./Dozen Eggs	Daily Average Intake	
					Protein gm.	M.E. cal.
D	59.93	64.33	38.48	2.00	17.15	298.08
G	61.84	65.31	40.35	2.00	18.25	313.78
	Body Weight Gain gm.	Egg Weight gm.	Haugh Unit Scores	Shell Thickness mm./100	Lost Eggs No.	Mortality %
D	159.60	59.23	84.94	34.30	32.25	18.75
G	163.78	59.87	84.79	35.09	10.50	15.63

*There were no significant differences at ($P \leq .05$)

TABLE 5

THE EFFECT OF TWO DIFFERENT CAGES DENSITIES ON EGG PRODUCTION, FEED INTAKE, FEED CONVERSION, DAILY PROTEIN AND ENERGY INTAKE, BODY WEIGHT GAIN, HAUGH UNIT SCORES, SHELL THICKNESS NUMBER OF LOST EGGS AND MORTALITY OF THE EXPERIMENTAL GROUPS F AND H

Cages Density Treatment	Hen-Housed Egg Production %	Hen-Day Egg Production %	Feed Intake Kg./Bird	Feed Conversion Kg./Dozen Eggs	Daily Average Intake: Protein gm.	Daily Average Intake: M.E. cal.
F (Two Birds/Cage)	60.68	63.79	41.70	2.10	18.90	337.98
H (Three Birds/Cage)	47.22	50.49	33.61*	2.27	15.23*	272.44*

	Body Weight Gain gm.	Egg Weight gm.	Haugh Unit Scores	Shell Thickness mm./100	Lost Eggs No.	Mortality %
F (Two Birds/Cage)	208.60	60.59	82.26	35.15	20.75	12.50
H (Three Birds/Cage)	281.12	61.22	84.69*	35.60	27.24	20.50

*Significant ($P \leq .05$)

**Highly significant ($P \leq .01$)

RESULTS

As can be seen in Appendix A, Tables 7, 9, and 17, the result of the first experiment has shown that the experimental groups which received diets "A", "B", "C", or "D" were significantly ($P \leq .05$) different in their final average feed conversion, and final average Haugh Unit values, and highly significantly ($P \leq .01$) different in their final average daily protein intake. Whereas the same experimental groups were not significantly different at the .05 level of probability in their final averages of the following traits: hen-housed and hen-day egg production, feed intake, daily energy intake, body weight gain, egg weight, shell thickness, number of lost eggs the mortality [Appendix A, Tables 1, 3, 5, 11, 13, 15, 19, 21, and 23].

Tukey's Test indicates that only the experimental groups which received diets "A" or "B" had highly significantly ($P \leq .01$) higher daily protein intake than the experimental group which received diet "D" [Appendix A, Table 10]. On the other hand the experimental group which received diet "A" consumed more feed and daily metabolizable energy ($P \leq .05$) than the experimental groups which received diet "D" [Appendix A, Tables 6 and 12]. As is shown in Appendix A, Tables 8 and 14, the experimental group which received diet "C" consumed less feed per dozen eggs produced and gained less weight than the experimental group which received diet "A" ($P \leq .05$). The same experimental group had highly significantly ($P \leq .01$) lower Haugh Unit values than the experimental group which received diet "B" and had significantly ($P \leq .05$) lower Hugh Unit values than the experimental group which received diet "D" [Appendix A, Table 18]. The result of the second experiment indicates that the experimental groups which received diets "E" or "G" were not significantly different at the .05 level of probability in their final averages of the following traits; hen-housed and hen-day egg production, feed intake, feed conversion, daily protein and energy intake, body weight gain, egg weight, Haugh Unit values, shell thickness, number of egg lost and mortality [Appendix A, Tables 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, and 36]. The result of the third experiment has shown that the experimental groups which received diets "D" or "G" were not significantly different at the .05 level of probability in their final averages of the following traits; hen-housed and hen-day egg producti... feed intake, feed conversion, daily protein and energy intake, body weight gain, Haugh Unit values, shell thickness, number of lost eggs and mortality [Appendix A, Tables 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, and 48]. As is indicated in Appendix A, Tables 51, 53, 54, and 57, the results of the fourth experiment show that the experimental groups "F" and "H" which had different cage density, two birds and respectively, and received the same diet, were significantly different at the .05 level of probability in their final average feed intake, final average daily protein and energy intake and in their final average Haugh Unit values. In contrast, there were no significant differences in the other traits [Appendix A, Tables 49, 50, 52, 55, 56, 58, 59, and 60].

DISCUSSION

The results reported herein show that diets "A", "B", "C", and "D" had no significant differences in their effects upon rate of egg production (hen-day and hen-housed), egg weight, shell thickness, number of lost eggs, and mortality. These findings suggest that neither varying protein nor varying methionine levels had any positive significant effects upon the aforementioned characteristics under the prevailing conditions of the experiment.

As can be seen from Table 1 and 2, the experimental group which received diet "C" tended to have higher average rate of lay, lower feed intake, body weight gain, egg weight, daily protein and energy intake than the experimental groups which received diet "A" or "B". This experimental group had significantly lower Haugh Unit values than the experimental groups which received diet "B" or "D" and consumed significantly less feed per dozen eggs produced than the experimental group which received diet "A". These observations suggest that the improvement achieved in the rate of lay and feed efficiency were associated with an adverse effect upon interior egg quality. This is supported by the findings of Harms and Douglas [1960] and by that of Deaton and Quisenberry [1965]. This result also suggests that the energy, protein and methionine levels of diet "C" were adequate to support higher rate of lay compared to the other experimental diets. This is in agreement with the findings of Hochreich et al. [1958], Nivas and Sunde [1969] and Gleaves et al. [1968] who reported that not lower than 18 gram protein intake per hen per day would support reasonable egg production.

In contrast, the experimental group which received diet "D" tended to have lower average egg yield, feed intake, daily energy intake, shell thickness, higher number of eggs lost and had significantly less average daily protein intake than the experimental groups which received diet "A", "B", or "C". This experimental group had significantly lower feed intake and daily energy intake than the experimental group which received diet "A" and had significantly higher Haugh Unit values than the experimental groups which received diet "C". This tendency suggests that the protein and/or methionine levels were not adequate to support a reasonable egg laying performance. These observations are in agreement with the findings of Milton and Ingram [1957], Nivas and Sunde [1969], Ingram et al. [1951], Quisenberry and Bradley [1962] and disagree with Blaylock et al. [1967] and Shapiro [1968] who reported that 14 gram protein intake per hen per day would support adequate egg production. The experimental group which received diet "A" tended to have higher feed intake, daily protein and metabolizable energy intake, and lower feed conversion, shell thickness, and mortality than the experimental groups which received diet "B" or "C". This experimental group also gained more weight than all other experimental groups. This trend suggests that a higher protein level supported higher body weight gain. This is in agreement with the findings of Nivas and Sunde [1969] and Gleaves et al. [1968]. On the other hand the experimental group which received diet "B had highly significantly higher Haugh Unit values than the experimental group which received diet "C" and ranked second in its average feed intake, daily protein, and metabolizable energy intake and body weight to the experimental group which received diet "A". This experimental group tended to have the highest average shell thickness and mortality of all experimental groups. This tendency suggests that the high protein and methionine levels of the diet "A" and "B" did have a negative effect upon egg laying performance. This observation is in disagreement with that of Gordon et al. [1962].

As can be seen in Table 3, the experimental group which received the lower energy level diet "G" tended to have higher average rate of lay, Haugh Unit values and feed efficiency than the experimental group which received the higher energy level diet "E". This experimental group had also lower feed intake, daily protein, and energy intake, number of eggs lost and mortality than the other experimental group. These observations suggest that chickens do not eat in order to satisfy their energy need for egg production and the higher energy level was not associated with an improvement in the rate of lay and feed efficiency. This is in disagreement with the findings of Hill [1962] and with that of

Price et al. [1957]. On the other hand the experimental group which received diet "E" gained more weight than the experimental group which received diet "G". This tendency suggests that the higher the energy content of the diet, the higher the body weight gains. This is in agreement with the findings of Santana and Quisenberry [1968] and Grover et al. [1972].

On the other hand, the results in Table 4 show that the ration composition has no significant effects upon rate of lay, feed intake, feed conversion, body weight gain and exterior and interior egg quality. This finding is supported by that of Card and Sloan [1935] and Griminger and Scott [1954]. However, the experimental group which received the simple corn-soybean diet "G" tended to have higher rate of lay, lower number of eggs lost and mortality than the experimental group which received the complex diet "D". This finding suggests that a simple corn-soybean diet supported a reasonable egg laying hen performance, which is comparable with that of a complex ration.

In respect to the influence of cage densities, the results [Table 5] indicate that the experimental group with two birds per cage had significantly higher feed intake, daily protein and metabolizable energy and lower Haugh Unit values than the experimental group with three birds per cage. This experimental group tended also to have a higher rate of lay (hen-housed and hen-day), feed efficiency and lower body weight gain, number of eggs lost and mortality, than the other experimental group. These observations suggest that two birds per cage had better egg production performance than three birds confined in the same cage size. This is in agreement with the findings of Champion and Zindel [1968], Bramhell et al. [1966], Adams and Jackson [1970], Carlson et al. [1967], Moore et al. [1965], and Magruder and Nelson [1966].

SUMMARY AND CONCLUSION

Four experiments were conducted over a production cycle (365 days), using twenty-two old DeKalb 231 pullets, to test a combination of several dietary treatments in order to determine which factors might be utilized to increase egg production of one of the major egg laying strains used by Michigan commercial poultry men. In the first experiment four dietary treatments using methionine and protein standards used in British egg production rations, were compared under the prevailing Michigan conditions. All of the four diets were isocaloric and contain varying levels of methionine and protein. In the second experiment a typical egg laying hen ration was compared with another diet which contained an equal amount of protein and methionine and had a similar ration composition. The two rations were different in their metabolizable energy content. This was to compare the caloric differences found in British rations and Michigan egg laying hen rations. The third experiment was to compare the ration composition differences found in British rations and Michigan egg laying hen rations. The fourth experiment was to compare different cage densities. Two birds and three birds, confined in 20 cm. x 40 cm. cage, were compared.

From the result of this study, the author concluded the following:

a) Neither the high protein and methionine levels used in certain European standard diets nor the high metabolizable energy level used in one of the U.S. egg laying rations, had any significant positive effect upon egg production performance.

b) The ration compositions used in the experiment could not be shown to influence rate of egg production or exterior and interior egg quality. On the other hand the simple corn-soybean diet supported egg production performance the same as a complex ration.

c) Whenever the diet has a high M.E. content or a high protein level, the birds tend to consume more feed and gain more weight.

d) From the result of this study, it is suggested that 16.94% protein, 0.36% methionine and 2838 M.E. per kg. of diet were sufficient to support highest rate of egg production, under the conditions of the experiment.

e) Under the conditions of the experiment, an average daily protein intake of 18.84 grams and an average daily M.E. intake of 312.7 calories per bird were shown to support highest rate of egg production.

f) Three birds per cage had a lower rate of egg production and higher body weight gain than two birds confined in the same cage size. This is due to the fact that the higher the cage density the less feed the birds consumed.

g) From the studies reported herein, it appears that the factors tested in the experiment would not explain the differences in egg laying performance found between Michigan and European commercial laying hens. There might be other factors which could be held responsible for the higher egg production achieved by certain European egg producers compared to their counterpart in the U.S. such as strain differences, different rearing diet, climate, . . . etc.

APPENDIX A

TABLE 1

ANALYSIS OF VARIANCE OF FINAL AVERAGE HEN-HOUSED EGG PRODUCTION OF THE EXPERIMENTAL GROUPS A, B, C, AND D

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatments	3	74.88	24.96	1.03
Experimental Error	12	290.02	24.17	
Total	15	364.90		

TABLE 2

MEANS DIFFERENCES OF FINAL AVERAGE HEN-HOUSED EGG PRODUCTION OF THE EXPERIMENTAL GROUPS A, B, C, AND D

	A	B	C	D
A	-	1.83	- .70	4.89
B		-	-2.53	3.07
C			-	5.59
D				-

Tukey's Test
MSD ($P \leq .05$) = 9.27
MSD ($P \leq .01$) = 12.90

TABLE 3

ANALYSIS OF VARIANCE OF FINAL AVERAGE HEN-DAY EGG PRODUCTION OF THE EXPERIMENTAL GROUPS A, B, C, AND D

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatments	3	125.71	41.90	1.95
Experimental Error	12	257.36	21.45	
Total	15	383.07		

TABLE 4

MEANS DIFFERENCES OF FINAL AVERAGE HEN-HOUSED EGG PRODUCTION OF THE EXPERIMENTAL GROUPS A, B, C, AND D

	A	B	C	D
A	-	-.61	-4.67	3.17
B		-	-4.06	3.78
C			-	7.84
D				-

Tukey's Test
MSD ($P \leq .05$) = 8.74
MSD ($P \leq .01$) = 11.68

TABLE 5

ANALYSIS OF VARIANCE OF FINAL AVERAGE FEED
INTAKE OF THE EXPERIMENTAL GROUPS
A, B, C, AND D

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatments	3	141.22	47.07	2.97
Experimental Error	12	190.05	15.84	
Total	15	331.27		

TABLE 6

MEANS DIFFERENCES OF FINAL AVERAGE FEED INTAKE
OF THE EXPERIMENTAL GROUPS A, B, C, AND D

	A	B	C	D
A	-	3.24	3.69	8.33*
B		-	6.43	5.09
C			-	4.64
D				-

Tukey's Test
MSD ($P < .05$) = 7.51
MSD ($P \leq .01$) = 10.04

TABLE 7

ANALYSIS OF VARIANCE OF FINAL AVERAGE FEED CONVERSION OF THE EXPERIMENTAL GROUPS A, B, C, AND D

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatments	3	.51	.17	3.53*
Experimental Error	12	.58	.05	
Total	15	1.09		

TABLE 8

MEANS DIFFERENCES OF FINAL AVERAGE FEED CONVERSION OF THE EXPERIMENTAL GROUPS A, B, C, AND D

	A	B	C	D
A	-	0.19	0.49*	0.15
B		-	0.31	-0.03
C			-	-0.34
D				-

Tukey's Test
MSD ($P \leq .05$) = 0.41
MSD ($P \leq .01$) = 0.75

TABLE 9

ANALYSIS OF VARIANCE OF FINAL AVERAGE DAILY PROTEIN INTAKE OF THE EXPERIMENTAL GROUPS A, B, C, AND D

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatments	3	20.57	6.86	10.22**
Experimental Error	12	8.05	.67	
Total	15	28.62		

TABLE 10

MEANS DIFFERENCES OF FINAL AVERAGE DAILY PROTEIN INTAKE OF THE EXPERIMENTAL GROUPS A, B, C, AND D

	A	B	C	D
A	-	0.99	-1.45	3.14**
B		-	0.46	2.15**
C			-	1.69*
D				-

Tukey's Test
MSD ($P \leq .05$) = 1.55
MSD ($P \leq .01$) = 2.07

TABLE 11

ANALYSIS OF VARIANCE OF FINAL AVERAGE DAILY ENERGY INTAKE OF THE EXPERIMENTAL GROUPS A, B, C, AND D

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatments	3	1637.54	545.8476	2.90
Experimental Error	12-	2256.18	188.62	
Total	15	3893.72		

TABLE 12

MEANS DIFFERENCES OF FINAL AVERAGE DAILY ENERGY INTAKE OF THE EXPERIMENTAL GROUPS A, B, C, AND D

	A	B	C	D
A	-	10.08	13.57	28.21*
B		-	3.49	18.13
C			-	14.69
D				-

Tukey's Test
MSD ($P \leq .05$) = 25.91
MSD ($P \leq .01$) + 47.15

TABLE 13

ANALYSIS OF VARIANCE OF FINAL AVERAGE BODY WEIGHT GAIN OF THE EXPERIMENTAL GROUPS A, B, C, AND D

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatments	3	16749.25	5583.08	3.05
Experimental Error	12	21578.59	1797.97	
Total	15	38263.92		

TABLE 14

MEANS DIFFERENCES OF FINAL AVERAGE BODY WEIGHT GAIN OF THE EXPERIMENTAL GROUPS A, B, C, AND D

	A	B	C	D
A	-	47.18	91.27*	48.90
B		-	44.09	1.72
C			-	-42.37
D				-

Tukey's Test
MSD ($P \leq .05$) = 79.99
MSD ($P \leq .01$) = 106.98

TABLE 15

ANALYSIS OF VARIANCE OF FINAL AVERAGE EGG WEIGHT
OF THE DIFFERENT EXPERIMENTAL GROUPS
A, B, C, AND D

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	3	6.89	2.30	2.07
Experimental Error	12	13.32	1.91	
Total	15	20.20		

TABLE 16

MEANS DIFFERENCES OF FINAL AVERAGE EGG WEIGHT OF
THE EXPERIMENTAL GROUPS
A, B, C, AND D

	A	B	C	D
A	-	0.22	1.57	1.20
B		-	1.35	0.98
C			-	-.37
D				-

Tukey's Test
MSD ($P \leq .05$) = 1.99
MSD ($P \leq .01$) = 2.66

TABLE 17

ANALYSIS OF VARIANCE OF FINAL AVERAGE HAUGH UNIT SCORES OF EXPERIMENTAL GROUPS A, B, C, AND D

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatments	3	24.54	8.15	4.97*
Experimental Error	12	19.67	1.64	
Total	15	44.12		

TABLE 18

MEANS DIFFERENCES OF FINAL AVERAGE HAUGH UNIT SCORES OF THE EXPERIMENTAL GROUPS A, B, C, AND D

	A	B	C	D
A	-	-0.97	2.28	-0.42
B		-	3.25**	0.55
C			-	-2.70*
D				-

Tukey's Test
MSD ($P \leq .05$) = 2.41
MSD ($P \leq .01$) = 3.23

TABLE 19

ANALYSIS OF VARIANCE OF FINAL AVERAGE SHELL THICKNESS OF THE EXPERIMENTAL GROUPS A, B, C, AND D

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatments	3	2.09	.70	1.06
Experimental Error	12	7.88	.66	
Total	15	9.97		

TABLE 20

MEANS DIFFERENCES OF FINAL AVERAGE SHELL THICKNESS OF THE EXPERIMENTAL GROUPS A, B, C, AND D

	A	B	C	D
A	-	-.58	-.37	-.37
B		-	.20	95
C			-	-.74
D				-

Tukey's Test
MSD ($P \leq .05$) = 1.53
MSD ($P \leq .01$) = 2.78

TABLE 21

ANALYSIS OF VARIANCE OF FINAL AVERAGE NUMBER OF LOST EGGS OF THE EXPERIMENTAL GROUPS A, B, C, AND D

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatments	3	248.20	82.73	0.42
Experimental Error	12	2370.25	197.52	
Total	15	2618.44		

TABLE 22

MEANS DIFFERENCES OF FINAL AVERAGE NUMBER OF LOST EGGS OF THE EXPERIMENTAL GROUPS A, B, C, AND D

	A	B	C	D
A	-	2.50	-5.75	-7.00
B		-	-8.25	-9.50
C			-	1.25
D				-

Tukey's Test
MSD ($P \leq .05$) = 26.51
MSD ($P \leq .01$) = 35.45

TABLE 23

ANALYSIS OF VARIANCE OF FINAL AVERAGE MORTALITY OF THE EXPERIMENTAL GROUPS A, B, C, AND D

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatments	3	390.63	130.21	0.95
Experimental Errors	12	1640.63	136.72	
Total	15	2031.26		

TABLE 24

MEANS DIFFERENCES OF FINAL AVERAGE MORTALITY OF THE EXPERIMENTAL GROUPS A, B, C, AND D

	A	B	C	D
A	-	-1250	-3.12	-9.37
B		-	9.38	3.13
C			-	-6.25
D				-

Tukey's Test
MSD ($P \leq .05$) = 22.06
MSD ($P \leq .01$) = 29.50

TABLE 25

ANALYSIS OF VARIANCE OF FINAL AVERAGE HEN-HOUSED EGG PRODUCTION OF THE EXPERIMENTAL GROUPS F AND G

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatments	1	6.23	6.23	0.07
Experimental Error	6	534.87	89.14	
Total	7	541.10		

TABLE 26

ANALYSIS OF VARIANCE OF FINAL AVERAGE HEN-DAY EGG PRODUCTION OF THE EXPERIMENTAL GROUPS F AND G

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatments	1	4.64	4.64	0.06
Experimental Error	6	491.76	81.96	
Total	7	496.40		

*Significant ($P \leq .05$)

**Highly significant ($P \leq .01$)

TABLE 27

ANALYSIS OF VARIANCE OF FINAL AVERAGE FEED INTAKE OF THE EXPERIMENTAL GROUPS F AND G

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatments	1	17.58	17.58	0.22
Experimental Error	6	487.70	81.28	
Total	7	505.28		

TABLE 28

ANALYSIS OF VARIANCE OF FINAL AVERAGE FEED CONVERSION OF THE EXPERIMENTAL GROUPS F AND G

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatments	1	0.09	0.09	0.37
Experimental Error	6	1.51	0.25	
Total	7	1.61		

*Significant ($P \leq .05$)

**Highly significant ($P \leq .01$)

TABLE 29

ANALYSIS OF VARIANCE OF FINAL AVERAGE DAILY PROTEIN INTAKE OF THE EXPERIMENTAL GROUPS F AND G

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatments	1	0.84	0.84	0.25
Experimental Error	6	20.29	3.38	
Total	7	21.13		

TABLE 30

ANALYSIS OF VARIANCE OF FINAL AVERAGE DAILY ENERGY INTAKE OF THE EXPERIMENTAL GROUPS F AND G

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatments	1	210.13	210.13	1.89
Experimental Error	6	665.75	110.96	
Total	7	7740.09		

*Significant ($P \leq .05$)

**Highly significant ($P \leq .01$)

TABLE 31

ANALYSIS OF VARIANCE OF FINAL AVERAGE BODY WEIGHT GAIN OF THE EXPERIMENTAL GROUPS F AND G

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	4024.84	4024.84	0.69
Experimental Error	6-	35065.51	5844.25	
Total	7	39090.35		

TABLE 32

ANALYSIS OF VARIANCE OF FINAL AVERAGE EGG WEIGHT OF THE EXPERIMENTAL GROUPS F AND G

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	1.04	1.04	0.36
Experimental Error	6	17.34	2.89	
Total	7	18.38		

*Significant ($P \leq .05$)

**Highly significant ($P \leq .01$)

TABLE 33

ANALYSIS OF VARIANCE OF FINAL AVERAGE HAUGH UNIT SCORES OF THE EXPERIMENTAL GROUPS F AND G

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	12.78	12.78	4.95
Experimental Error	6-	15.49	2.58	
Total	7	28.26		

TABLE 34

ANALYSIS OF VARIANCE OF FINAL AVERAGE SHELL THICKNESS OF THE EXPERIMENTAL GROUPS F AND G

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	0.01	0.01	0.01
Experimental Error	6	7.12	1.19	
Total	7	7.12		

*Significant ($P \leq .05$)

**Highly significant ($P \leq .01$)

TABLE 35

ANALYSIS OF VARIANCE OF FINAL AVERAGE NUMBER OF EGG LOST OF THE EXPERIMENTAL GROUPS OF F AND G

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	210.18	210.13	1.89
Experimental Error	6	665.75	110.96	
Total	7	875.87		

TABLE 36

ANALYSIS OF VARIANCE OF FINAL AVERAGE MORTALITY OF THE EXPERIMENTAL GROUPS F AND G

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	19.53	19.53	0.16
Experimental Error	6	742.19	123.70	
Total	7	761.72		

*Significant ($P \leq .05$)

**Highly significant ($P \leq .01$)

TABLE 37

ANALYSIS OF VARIANCE OF HEN-HOUSED EGG PRODUCTION OF THE EXPERIMENTAL GROUPS D AND G

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	7.32	7.32	0.18
Experimental Error	6	248.54	41.42	
Total	7	255.86		

TABLE 38

ANALYSIS OF VARIANCE OF FINAL AVERAGE HEN-DAY EGG PRODUCTION OF THE EXPERIMENTAL GROUPS D AND G

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	1.93	1.93	0.03
Experimental Error	6	336.35	56.06	
Total	7	338.29		

*Significant ($P \leq .05$)

**Highly significant ($P \leq .01$)

TABLE 39

ANALYSIS OF FINAL AVERAGE FEED INTAKE OF THE EXPERIMENTAL GROUPS D AND G

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	34.07	34.07	1.11
Experimental Error	6	183.53	30.59	
Total	7	217.60		

TABLE 40

ANALYSIS OF VARIANCE OF FINAL AVERAGE DAILY PROTEIN INTAKE OF THE EXPERIMENTAL GROUPS D AND G

Source Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	2.41	2.41	1.90
Experimental Error	6	7.62	1.27	
Total	7	10.02		

*Significant ($P \leq .05$)

**Highly significant ($P \leq .01$)

TABLE 41

ANALYSIS OF VARIANCE OF FINAL AVERAGE DAILY ENERGY INTAKE OF THE EXPERIMENTAL GROUPS D AND G

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	493.45	493.45	1.30
Experimental Error	6	2280.14	380.02	
Total	7	2773.59		

TABLE 42

ANALYSIS OF VARIANCE OF FINAL AVERAGE FEED CONVERSION OF THE EXPERIMENTAL GROUPS D AND G

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	0.0003	0.0003	0.0026
Experimental Error	6	0.6660	0.1110	
Total	7	0.6663		

*Significant ($P \leq .05$)

**Highly significant ($P \leq .01$)

TABLE 43

ANALYSIS OF VARIANCE OF FINAL AVERAGE BODY WEIGHT GAIN OF THE EXPERIMENTAL GROUPS D AND G

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	34.10	34.10	0.01
Experimental Error	6	20203.70	3367.28	
Total	7	20238.60		

TABLE 44

ANALYSIS OF VARIANCE OF FINAL AVERAGE EGG WEIGHT OF THE EXPERIMENTAL GROUP D AND G

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	0.82	0.82	0.34
Experimental Error	6	14.57	2.43	
Total	7	15.39		

*Significant ($P \leq .05$)

**Highly significant ($P \leq .01$)

TABLE 45

ANALYSIS OF VARIANCE OF HAUGH UNIT SCORES OF THE EXPERIMENTAL GROUPS D AND G

Scource of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	0.05	0.05	0.02
Experimental Error	6	17.13	2.85	
Total	7	17.18		

TABLE 46

ANALYSIS OF VARIANCE OF FINAL AVERAGE SHELL THICKNESS OF THE EXPERIMENTAL GROUPS D AND G

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	1.26	1.26	1.50
Experimental Error	6	5.03	0.84	
Total	7	6.29		

*Significant ($P \leq .05$)

**Highly significant ($P \leq .01$)

TABLE 47

ANALYSIS OF VARIANCE OF FINAL AVERAGE NUMBER OF LOST EGGS OF THE EXPERIMENTAL GROUPS D AND G

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	946.13	946.13	4.83
Experimental Error	6	1175.75	195.96	
Total	7	2121.88		

TABLE 48

ANALYSIS OF VARIANCE OF FINAL AVERAGE MORTALITY OF THE EXPERIMENTAL GROUPS D AND G

Source of Variation	Degree of Freedom	Sum Square	Mean of Square	F-Statistic
Treatment	1	34.07	34.07	0.10
Experimental Error	6	1296.40	201.82	
Total	7	1230.45		

*Significant ($P \leq .05$)

**Highly significant ($P \leq .01$)

TABLE 49

ANALYSIS OF VARIANCE OF FINAL AVERAGE HEN-HOUSED EGG PRODUCTION OF THE EXPERIMENTAL GROUPS F AND H

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	330.89	330.89	4.23
Experimental Error	6	469.59	78.26	
Total	7	800.47		

TABLE 50

ANALYSIS OF VARIANCE OF FINAL AVERAGE HEN-DAY EGG PRODUCTION OF THE EXPERIMENTAL GROUPS F AND H

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	353.51	353.51	4.80
Experimental Error	6	441.49	73.58	
Total	7	795.01		

*Significant ($P \leq .05$)

**Highly significant ($P \leq .01$)

TABLE 51

ANALYSIS OF VARIANCE OF FINAL AVERAGE FEED
INTAKE OF THE EXPERIMENTAL
GROUPS F AND H

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	632.97	632.97	8.18*
Experimental Error	6	464.57	77.43	
Total	7	1097.53		

TABLE 52

ANALYSIS OF VARIANCE OF FINAL AVERAGE FEED
CONVERSION OF THE EXPERIMENTAL
GROUPS F, AND H

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	0.29	0.29	1.06
Experimental Error	6	1.64	0.27	
Total	7	1.93		

*Significant ($P \leq .05$)

**Highly significant ($P \leq .01$)

TABLE 53

ANALYSIS OF VARIANCE OF FINAL AVERAGE DAILY PROTEIN INTAKE OF THE EXPERIMENTAL GROUPS F AND H

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	26.86	26.86	8.19*
Experimental Error	6	19.58	3.28	
Total	7	46.54		

TABLE 54

ANALYSIS OF VARIANCE OF FINAL AVERAGE DAILY ENERGY INTAKE OF THE EXPERIMENTAL GROUPS F AND H

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	8590.33	8590.33	8.17*
Experimental Error	6	6305.92	1050.99	
Total	7	14896.24		

*Significant ($P \leq .05$)

**Highly significant ($P \leq .01$)

TABLE 55

ANALYSIS OF VARIANCE OF FINAL AVERAGE BODY WEIGHT GAIN OF THE EXPERIMENTAL GROUPS F AND H

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	10505.25	10505.25	2.19
Experimental Error	6	28844.59	4807.43	
Total	7	39349.84		

TABLE 56

ANALYSIS OF VARIANCE OF FINAL AVERAGE EGG WEIGHT OF THE EXPERIMENTAL GROUPS F AND H

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	0.80	0.80	0.54
Experimental Error	6	8.90	1.48	
Total	7	9.70		

*Significant ($P \leq .05$)

**Highly significant ($P \leq .01$)

TABLE 57

ANALYSIS OF VARIANCE OF FINAL AVERAGE HAUGH UNIT SCORES OF THE EXPERIMENTAL GROUPS F AND H

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	11.86	11.86	10.07*
Experimental Error	6	7.06	1.18	
Total	7	18.92		

TABLE 58

ANALYSIS OF VARIANCE OF FINAL AVERAGE SHELL THICKNESS OF THE EXPERIMENTAL GROUPS F AND H

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	0.41	0.41	0.59
Experimental Error	6	4.10	0.68	
Total	7	5.50		

*Significant ($P \leq .05$)

**Highly significant ($P \leq .01$)

TABLE 59

ANALYSIS OF VARIANCE OF FINAL AVERAGE NUMBER OF EGGS LOST OF THE EXPERIMENTAL GROUPS F AND H

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	84.50	84.50	0.66
Experimental Error	6	773.50	128.92	
Total	7	858.00		

TABLE 60

ANALYSIS OF VARIANCE OF FINAL AVERAGE MORTALITY OF THE EXPERIMENTAL GROUPS F AND H

Source of Variation	Degree of Freedom	Sum of Square	Mean of Square	F-Statistic
Treatment	1	138.94	138.94	0.68
Experimental Error	6	1220.39	203.40	
Total	7	1354.33		

*Significant ($P \leq .05$)

*Highly significant ($P \leq .01$)

APPENDIX B

TABLE 1

COMPOSITION OF THE BRITISH STANDARD DIET "A"
USED IN THE EXPERIMENT

Ingredient	Percent
Yellow Corn	49.55
Ground Wheat	20.00
Soybean Meal 49%	12.50
Alfalfa Meal	0.55
Fish Meal Min 60%	3.75
Meat and Bone Meal 50%	4.00
Lime Stone	6.20
Lime Grit	2.50
Salt	0.25
Premix	0.60
DL-Methionine	0.10
TOTAL	100.00

TABLE 2

NUTRIENT COMPOSITION OF THE BRITISH STANDARD DIET "A" USED IN THE EXPERIMENT BASED ON CALCULATED ANALYSIS

Nutrient	Percent
Protein	17.52
Fat	3.28
Fiber	2.79
Calcium	3.59
Available Phosphorus	0.46
Sodium	0.17
Methionine	0.40
Cystine	0.29
Lysine	0.90
Tryptophane	0.21
Metabolizable Energy Cal./Kg.	2823.85

TABLE 3

COMPOSITION OF THE BRITISH STANDARD DIET "B" USED IN THE EXPERIMENT

Ingredient	Percent
Yellow Corn	49.50
Ground Wheat	20.81
Soybean Meal 49%	13.25
Alfalfa Meal 17%	1.00
Fish Meal Min 60%	2.50
Meat and Bone Meal 50%	4.00
Lime Stone	5.50
Lime Grit	2.50
Salt	0.25
Premix	0.60
DL-Methionine	0.09
TOTAL	100.00

TABLE 4

NUTRIENT COMPOSITION OF THE BRITISH STANDARD DIET "B" USED IN THE EXPERIMENT BASED ON CALCULATED ANALYSIS

Nutrient	Percent
Protein	17.27
Fat	3.08
Fiber	2.39
Calcium	3.72
Available Phosphorus	0.42
Sodium	0.16
Methionine	0.38
Cystine	0.29
Lysine	0.88
Tryptophane	0.21
Metabolizable Energy Cal./Kg.	2835.42

TABLE 5

COMPOSITION OF THE BRITISH STANDARD DIET "C" USED IN THE EXPERIMENT

Ingredient	Percent
Yellow Corn	38.50
Ground Wheat	35.00
Soybean Meal 49%	10.00
Alfalfa Meal 17%	1.00
Fish Meal Min 60%	2.50
Meat and Bone Meal 50%	4.00
Lime Stone	6.60
Lime Grit	1.47
Salt	0.25
Premix	0.60
DL-Methionine	0.08
TOTAL	100.00

TABLE 6

NUTRIENT COMPOSITION OF THE BRITISH STANDARD DIET "C" USED IN THE EXPERIMENT BASED ON CALCULATED ANALYSIS

Nutrient	Percent
Protein	16.94
Fat	2.89
Fiber	2.36
Calcium	3.66
Available Phosphorus	0.42
Sodium	0.17
Methionine	0.36
Cystine	0.30
Lysine	0.79
Tryptophane	0.20
Metabolizable Energy Cal./Kg.	2838.44

TABLE 7

COMPOSITION OF THE BRITISH STANDARD DIET "D" USED IN THE EXPERIMENT

Ingredient	Percent
Yellow Corn	39.50
Ground Wheat	35.00
Soybean Meal 49%	9.05
Alfalfa Meal 17%	1.53
Fish Meal Min 50%	2.50
Meat and Bone Meal 50%	4.00
Lime Stone	5.00
Lime Grit	2.50
Salt	0.25
Premix	0.60
DL-Methionine	0.07
TOTAL	100.00

TABLE 8

NUTRIENT COMPOSITION OF THE BRITISH STANDARD DIET "D" USED IN THE EXPERIMENT BASED ON CALCULATED ANALYSIS

Nutrient	Percent
Protein	16.27
Fat	2.82
Fiber	2.67
Calcium	3.45
Available Phosphorus	0.37
Sodium	0.16
Methionine	0.34
Cystine	0.29
Lysine	0.74
Tryptophane	0.19
Metabolizable Energy Cal./Kg.	2833.55

TABLE 9

COMPOSITION OF THE TYPICAL EGG LAYING HEN RATION USED IN MICHIGAN "E" USED IN THE EXPERIMENT

Ingredient	Percent
Yellow Corn	70.74
Soybean Meal 49%	13.15
Oil	0.50
Fish Meal Min 60%	1.00
Meat and Bone Meal 50%	6.50
Lime Stone	6.70
Dicalcium Phosphate	0.50
Salt	0.25
Premix	0.60
DL-Methionine	0.06
TOTAL	100.00

TABLE 10

NUTRIENT COMPOSITION OF THE TYPICAL EGG LAYING RATION USED IN MICHIGAN "E" USED IN THE EXPERIMENT BASED ON CALCULATED ANALYSIS

Nutrient	Percent
Protein	16.54
Fat	4.01
Fiber	2.48
Calcium	3.39
Available Phosphorus	0.55
Sodium	0.17
Methionine	0.34
Cystine	0.26
Lysine	0.81
Tryptophane	0.18
Metabolizable Energy Cal./Kg.	2958.32

TABLE 11

COMPOSITION OF THE DIET "G" USED
IN THE EXPERIMENT

Ingredient	Percent
Yellow Corn	67.62
Soybean Meal 49%	12.95
Alfalfa Meal 17%	3.50
Fish Meal Min 60%	0.50
Meat and Bone Meal 50%	7.00
Lime Stone	6.80
Dicalcium Phosphate	0.70
Salt	0.25
Premix	0.60
DL-Methionine	0.08
TOTAL	100.00

TABLE 12

NUTRIENT COMPOSITION OF THE DIET "G" USED IN THE EXPERIMENT BASED ON CALCULATED ANALYSIS

Nutrient	Percent
Protein	16.51
Fat	3.48
Fiber	3.24
Calcium	3.55
Available Phosphorus	0.59
Sodium	0.17
Methionine	0.34
Cystine	0.27
Lysine	0.81
Tryptophane	0.19
Metabolizable Energy Cal./Kg.	2844.22

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