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I am submitting herewith a thesis written by Yalcin Suren entitled "The Comparison of Barley and Corn and Barley and Oats as Major Protein Sources in Diets for Laying Pullets." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Poultry.

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**A COMPARISON OF BARLEY AND CORN AND BARLEY
AND OATS AS MAJOR PROTEIN SOURCES IN DIETS FOR LAYING PULLETS**

**A Thesis
Presented to
the Graduate Council of
The University of Tennessee**

**In Partial Fulfillment
of the Requirements for the Degree
Master of Science**

**by
Yalcin Suren
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ABSTRACT

Experiments were conducted to evaluate yellow corn, barley, oats and combinations of corn or oats with barley as the major protein source in diets for laying pullets.

In trial 1, corn and barley were compared. Six diets were fed calculated to contain 8.26 percent of crude protein (7.16 percent from grain and 1.1 percent from non-variables) and about 2966 kilocalories of metabolizable energy per kilogram. The diets were formulated so that 0, 20, 40, 60, 80, or 100 percent of grain protein was supplied by barley and the remainder by corn.

Mortality, egg quality, egg size, and feed consumption were not significantly ($P > 0.05$) influenced by the experimental diets. Average egg production was lower for pullets fed the all-barley diet than for those fed the corn and the barley-corn combinations ($P \leq 0.05$). Barley fed hens produced much lighter colored yolks of eggs than hens fed the corn and corn-barley mixtures. The average weight was less as the percentage of corn was increased in the diet. The birds receiving the all-corn diet lost more body weight than those fed all-barley and barley-corn combinations.

In trial 2, barley and oats were compared. The diets were calculated to contain the same protein and metabolizable energy levels as used in trial 1. The diets were formulated as in trial 1.

Mortality, egg quality, egg weights, and egg size were not significantly ($P > 0.05$) influenced by the experimental diets. The pullets receiving the all-oats diet had the lowest rate of egg

production, the difference being significant at the 5 percent level of probability. As the percent oats increased in the diet, the egg production tended to decrease. The birds receiving all-oats diets consumed more feed per dozen eggs produced, and lost more body weight than the other groups of birds.



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I. INTRODUCTION

The poultry industry in Turkey is not presently of major economic importance, nor do poultry and poultry products constitute a large portion of the nation's diet. The average annual per capita egg and poultry meat consumption is low in Turkey when compared with other countries. The following reasons cause the low standing of the poultry industry in Turkey: (1) most poultrymen are unfamiliar with the dietary requirements of poultry, (2) production techniques are very primitive, and (3) rations and feeding techniques are poor (Acil, 1960).

Protein is a major important constituent in the diet of laying chickens. Scott et al. (1969) stated that the scientific protein requirements of poultry is no longer based upon the crude protein content of the diet. Instead, the dietary levels and biological availability of each essential amino acid are considered, together with a sufficient dietary level of non-essential amino acid nitrogen to supply the chicken at the cellular level with all of the elements needed to synthesize all its body and egg proteins efficiently and economically.

For a high percent of production and efficient utilization of feed, the essential amino acids must be present in a sufficient amount in a diet. Most of the proteins in natural feedstuffs are deficient in one or more of the essential amino acids, and the protein content of the grains is too low to support the maximum egg production. In feeding poultry, efficient results cannot therefore be secured unless protein supplements of good quality

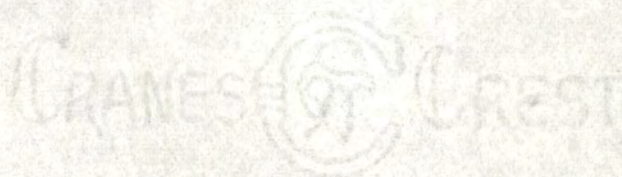
are fed in addition to grain, so that sufficient amounts of these amino acids will be supplied. In recent years efforts have been undertaken to improve the poultry business in Turkey to meet the increasing demand for eggs and poultry meat. Special attention has been given to the optimal use of indigenous feedstuffs (Onel, 1967). Cereal grains such as barley, oats, and wheat are grown extensively in Turkey. Corn is ususally grown in the northern part of Turkey. These four grains are widely used as food for man and as feed for animals.

The first Five-Year Development Plan in Turkey gave great importance to the poultry field and it is expected that it will continue to do so. It is expected that in the second Five-Year Development Plan, the egg and poultry meat production will be two times higher than in the previous program (Gunduz, 1971).

Soybean meal and fish meal, which are widely used in poultry rations in the united States, are quite costly in Turkey because of low production of soybean and fish meal. Oats, barley, wheat, and corn are lower in price, and industrial (commercially manufactured feed) laying feed, a locally produced feedstuff, is often a less expensive protein supplement than soybean and fish meal. The industrial feed contains sunflower meal, blood meal, fish meal, cottonseed meal, soybean meal, sesame meal, and dried trefoils, and sufficient amounts of vitamins and minerals (Anonymous, 1971). In general, barley, oats, corn, and wheat bran are usually used at the same time in the diet (Onel, 1967).

Although recent studies have provided more information on the nutritive requirements of chicken, and new feed supplements

have been made available for poultry feeds, there have been very few reports of experimental studies concerning the nutritive value of these cereal grains for poultry in Turkey.



II. OBJECTIVE

The objective of this study was to evaluate the quality of the protein in yellow corn, barley, and oats and combinations of corn and barley or of barley and oats as the principal protein source in protein deficient, isonitrogenous, isocaloric diets for laying pullets.

III. LITERATURE REVIEW

Nutritional Characteristics of Corn, Barley, and Oats as Cereal Grains for Feeding Poultry

Corn, grain sorghums, barley, wheat, and oats are the major grains used for feeding poultry.

Yellow corn

Corn has been the most widely used single grain in poultry feeding. Its extensive use is the result of a combination of desirable characteristics. It is palatable, readily digested, and is low in crude fiber.

A feedstuff analysis table (Commerical Solvents Corporation, 1970) showed that the average protein content of yellow corn is 8.9 percent, the average metabolizable energy content is 3432 kilocalories per kilogram; and the average vitamin A activity is 2200 international units per kilogram. Scott et al. (1969) reported that the average xanthophyll content of yellow corn was 25 milligram.

The limiting factor in the growth promoting ability of corn protein, zein, is the relatively low content of lysine residues. It is also low in calcium (Morrison, 1961; Ewing, 1963; and Shaible, 1970).

Ewing (1963) concluded that corn is a better single grain than oats for egg production but mortality is lower with hens fed a high oats diet.

First year corn is desirable because if corn is stored for a long time--a year or more--yellow corn tends to lose 30 percent

or more of its vitamin A activity (Titus, 1949).

Barley

A feedstuff analysis table (Commercial Solvents Corporation, 1970) gave the average protein content of barley as 11.6 percent, and the average metabolizable energy content as 2640 kilocalories per kilogram.

The protein in barley is low in lysine. Barley has no xanthophyll nor vitamin A activity and is less palatable than corn. Frequently, birds have to be trained to eat it. Barley is higher in niacin than corn, thus a niacin deficiency never occurs when barley is fed as the principal part of the diet. Barley contains more fiber than corn but less than oats (Morrison, 1961; Ewing, 1963; and Shaible, 1970).

Fry et al. (1957a) reported that water treating ground barley markedly improved the nutritional value of barley for the chick. The growth rate and feed efficiency with treated barley were practically equal to those obtained with corn.

Jensen et al. (1957) reported a significant growth and feed efficiency response to a commercial enzyme preparation--"Clarase 300"-- was obtained with chicks fed diets containing pearled barley. Rations containing either water treated pearled barley or untreated pearled barley plus the enzyme preparation supported growth and gave a feed efficiency comparable with diets containing corn.

The enzyme--"Clarase 300"--contains a mixture of many enzymes in addition to amylolytic enzymes.

Dobson and Anderson (1958), and Nelson and Hutto (1958) reported that the nutritional value of hullless barley was improved

by the addition of crude fungal and bacterial enzymes and by water soaking. Other investigators (Gerry, 1969; and Willingham et al., 1959) reported no chick growth response when alpha amylase was added to barley diets, but they obtained growth response to water treatment of barley or the use of enzyme supplements (fungal and bacterial enzyme).

Willingham et al. (1960) reported that barley grown in the midwest and east, in the United States, did not respond significantly to enzyme supplements (fungal and bacterial enzymes) as did barley grown in the west. These differences were resolved when it became apparent that barley which was improved by water treatment was grown in semi-arid regions while the barley giving no response to water treatment was grown in regions where moisture during harvest was relatively high.

Adams and Naber (1969a,b) reported that the nutritional value of barley and wheat was improved by soaking the grains in water, 0.1 or 0.2 normal hydrochloric acid solution or aqueous solutions of alpha amylase, Agrozyme (a mixture of amylitic and proteolytic enzymes), and DawEnzyme.

Oats

Heuser (1946) concluded that oats make a desirable grain for poultry feeding, but they should be restricted to plump, heavy oats. For poultry feeding, they should weigh 40 pounds or better to the bushel. The heavy, favorable oats should not have more than 10 percent fiber. They are not as palatable to chickens as wheat or corn, which are usually eaten first.

Oats have the same general amino acid deficiencies as other

grains. A feedstuff analysis table (Commercial Solvents Corporation, 1970) gives the average protein content of oats as 12 percent and the average metabolizable energy content as 2552 kilocalories per kilogram. Oats are low in calcium, riboflavin, and niacin. Oats lack carotene, xanthophyll, and vitamin A, and consequently are not used extensively in poultry feed of today, except when the price is favorable (Morrison, 1961; Ewing, 1963; and Shaible, 1970).

Wilcke (1940) suggested that up to 40 percent, or perhaps even more, of the ration of the growing chick, the laying hen, and the turkey could be made of oats, when the quality is good and the price justifies it.

Shaible (1970) concluded that high oat diets produce chicks with light or no yellow pigment in the beaks and shanks. Where oats are the main cereal in the chick ration, there is less slipped tendons due to higher manganese content of oats than is the case with corn.

Cereals in the Laying Diets

Elford (1928), according to Heuser (1946), reported that on five out of six experimental farms, barley gave more economical production when fed in place of corn. On several farms greater egg production was made on corn but at a greater cost.

Kennard and Chamberlin (1936) reported that rations were improved when 20 to 40 percent of corn was replaced with a like amount of oats. There was practically no difference according to the form in which they were fed. With the free choice system of feeding whole oats, feather picking and cannibalism largely disappeared.

From a review of published data, Crampton (1936), according to Heuser (1946), indicated that the cereals might be rated in the following order: for growth oats, barley, maize, wheat, and rye; for laying and breeding maize, barley, wheat, oats, and rye; for fattening maize, barley, wheat, and oats. When the ration is scientifically balanced, the differences between barley, maize, and wheat are very small and likely to be masked in many cases by differences in the quality of different samples of grains. A mixture of two or more cereals is preferred to the exclusive use of any single one.

The various grains differ in their value for poultry feeding. If used singly in large amounts, the results will be influenced by the nature of the grain. Experiments at the Iowa Agricultural Experiment Station (Wilcke, 1937) showed that rations consisting largely of ground oats are more satisfactory for chicks than rations containing large amounts of barley, wheat, or corn. However, Heuser et al. (1944) reported that rations containing feed ingredients of a fibrous nature such as oats and wheat by-products were less efficient for growth, egg production, and maintenance of body weight than feeds of a less fibrous nature such as whole wheat and corn.

Taylor, et al. (1944) stated that a ration composed of a high proportion of corn, fed continuously during the first 18 months of life, produced a significantly higher laying hen mortality than a similar ration in which a large part of the corn had been replaced by barley and alfalfa meal.

Carrick and Roberts (1948) conducted experiments which

measured in a definite way the relative value of heavy and light weight oats in comparison with corn. When ground heavy oats (39 pounds per bushel) replaced 20 percent of the ground yellow corn in a ration known to give rapid growth, the gains in weight and the feed-gain ratios were almost identical. When ground light oats (28 pounds per bushel) replaced 20 percent of the ground yellow corn in the ration, more feed was required per unit of gain than when the oats were not included. Furthermore, the oat ration retarded the rate of growth.

Berg et al. (1956) showed that under the climatic conditions of Western Washington, hens will lay equally well on corn and barley diets. However, barley was found to be only 82.7 percent as efficient as corn in the production of eggs. It was also noted that hens fed barley rations voided a larger volume of wetter dropping than did hens fed corn diets.

Fry et al. (1957b) compared the feeding value of barley and pearled barley with corn. They reported that a marked depression in growth and feed utilization occurred when either barley or pearled barley was substituted for all of the corn in a ration. Removal of approximately 17 percent of the outer portion of the barley through a pearling process slightly improved the feeding value of barley.

Moran and McGinnis (1967) reported on experiments with both chicks and poults using diets in which the cereal grain was either corn or western barley. Birds fed the corn basal rations always grew better than those birds fed the barley basal rations. Enzyme supplementation (bacterial amylase) significantly improved the

growth of birds fed the diets containing barley.

Onel (1967) reported that satisfactory egg production was obtained with a diet containing 20 percent barley, 21 percent oats, 16 percent corn and 14.5 percent wheat bran.

Smith and Chancey (1967) reported that a mixture of wheat and oats (50:50) was found to be superior to wheat alone when fed without protein supplement. The required level of supplemental fish meal for optimal performance decreased from 5 percent to 2 percent on the mixed grain diet. The need for as little as 2 percent protein supplement (excluding alfalfa meal) to maximize egg weight and egg numbers on the wheat-oats mixture demonstrates that all-grain rations for laying hens may be a reasonable objective, at least for areas experiencing little hot weather during the laying year.

Barley, oats, wheat, and corn were individually tested as the sole grain at three different protein levels (10, 12.5, and 15 percent) for caged layers by Lillie and Denton, (1967). All diets were isocaloric for each protein level. They reported that the higher the protein level, the greater was egg production and body weight gains. Feed consumption per dozen eggs was greater on 10 percent than on higher protein levels. They concluded that grain effects for egg production showed a rank in decreasing order: oats corn wheat barley, regardless of protein level. The birds fed the oats diet produced the greatest body weight gains, had lower mortality than the birds fed wheat, and had lower feed intake per dozen eggs than the birds fed barley, wheat or corn. Grain x protein interactions indicated that oats was superior to

barley, wheat, and corn for egg production in a 10 percent protein diet and for body weight gains on 10 and 12.5 percent protein diets.

Biely et al. (1970) reported that satisfactory egg production was obtained when wheat served as the only source of protein in the laying ration (excluding 2 percent cereal grass). The ration was supplemented with lysine and methionine. Egg weight was lower when hens were fed the wheat ration than when fed the control ration (wheat and corn supplemented with soybean meal).

Protein Requirements of Laying Hens

It has been customary for many years to express the protein requirements of chicks and hens as a percentage of the diet. While this is a convenient method of measurement from the standpoint of formulation of diets, it is undoubtedly a less accurate way of stating the requirement than to consider it as a definite quantity of protein required per day for the particular functions which the animal performs.

When expressed as a percentage of the diet, the protein requirement of both chicks and layers is affected by every factor which influences rate of feed consumption. If it is considered that the protein requirement is a definite quantity per day, it must be provided in the feed consumed in that interval of time. As the efficiency of the diet is increased by raising its energy concentration, a smaller amount of feed is consumed to meet the energy requirement and the fixed quantity of protein required must be supplied by this smaller amount of feed. Therefore, it would be expected that the protein requirement as a percentage of the

diet would increase progressively as the energy content of the diet is increased (Ewing, 1963; Scott et al., 1969; and Schaible, 1970).

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

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

Investigators have found much variation in the protein requirements of laying hens. For example, Graham (1934), Miller et al. (1957), Thornton et al. (1957), and Adams et al. (1958) reported that the hen requires only 12-13 percent protein. However, Heuser (1941), Heywang et al. (1955), and Lillie and Denton (1966) reported that the protein required for optimum production was at least 15 percent, while Reid et al. (1951) and Milton and Ingram (1957) stated that an 18 percent protein ration was superior for egg production to either a 13 or 15 percent ration.

Hill and Anderson (1955) concluded that a smaller type Leghorn hen had a higher protein requirement than did a heavier type. In the same report these authors also reported that increasing the energy level with animal fat appeared not to increase the protein requirement and that the higher energy level may have slightly spared this nutrient.

Thornton et al. (1957) reported that the incidence of small eggs was greater in birds fed diets containing 11 percent protein

than in those fed a 17 percent level of protein. DL-methionine was effective in changing the incidence of small eggs at protein levels ranging from 11 to 17 percent.

Waibel (1959) and Scott et al. (1969) concluded that several factors have been suggested as being predominant in effecting a possible change in protein needed for egg production. Among these suggested factors are (1) size and breed of hen, (2) environmental temperature, (3) stage of production, (4) cage management, (5) protein quality, (6) age of birds, and (7) energy content of the diet.

Efficiency of protein utilization depends, among other things, upon the amino acid pattern of the diet. Dietary amino acid pattern in turn is determined by the choice of protein source materials and the proportions in which they are combined. It can also be modified by supplementation of the diet with crystalline amino acids. Attempts have been made to reduce protein in laying rations by feeding less than the accepted 15 percent crude protein. To achieve these lower protein levels, however, the proportion of dietary protein coming from grain is usually increased while that from non-grain sources is decreased. The amino acid pattern of the diet is consequently altered with the result that changes in dietary protein level and amino acid pattern are confounded.

Changes in amino acid pattern have been counteracted in part by supplementation with crystalline amino acids. For example, it has been shown that supplementary lysine can improve the performance of birds fed low protein diets (Thornton et al., 1957; Waibel and Johnson, 1961; and Schaible, 1970). Methionine

supplementation, on the other hand, appears to be more beneficial at higher protein levels or in low protein diets already supplemented with lysine (Sell, 1964; Harms and Waldroup, 1962; Barton and Stephenson, 1960). This is most likely because grains, which, as a class, are low in lysine, provide most of the protein in low protein diets; whereas a greater proportion of soybean meal, a poor source of methionine, is used in formulating diets of higher protein content. In spite of this possibility, there is a tendency to believe that responses to these amino acids result from the low protein feeding (Seel, 1964; Harms and Waldroup, 1962; Barton and Stephenson, 1960; and Bradley and Quisenberry, 1961).

Quisenberry and Bradley (1962) reported that egg weights were significantly improved with each increase of dietary protein when using 13, 15, and 17 percent levels and one percent added fat.

Novacek and Carlson (1969) fed laying hens diets containing 9.4 percent protein. They showed that egg production, feed conversion and egg weights were improved by supplements of methionine and lysine.

Scott et al. (1969), and Schaible (1970) concluded that the laying White Leghorn hen deposits about six grams of protein in an average egg and the hen requires about three grams of protein daily for maintenance of the protein tissues of the body. Thus, a daily intake of approximately 10 grams of protein should be sufficient for maintenance of body tissues and maximum egg production in mature hens. Leghorn hens must consume about 17.5-18.5 grams of protein per day because a hen is only about 55 percent efficient in converting the protein of present-day practical diets into egg

protein and into the protein and other nitrogenous compounds required for maintenance.

The protein requirements of laying hens, during phases I and II, as given by Scott et al. (1969) and Schaible (1970), are as follows: 13.7-20 percent and 13-22 percent of the diet depending upon energy content of the diet, feed consumption, and environmental temperature. The protein requirement of laying hens as given by the National Research Council (1966) is 15 percent of the diet.

Amino Acid Requirement

Almquist (1952) and Miller et al. (1954) reported that lysine, methionine, tryphophan, leucine, and isoleucine were essential for egg production with the use of proteins deficient in one or more amino acids. Johnson and Fisher (1956) reported that arginine, glutamic acid, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine were found to be essential for egg production. With the exception of glutamic acid, omission of any one of the above amino acids resulted in immediate disruption of feed consumption. Although feed consumption was not affected by the omission of glutamic acid, normal egg production could not be maintained.

Maddy (1958) stated that all essential amino acids must be present in a specific amount for a particular tissue synthesis. If one of the essential amino acids is deficient, it will limit the utilization of the other amino acids. The amino acid requirement of an animal may be affected by the level of total protein and energy of the diet, the animal's plane of nutrition, the ratio of

the amino acids to each other, and the age and strain of the animal.

Bray (1964) found that isoleucine and lysine were the most limiting essential amino acids among several explored in 8.5 percent protein layer diets in which a 60:40 blend of corn and soybean protein were the sole sources of protein.

Bray (1965) showed that the sulfur-containing amino acids are considerably more limiting than any other essential amino acid when soybean meal was the sole source of protein in layer diets. When corn was the major source of protein in low protein corn-soya diets, lysine was found to be more limiting than sulfur-containing amino acids by Bradley and Quisenberry (1961), Harms and Waldroup (1962) and Britzman and Carlson (1965).

Creek (1968) has called attention to the fact that when phenylalanine is converted to tyrosine the molecular weight increases approximately from 1 to 1.1. Conversely, when methionine is converted to cystine, weight decreases from 1 to 0.805. These facts should be taken into account in calculating conversions.

Dean and Scott (1968) further demonstrated that up to 0.73 percent arginine overcomes the depressive effect of adding excess lysine (1.25 percent) but that the utilization of arginine decreased with each added increment.

Manoukas and Young (1969) reported that the addition of 3.0 percent of a non-essential amino acids mixture (L-aspartic acid, DL-alanine and glycine) to a 12.5 percent protein diet supported egg production equivalent to that of hens fed either 15.5 percent protein or hens fed a practical control diet. They also added that a total intake of 14.4 to 15 grams of protein per hen per day

supported optimum egg production. At this protein intake, the ratio of essential amino acids to non-essential amino acids could vary from 0.7 to 1.1 without influencing the performance of the hen provided the diet contained at least 12.5 percent of the intact protein.

Shaible (1970) concluded that the amino acids requirements of poultry should be based on daily intake, not as a percentage of the diet. Many factors modify requirements: growth rate, body size, egg production, body composition, genetics, and environmental temperature. Amino acid balance involves relationships with other nutrients. In a study with chicks they found that increasing the energy content of the ration without also increasing the protein content actually resulted in less growth. When both protein and energy were increased, expected improvement in performance was obtained. Another consideration is balance between essential amino acids. An indiscriminate increase in protein is not a good way to improve amino acid balance. To accurately meet requirements, one must know quantitative needs and exact composition of the available feed ingredients.

The recommended levels of amino acids for laying hens as given by the National Research Council (1966) and Scott et al. (1969), respectively, are as follows: arginine - 0.8 percent, 0.8 percent; cystine - 0.25 percent, 0.26 percent; histidine - 0.3 percent, 0.3 percent; isoleucine - 0.5 percent, 0.8 percent; leucine - 1.2 percent, 1.2 percent; lysine - 0.5 percent, 0.64 percent; methionine - 0.28 percent, 0.32 percent; phenylalanine -

0.70 percent, 0.70 percent; threonine - 0.40 percent, 0.55 percent; tryptophan - 0.15 percent, 0.16 percent; and valine - 0.8 percent, 0.8 percent.

Energy-Protein Relationship

The importance of maintaining protein and energy in a specific relationship (protein-calorie ratio) in poultry diets has been shown in chick nutrition studies by Hill and Dansky (1950), Leon et al. (1955), Donaldson et al. (1955, Scott et al. (1955), Gordon and Maddy (1956), and Sunde (1956). These studies have shown in general that as the energy content of the ration is increased, the percent of the protein required for best feed efficiency and growth is also increased. A high level of energy from carbohydrate and fat in relation to protein produces a high level of fat deposition; fat content is markedly reduced when a high level of protein in relation to energy from fat and carbohydrate is employed. In general, these principles were shown by Hill (1956) to apply to the nutrition of layers.

Hill et al. (1956) studied the effect of dietary energy levels on the rate of egg production. They kept the protein level constant, but the energy levels varied from 740 to 940 Calories of productive energy per pound. They reported that good egg production was obtained when the experimental diets contained 12.5 to 13 percent protein. Egg production was not affected by the level of energy used in this experiment.

It is important to realize that protein is a source of amino acids, but that calorie-protein ratios obviously are

dependent upon the amino acid quality of the protein involved. Undoubtedly, accurate ratios of amino acids to energy would be more dependable since the protein quality of a ration may sometimes be appreciably changed as the calorie-protein ratio is modified (Combs, 1956).

Harms et al. (1957) reported that a high energy feed supported a higher rate of egg production with better utilization of feed than did a low energy feed. They found this difference to exist throughout the year although there was a trend for the difference in egg production of the two groups to narrow with the onset of warm weather.

Hochreich et al. (1957) reported that suddenly changing the calorie-protein ratio in the feed had no deleterious effect upon rate of egg production. They used five different levels of productive energy varying from 941 to 1072 Calories and protein levels ranging from 15.70 to 16.99 percent in five diets..

Hochreich et al. (1958) reported that 17 percent protein in the feed was required to maintain maximum egg production and feed efficiency when the feed contained at least 950 Calories of productive energy per pound. The addition of 6.6 percent stabilized yellow grease to this diet significantly improved feed efficiency, but was without effect on egg production. They also concluded that the addition of the grease resulted in increased egg weights, but egg shell thickness decreased.

MacIntyre and Aitken (1957) reported that neither the high energy nor the high protein diet fed to birds influenced egg production or egg weight. The energy content of the diets

varied from 700 to 900 Calories of productive energy per pound.

Combs et al. (1961) stated that rate of increase in egg size was reduced following energy restriction of heavy type layers and they concluded that egg weight was related to energy content of the diet.

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

Bragg and Hodgson (1969) conducted experiments with diets containing three levels of metabolizable energy (2794, 2570, and 2354 kilocalorie per kilogram) yet maintained the protein constant at 16.1 percent. The diet containing 2354 kilocalorie per kilogram was divided into two parts with wheat bran or wheat straw replacing wheat, so there were two dietary treatments at the low energy level. They reported that no differences were found in egg production between the three levels of dietary energy or between low energy (wheat bran and wheat straw) rations. Egg weight decreased slightly from the high to the low dietary energy level, but no change was observed between the two low energy rations. Feed consumption increased significantly as energy was decreased in the laying rations with a concomitant change in efficiency of feed utilization.

Scott et al. (1969) concluded that the White Leghorn hen can adjust her feed consumption to obtain adequate energy when receiving laying diets ranging in energy from approximately 2500 to 3300 kilocalorie metabolizable energy per kilogram of diet.

When the energy is decreased, a greater quantity of feed is consumed and a lesser amount when the energy is increased; thus it is necessary to adjust the protein content of the diet in relation to the energy level. Daily minimum protein requirements of laying hens ranged from 15 to 18 grams according to the three phases of egg production.

Bray's Methods for Evaluating Protein Quality of the Feedstuffs

Bray (1960), when studying the deficiencies of corn and soybean oil meal diets for laying hens, used assay diets which contained either 9 or 10 percent protein. He believed that these low protein diets would insure sensitivity to graded combinations of corn and soybean protein. In this early study he used pullets of 182, 205, and 203 days of age and continued the assay for 13 weeks.

Bray and Gesell (1961) reported that when pullets were fed low protein diets, egg production was affected and varied with season, but no such effect was observed when the diets contained an adequate level of protein.

In 1962, Bray and Morrissey reported that the level of feed consumption and, hence, protein intake, was influenced by environmental temperature.

Bray (1968) continued to adjust his assay. His basal diets continued 8.5 percent protein. He concluded that an assay period of eight weeks was sufficient. His reports indicated that one lot of pullets was used only for one assay.

IV. EXPERIMENTAL PROCEDURE

General

Experimental Animals

Babcock B-300 Single Comb White Leghorn pullets were used in two trials. At 20 weeks of age, the chickens were vaccinated for Newcastle disease and infectious bronchitis by the intra-ocular method and for fowl pox by the wing stab method, leg banded, and housed two birds per 8 by 16 inch cage. They were fed a 17 percent protein layer diet (Table I) for about two months before being assigned to the test diets.

Trial 1 was conducted during the time the pullets were 29 to 36 weeks of age. Following this the birds were fed a 17 percent protein laying diet for eight weeks to permit recovery from the effects of the diets fed in trial 1. Before starting trial 2, non-producing birds were removed from the flock. Trial 2 was conducted during the time the pullets were 44 to 52 weeks of age.

Sources of Grains

Number 2 barley, number 2 finely ground white oats and number 2 yellow corn, as obtained from commercial sources, were used. To determine the crude protein, samples of each grain were analyzed by the Kjeldahl method ($N \times 6.25$) as described by Triebold (1946). The protein content of barley and of corn was 10.10 percent and 8.48 percent, respectively, in trial 1. In trial 2, the protein content of barley was 10.19 percent, and of oats 13.10 percent.

TABLE I
COMPOSITION AND CALCULATED ANALYSIS OF THE 17 PERCENT
PROTEIN LAYER DIET

Feedstuffs	Percent
Yellow corn	66.975
Alfalfa meal, 17% protein	5.000
Fish meal, 65% protein	2.500
Vitamin mix ¹	0.600
Defluorinated rock phosphate	1.500
Ground limestone	6.000
Salt	0.500
Manganese sulfate	0.025
Soybean oil meal, 50% protein	17.000
Total	100.000
Calculated analysis:	
Crude protein, %	17.19
Metabolizable energy, Cal./kg.	2816.00
Calcium, %	2.957
Phosphorus, %	0.621
Vitamin A, I.U./kg.	15671.00
Vitamin D ₃ , I.C.U./kg.	2952.00
Riboflavin, mg./kg.	6.448
Niacin, mg./kg.	45.496
Pantothenic acid, mg./kg.	11.968
Choline, mg./kg.	1389.19

¹227 grams vitamin mix supplies vitamin D₃, 134,187 I.C.U.; vitamin A, 111,823 I.U.; riboflavin, 201 mg.; vitamin B₁₂, 0.295, choline 20,000 mg.; niacin, 1,097 mg.; and pantothenic acid, 216 mg.

Diets

In each trial six different diets were fed. They were calculated to contain 8.26 percent of crude protein and 2966 kilocalories of metabolizable energy per kilogram.

The concept of evaluating the protein quality of feedstuffs by using low protein diets as described by Bray (1964) was employed in formulating the diets for evaluating corn, barley, and oats as cereal grains for layers.

Since corn has the lowest protein and the highest energy content of the grains studied, sugar and fat were added to the barley, oats and the combination diets in order to make all diets iso-nitrogenous and iso-caloric.

The formulations were based upon analyzed values for the crude protein of the corn, barley and oats sources used, and upon the energy level of feed ingredients as reported by the Commercial Solvents Corporation (1970). Feed and water were available to the chickens at all times.

The non-variable (dehydrated alfalfa meal, mineral, and vitamin concentrates) made up 15.525 percent of the diet, and supplied 1.1 percent protein. The remainder of the diet consisted of the grain or grains being studied, with or without fat and/or sugar, with the cereal grains providing the balance of the dietary protein (1.16 percent).

Trial 1

A total of 720 pullets, 28 weeks of age, in groups of 30 birds each, were assigned dietary treatments according to a

randomized complete block design with four replications. The blocks of groups of cages selected to allow removal of some of the environmental effects when the data were analyzed. Any bird that died during the first week of the study was replaced with one that had been fed the 17 percent protein layer diet.

In this trial diets based on yellow corn, or barley or combinations of corn and barley were compared (Table II). The diets were formulated so that 0, 20, 40, 60, 80, or 100 percent of the grain protein was supplied by corn and the remainder by barley. The calculated amino acid composition of the diets is shown in Table III.

Egg production was recorded on five days each week and adjusted to seven days on a group basis throughout the laying period. Egg production was calculated for each group as percent hen-day production. Feed consumption was determined each 28 days for each group.

Egg weights in grams were obtained by individually weighing all eggs collected from each group one day every week during the experimental period.

On the twenty-eighth day, all eggs from each group were used to obtain an estimate of shell thickness using the specific gravity method which was used in the Thirteenth Tennessee Random Sample Laying Test (1970). Eggs were subjected to a series of salt solutions, ranging in specific gravity from 1.068 to 1.100, by increments of 0.004. A score of 0 was given to eggs having a specific gravity of less than 1.068, eggs having a specific gravity higher than 1.100 were given a score of 9.

TABLE II

COMPOSITION AND CALCULATED ANALYSIS OF THE LAYING DIETS, TRIAL 1

Feedstuffs	Percent of grain protein supplied by						
	Barley	100	80	60	40	20	0
	Corn	0	20	40	60	80	100
				percent			
Barley	70.891	56.063	42.574	28.317	14.257	--	--
Corn	--	16.981	33.726	50.707	67.452	84.475	84.475
Non-variables ¹	15.525	15.525	15.525	15.525	15.525	15.525	15.525
Animal fat	13.584	10.798	8.116	5.397	2.716	--	--
Sugar	--	0.062	0.059	0.054	0.050	--	--
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated analysis:							
Crude protein, %	8.26	8.26	8.26	8.26	8.26	8.26	8.26
Metabolizable energy, Kcal/kg.	2969.04	2966.85	2966.83	2966.83	2966.83	2966.83	2966.83

¹Non-variable (%): alfalfa meal (17% protein), 5; defluorinated rock phosphate (32% Ca and 18% P), 2.5; ground limestone (38% Ca), 7; salt, 0.5 manganese sulphate, 0.025; vitamin mix, 0.5 (supplies vitamin D₃, 134,187 I.C.U.; vitamin A, 111,823 I.U.; riboflavin, 201 mg.; vitamin B₁₂, 0.295 mg., choline, 20,000 mg.; niacin, 1,097 mg.; and pantothenic acid, 216 mg.).

TABLE III
CALCULATED AMINO ACID CONTENT OF DIETS IN TRIAL 1, AND AMINO ACID REQUIREMENTS

Amino acids	Calculated amino acid content							NRC(1966) require- ment
	Percent of grain protein supplied by							
	Barley	100	80	60	40	20	0	
	Corn	0	20	40	60	80	100	
percent of diet								
Arginine		.345	.384	.390	.416	.437	.462	.80
Cystine		.176	.176	.175	.173	.172	.172	.25
Glycine		.258	.300	.342	.384	.425	.467	--
Histidine		.172	.175	.177	.179	.182	.185	.30
Isoleucine		.324	.335	.345	.356	.367	.378	.50
Leucine		.485	.587	.686	.788	.888	.989	1.20
Lysine		.274	.265	.256	.247	.239	.230	.50
Methionine		.116	.127	.138	.148	.158	.169	.28
Phenylalanine		.378	.395	.411	.428	.443	.460	.70
Threonine		.231	.260	.287	.315	.343	.371	.40
Tryptophane		.104	.103	.101	.100	.098	.096	.15
Valine		.366	.369	.371	.373	.376	.378	.80

The same eggs used for specific gravity determinations were used to determine interior quality in terms of Haugh units (Haugh, 1937), the incidence of large and small blood and meat spots, and yolk color. Yolk color determinations were made by comparing the yolk color with that of the blades on a Roche Yolk Colour Fan.

A daily mortality record was maintained during the experimental periods.

Individual body weights of the pullets in grams were obtained at the beginning and the end of the experiment.

Data collected were statistically analyzed by the analysis of variance method according to Snedecor (1956) with significant treatment differences determined by Duncan's Multiple Range Test (1955).

Trial 2

After the pullets used in trial 1 had been fed a 17 percent protein diet for 8 weeks, (Table I, page 24), they were considered to be sufficiently recovered from the effects of the trial 1 diets to proceed with trial 2. A total of 655 pullets (now 44 weeks of age), all in laying condition, were selected for use in trial 2. There were from 24 to 29 pullets per group. The birds were maintained in the same cage groups that they were in trial 1. Trial 2 was also a randomized complete block design, but a new randomization scheme was used. The diets were assigned to groups of pullets according to a randomized block design which was different than that used in trial 1 but again four replications were used.

Barley and oats were compared. The diets consisted of barley or oats or combinations of barley and oats, non-variables, fat, and in five diets, sugar (Table IV).

Diets were calculated to contain the same protein and metabolizable energy levels as used in trial 1. The diets were formulated so that 0, 20, 40, 60, 80, or 100 percent of the grain protein was supplied by oats and the remainder by barley. The calculated amino acid composition of the diets is shown in Table V.

Data were collected for egg production, egg weight, egg quality, feed consumption, mortality, and body weights, and statistically analyzed as in trial 1.

TABLE IV

COMPOSITION AND CALCULATED ANALYSIS OF THE LAYING DIETS, TRIAL 2

Feedstuffs	Percent of grain protein supplied by							
	Barley	100	80	60	40	20	0	
	Oats	0	20	40	60	80	100	
		percent						
Barley	70.891	56.133	42.198	28.067	14.033	--	--	
Oats	--	10.992	21.832	32.824	43.740	54.657	54.657	
Non-variables ¹	15.525	15.525	15.525	15.525	15.525	15.525	15.525	
Animal fat	13.584	12.658	11.982	11.297	10.617	9.937	9.937	
Sugar	--	4.692	8.463	12.287	16.085	19.881	19.881	
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	
Calculated analysis:								
Crude protein, %	8.26	8.26	8.26	8.26	8.26	8.26	8.26	
Metabolizable energy, Kcal/kg.	2969.04	2966.83	2966.81	2966.83	2966.83	2966.83	2966.83	

¹Non-variable (%): alfalfa meal (17% protein), 5; defluorinated rock phosphate (32% Ca and 18% P), 2.5; ground limestone (38% Ca), 7; salt, 0.5; manganese sulfate, 0.025; vitamin mix, 0.5 (supplies vitamin D₃, 134,187 I.C.U.; vitamin A, 111,823 I.U.; riboflavin, 201 mg.; vitamin B₁₂, 0.295 mg.; choline, 20,000 mg.; niacin, 1.097 mg.; and pantothenic acid, 216 mg.).

V. RESULTS

Trial 1

Egg Production

The egg production data, on a hen-day basis, are summarized for the entire 56-day experimental period and for the last 28 and seven days of the experiment in Table VI.

In both the 56 and 28 day periods, significant ($P \leq 0.05$) differences were found between the treatments. The birds fed the all-barley diet produced the smallest number of eggs. No significant ($P > 0.05$) differences in egg production were found among the other diets.

No significant differences were found in the last week's egg production between the treatments at the 5 percent level of probability, although the all-barley diet would have been judged lowest if a 10 percent level of significance had been used.

The weekly average egg production of the birds fed the six diets in trial 1 is summarized in Table VII. It is seen that week to week reduction in percent egg production occurs. In general the decrease in egg production for all treatments was at about the same rate with an exception in the second week. The birds receiving the all-barley diet and the 80 percent barley-20 percent corn diet experienced a sharp reduction in egg production in the second week, a slight increase in egg production in the third week, and a decrease in egg production in each subsequent week.

TABLE VI

THE EFFECT OF VARYING LEVELS OF CORN AND BARLEY IN DIETS FOR
LAYERS ON EGG PRODUCTION AND LAYING HOUSE MORTALITY

Percent of grain protein supplied by		Average egg production			Laying house mortality
		56 days	Last 28 days	Last 7 days	
barley	corn		percent		percent
100	0	30.50 ^{a1}	17.22 ^{a1}	7.25 ^{2,3}	2.53 ²
80	20	34.93 ^b	20.18 ^b	11.88	1.67
60	40	36.81 ^b	21.03 ^b	12.43	2.49
40	60	37.05 ^b	20.00 ^b	12.09	2.49
20	80	36.71 ^b	20.30 ^b	15.36	1.67
0	100	35.32 ^b	20.39 ^b	12.37	1.67

¹Means in the same column with the same superscripts are not significantly ($P > 0.05$) different as determined by Duncan's New Multiple Range Test (1955).

²There were no significant ($P > 0.05$) differences.

³The value for the 100% barley diet would have been significantly lower than those for the other diets if the test had been made at the 10% level of probability.

TABLE VII

PERCENT AVERAGE EGG PRODUCTION BY WEEKS, TRIAL 1

[illegible]

Mortality

Laying house mortality is also presented in Table VI (page 34). No significant differences were found in mortality among the treatment groups.

Egg Quality Characteristics

The effect of experimental diets on specific gravity score and the Haugh unit score (Haugh, 1937) is shown in Table VII. Shell thickness as determined by specific gravity and the average Haugh unit score of eggs from all of the treatments were not significantly ($P > 0.05$) influenced by the experimental diets. It was seen that the arithmetic mean of Haugh unit and specific gravity scores were lowest for eggs laid by the birds fed the all-corn and 80 percent corn-20 percent barley diets.

Eggs used for Haugh unit determinations were also observed for the presence of blood or meat spots (Table VIII). Three eggs from birds fed the all-corn diet contained blood spots, two large and one small; one egg from birds fed the 80 percent barley-20 percent corn diet had a small meat spot; two eggs from birds fed the 60 percent barley-40 percent corn diet had blood spots, one of them contained small and the other large blood spots. The broken-out eggs laid by birds receiving the all-barley, 40 percent barley-60 percent corn, and 20 percent barley-80 percent corn diets contained neither blood nor meat spots (Table VIII). Due to the small numbers involved, these data were not statistically analyzed.

TABLE VIII

THE EFFECT OF VARYING LEVELS OF CORN AND BARLEY IN DIETS FOR
LAYERS ON EGG SPECIFIC GRAVITY AND HAUGH UNIT SCORES

Percent of grain protein supplied by		Av. specific gravity score	Av. Haugh unit score	No. of eggs ¹	Blood and meat spots			
					Blood spots		Meat spots	
barley	corn				Small	Large	Small	Large
number								
100	0	2.95 ²	90.52 ²	55	-	-	-	-
80	20	3.34	90.20	75	-	-	1	-
60	40	2.72	90.27	81	1	1	-	-
40	60	3.57	89.79	74	-	-	-	-
20	80	1.96	89.16	75	-	-	-	-
0	100	2.58	86.94	85	1	2	-	-

¹Number of eggs broken out to determine the effect of diet on interior egg quality.

²There were no significant ($P > 0.05$) differences.

Yolk Color

The effect of experimental diets on yolk color score is summarized in Table IX. Barley produced much lighter colored yolks of eggs than the corn and corn-barley mixtures. As the percent corn increased in the diets, the yolks of the eggs became darker in color.

Egg Size

Egg size distribution and average egg weight are summarized in Table X. There were significant ($P \leq 0.05$) differences found in the average weight of eggs laid by hens receiving the different diets. The average egg weight was less as the percentage of corn was increased in the diet. The smallest eggs were laid by pullets fed the all-corn diet and the largest eggs were laid by pullets fed the all-barley diets.

No significant ($P > 0.05$) differences were found between treatments in the percent of peewee, small, medium, large, and extra large eggs produced. The average egg weights of the groups which were fed the all-barley diet, the 20 percent corn-80 percent barley diet, and the 40 percent corn-60 percent barley diet produced eggs with weights which would have averaged medium size according to USDA standards (1968) while the weight of eggs laid by birds fed the other three diets averaged "USDA small."

Feed Consumption and Feed Efficiency

The data on the pounds of feed consumed per hen and per dozen eggs are presented in Table XI. Among the treatment means there were no significant ($P > 0.05$) differences found in the pounds

TABLE IX

THE EFFECT OF VARYING LEVELS OF CORN AND BARLEY IN DIETS FOR
LAYERS ON YOLK COLOR

Percent of grain protein supplied by		Average yolk color score ¹
barley	corn	
100	0	4.06 ^{a2}
80	20	5.44 ^b
60	40	6.30 ^b
40	60	8.04 ^c
20	80	8.20 ^c
0	100	9.01 ^c

¹Yolk color scores were determined by using Roche Yolk Color Fan.

²Means with the same superscripts are not significantly ($P > 0.05$) different as determined by Duncan's New Multiple Range Test (1955).

TABLE X

THE EFFECT OF VARYING LEVELS OF CORN AND BARLEY IN DIETS FOR
LAYERS ON EGG SIZE

Percent of grain protein supplied by		Av. egg weights	Egg size distribution				Extra large
barley	corn		Peewee	Small	Medium	Large	
		grams			percent		
100	0	49.15 ^c ¹	0.71 ²	32.57 ²	58.95 ²	7.77 ²	0.0 ²
80	20	48.23 ^{bc}	3.68	28.77	60.06	6.56	0.32
60	40	48.01 ^{bc}	4.53	29.70	58.32	7.10	0.35
40	60	47.08 ^{ab}	5.54	32.37	54.14	7.10	0.85
20	80	46.73 ^{ab}	6.39	36.67	52.20	4.43	0.31
0	100	46.08 ^a	5.14	44.21	44.13	6.14	0.38

¹Means in the same column with the same superscripts are not significantly ($P > 0.05$) different as determined by Duncan's New Multiple Tange Test (1955).

²There were no significant differences found ($P > 0.05$).

TABLE XI

THE EFFECT OF VARYING LEVELS OF CORN AND BARLEY IN DIETS FOR
LAYERS ON FEED EFFICIENCY

Percent of grain protein supplied by		Feed consumed ¹	
		Per hen	Per dozen eggs
barley	corn	grams	
100	0	3,970 ²	2,695 ²
80	20	4,209	2,590
60	40	3,972	2,318
40	60	4,068	2,345
20	80	3,940	2,309
0	100	4,040	2,454

¹For 56 days.

²There were no significant differences found ($P > 0.05$).

of feed consumed per hen and of feed per dozen eggs produced.

Body Weights

Average body weights at 28 weeks of age and 36 weeks of age (after 8 weeks on the experimental diets) are given in Table XII. The experimental diets caused a reduction in body weights.

Significant ($P \leq 0.05$) differences were found among the treatments. Those birds fed the all-corn diet lost significantly more body weight than those fed the all-barley, 80 percent barley-20 percent corn, and 60 percent barley-40 percent corn diets. Birds receiving the 80 percent barley-20 percent corn diet lost significantly less body weight than those fed the all-corn and 80 percent corn-20 percent barley diets. The least body weight loss was by birds fed the diet with 80 percent barley-20 percent corn.

Trial 2

Egg Production

The egg production data, on a hen-day basis, are summarized for the entire 56-day experimental period and for the last 28 and seven days of the experiment in Table XIII.

In the 56-day period, significant ($P \leq 0.05$) differences were found between the treatments. The pullets receiving the all-oats diet had the lowest rate of production, but this did not differ significantly ($P > 0.05$) from that of birds fed 60 percent barley-40 percent oats diet and the 20 percent barley-80 percent oats diet. The pullets fed the all-barley diet had the highest rate of production, but did not significantly ($P > 0.05$) differ from that

TABLE XII

THE EFFECT OF VARYING LEVELS OF CORN AND BARLEY IN DIETS FOR
LAYERS ON THE BODY WEIGHT OF LAYING PULLETS

Percent of grain protein supplied by		Body weights		
		Av. initial body weights (28 wks. of age)	Av. final body weights (36 wks. of age)	Av. body weight lost
barley	corn	grams		
100	0	1537.98	1470.21	67.77 ^{ab¹}
80	20	1546.55	1490.93	55.62 ^a
60	40	1537.65	1469.92	67.73 ^{ab}
40	60	1563.47	1465.35	98.12 ^{abc}
20	80	1519.36	1412.95	106.41 ^{bc}
0	100	1573.22	1445.14	128.08 ^c

¹Means in the same column with same superscripts are not significantly ($P > 0.05$) different as determined by Duncan's New Multiple Range Test (1955).

TABLE XIII

THE EFFECT OF VARYING LEVELS OF OATS AND BARLEY IN DIETS FOR
LAYERS ON EGG PRODUCTION AND LAYING HOUSE MORTALITY

Percent of grain protein supplied by		Average egg production			Laying house mortality
barley	oats	56 days	Last 28 days	Last 7 days	
			percent		percent
100	0	20.75 ^{d1}	6.29 ^{bc1}	4.77 ²	0.89 ²
80	20	18.39 ^{cd}	6.39 ^c	5.30	1.78
60	40	14.23 ^{ab}	4.30 ^b	3.40	0.89
40	60	16.63 ^{bc}	6.53 ^c	6.40	2.21
20	80	15.41 ^{abc}	4.60 ^{bc}	3.77	0.93
0	100	12.16 ^a	2.34 ^a	1.84	0.00

¹Means in the same column with the same superscripts are not significantly ($P > 0.05$) different as determined by Duncan's New Multiple Range Test (1955).

²There were no significant ($P > 0.05$) differences.

of birds fed 80 percent barley-20 percent oats diet. As the percent oats increased in the diet, the egg production tended to decrease.

In the last 28-day period, significant ($P \leq 0.05$) differences were found among the treatment groups. The hens receiving the all-oats diet exhibited the lowest rate of production ($P \leq 0.05$). The hens receiving the 80 percent barley-20 percent oats and 40 percent barley-60 percent oats diets exhibited the highest rates of production on a hen-day basis; no significant ($P > 0.05$) differences were found between these two groups, and those fed the 100 percent barley diet and the 20 percent barley-80 percent oats diet.

In the last 7-day period, no significant ($P > 0.05$) differences were found among the treatments, however, the average egg production per hen was lowest for the birds receiving the all-oats diet.

The weekly average egg production of birds fed the six diets, in trial 2, is summarized in Table XIV. Percent egg production tended to decrease each week for all treatments. Regardless of diet, birds experienced a sharp reduction in egg production in the second week. In the third week, a small increase in percent egg production occurred followed by a reduction in succeeding weeks.

Mortality

Laying house mortality is presented in Table XIII (page 44). No significant ($P > 0.05$) differences were found in laying house mortality; no mortality occurred in lots fed the all-oats diet.

TABLE XIV
PERCENT AVERAGE EGG PRODUCTION BY WEEKS, TRIAL 2

Weeks	Percent of grain protein supplied by						
	Barley Oats	100 0	80 20	60 40	40 60	20 80	0 100
		percent					
1		66.70	61.07	53.16	56.63	57.78	52.37
2		28.85	20.12	13.61	14.39	13.91	9.85
3		28.17	23.13	16.58	23.21	20.45	16.23
4		16.78	17.22	13.28	12.66	12.84	9.51
5		6.03	7.52	3.26	5.93	4.47	2.98
6		7.07	5.24	5.87	5.60	4.91	3.21
7		6.78	7.14	4.80	6.83	4.66	1.34
8		4.77	5.30	3.40	6.40	3.77	1.84

Egg Quality Characteristics

Data regarding the effect of diets on specific gravity score and Haugh unit score are shown in Table XV. The specific gravity scores and Haugh unit scores were not significantly ($P > 0.05$) different among diets containing oats or barley, or their combinations. Of the eggs broken out for the determination of Haugh unit scores, only one contained a small blood spot. It was laid by a pullet fed the 80 percent oats-20 percent barley diet.

Yolk Color

Since neither oats nor barley contain xanthophyll no comparisons were made of yolk color with the Roche Yolk Colour Fan. It was observed that yolk color in all eggs became quite light after the birds had been fed the experimental diets for about three weeks.

Egg Size

Egg size distribution and average egg weight are shown in Table XVI. No significant ($P > 0.05$) differences were found among the treatments in average egg weights and in the percent of small, medium, large, and extra large eggs produced. The only peewee eggs found in the eggs weighed were laid by birds fed the 40 percent oats-60 percent barley diet.

The average egg weight of the groups of birds fed the 40 percent oats-60 percent barley and 80 percent oats-20 percent barley was medium size, while the average egg weight for all other diets was large size according the USDA standards (1968).

TABLE XV

THE EFFECT OF VARYING LEVELS OF OATS AND BARLEY IN DIETS
FOR LAYERS ON EGG SPECIFIC GRAVITY AND
HAUGH UNIT SCORES

Percent of grain protein supplied by		Average specific gravity score	Average Haugh unit score
barley	oats		
100	0	2.46 ¹	82.90 ¹
80	20	1.78	80.94
60	40	2.43	83.73
40	60	1.77	82.54
20	80	2.45	78.50
0	100	2.04	78.19

¹There were no significant ($P > 0.05$) differences.

TABLE XVI

THE EFFECT OF VARYING LEVELS OF OATS AND BARLEY IN DIETS
FOR LAYERS ON EGG SIZE

Percent of grain protein supplied by		Av. egg weights	Egg size distribution				
			Peewee	Small	Medium	Large	Extra large
barley	oats	grams			percent		
100	0	55.57 ¹	0.0	4.83 ¹	37.47 ¹	50.57 ¹	7.14 ¹
80	20	55.36	0.0	4.28	44.36	45.19	6.17
60	40	54.30	0.38	5.92	38.83	50.57	5.40
40	60	54.95	0.0	1.88	47.36	40.60	10.16
20	80	54.04	0.0	4.38	51.17	41.84	2.61
0	100	55.74	0.0	1.32	37.16	49.62	11.90

¹There were no significant ($P > 0.05$) differences.

Feed Consumption and Feed Efficiency

The pound of feed per hen and per dozen eggs are summarized in Table XVII. Significant ($P \leq 0.05$) differences were found among the treatments for pounds of feed per hen. The birds receiving the all-oats diet consumed less feed per bird than those fed the all-barley and barley-oats mixtures. There were no significant ($P > 0.05$) differences found among the other diets.

There were significant ($P \leq 0.05$) differences found among the treatments for pounds of feed consumed per dozen eggs. The birds fed all-oats diet consumed more feed per dozen eggs than those fed the all-barley, 80 percent barley-20 percent oats and 40 percent barley-60 percent oats diets. The least feed consumption was by the birds fed the 100 percent barley diet. No significant ($P > 0.05$) differences in feed consumed per dozen eggs were found among the birds fed the barley-oats combinations diets.

Body weight

Average body weights of the birds at 44 weeks (start of experiment) and 52 weeks (end of experiment) of age are given in Table XVIII. All birds lost weight during the experimental period. The hens receiving the all-oats diet experienced a greater loss in body weight than did those fed other diets ($P \leq 0.05$). No significant differences were found among the other diets.

TABLE XVII

THE EFFECT OF VARYING LEVELS OF OATS AND BARLEY IN DIETS
FOR LAYERS ON FEED EFFICIENCY

Percent of grain protein supplied by		Feed consumed ¹	
		Per hen	Per dozen eggs
barley	oats	grams	
100	0	4,109 ^{a 2}	4,254 ^{c 2}
80	20	3,868 ^a	4,462 ^b
60	40	3,773 ^a	5,813 ^{ab}
40	60	4,164 ^a	5,381 ^b
20	80	4,055 ^a	5,895 ^{ab}
0	100	3,645 ^b	6,900 ^a

¹For 56 days.

²Means with the same superscripts are not significantly ($P > 0.05$) different as determined by Duncan's New Multiple Range Test (1955).

TABLE XVIII

THE EFFECT OF VARYING LEVELS OF OATS AND BARLEY IN
DIETS FOR LAYERS ON THE BODY WEIGHT
OF LAYING PULLETS

Percent of grain protein supplied by		Body weights		
		Av. initial body weight (46 wks. of age)	Av. final body weight (54 wks. of age)	Av. body weight lost
barley	oats	grams		
100	0	1693.67	1393.62	300.05 ^{a1}
80	20	1677.97	1348.83	329.14 ^a
60	40	1691.39	1330.65	360.75 ^a
40	60	1670.27	1402.90	256.37 ^a
20	80	1614.01	1279.13	334.88 ^a
0	100	1732.49	1214.28	518.22 ^b

¹Means in the same column with the same superscripts are not significantly ($P > 0.05$) different as determined by Duncan's New Multiple Range Test (1955).

VI. DISCUSSION

Egg Production

In this experiment the same birds were used in both trial 1, during the time they were 28 to 36 weeks of age, and trial 2, 44 to 56 weeks of age. Trial 1 was conducted in the fall and trial 2 was conducted during the winter.

The results of feeding assay diets in this experiment indicated that egg production of Single Comb White Leghorn pullets is higher when fed corn than when fed barley, and higher when fed barley than when fed oats. This confirms the data of Crampton (1936) and Heuser et al. (1944), however, it is in conflict with Wilcke (1937) who reported that rations consisting largely of ground oats are more satisfactory for hens than rations containing large amounts of barley, wheat, or corn. These data are also in conflict with Wilcke (1940) who concluded that oats ranked first for poultry feed in comparison with corn, wheat, and barley. He suggested that up to 40 percent, or perhaps even more, of the ration of the growing chick and the laying hen could be made of oats, when the quality was good and the price justified.

Berg et al. (1956) stated that under the climatic conditions of Western Washington, hens laid equally well on corn or barley diets.

Lillie and Denton (1967) reported that the desirability of grain for egg production was as follows: oats > corn > barley.

Mortality

In two experiments, no significant ($P > 0.05$) differences were found in the laying house mortality between birds fed corn, barley, or oats diets or diets containing combinations of corn and barley or of barley and oats. However, Taylor et al. (1944) stated that a ration composed of a high proportion of corn produced a significantly higher laying hen mortality than a similar ration in which a large part of the corn had been replaced by barley and alfalfa meal.

Yolk Color

The birds receiving the barley and oats diets produced lighter colored egg yolks than the birds receiving the corn diets due to the lack of xanthophyll in the barley and oats. Palmer (1915) determined that dietary xanthophyll is required for yellow color in egg yolks, and, thus replacing yellow corn with barley was expected to result in lighter colored egg yolks. Feeding diets containing less corn than was in the 60 percent corn-40 percent barley diet (about 51 percent corn) resulted in marked reductions in egg yolk color.

Body Weights

In this experiment, it was found that barley was superior to corn and oats in maintaining body weight. The birds receiving the high percentage corn and oats diets lost more body weight than the birds receiving the same level of barley diet. However,

Lillie and Denton (1967) using diets with higher protein content than the ones used in this experiment, reported oats produced greater body weight gains than barley and corn.

Feed Consumption Per Dozen Eggs

Lillie and Denton (1967) reported that the birds receiving oats diets consumed less feed per dozen eggs than those fed barley, wheat, or corn diets; however, it was found that the birds receiving 100 percent oats diet consumed more feed than the birds receiving 100 percent barley diet per dozen eggs produced, and the birds receiving the 100 percent barley and 100 percent corn diets consumed the same amounts of feed per dozen eggs.

Feed Consumption Per Hen

Among the treatment means there were no significant ($P > 0.05$) differences found in the pounds of feed consumed per hen, in trial 1; however, significant ($P \leq 0.05$) differences were found among the treatments for pounds of feed consumed per hen in trial 2. The birds receiving the all-oat diet consumed less feed per hen than those fed the all-barley and barley-oat mixtures.

Egg Quality Characteristics

The specific gravity scores and Haugh unit scores were not influenced by feeding diets containing corn, barley, or oats and corn-barley and barley-oats combinations.

Of the eggs broken out for determination of Haugh unit scores, only five contained small or large blood spots and one contained

and one contained a small meat spot in trial 1, and only one contained a small blood spot in trial 2. The diets did not affect the occurrence of the blood or meat spots in the eggs.

Egg Size

In trial 1, significant ($P \leq 0.05$) differences were found in the average weight of eggs laid by hens receiving the different diets. The average egg weight was lower as the percentage of corn in the diet was increased; however, Bert (1959) and Shutze et al. (1962) reported that birds fed diets containing corn produced eggs with a greater average egg weight than birds fed diets with barley.

No significant ($P > 0.05$) differences were found among the treatments in the percent of peewee, small, medium, large, and extra large eggs produced.

In trial 2, no significant ($P > 0.05$) differences were found among the treatments in the average egg weights. However, Shutze et al. (1962) stated that the birds fed an oats diet had a greater average egg weight than birds fed a barley diet.

There were no significant ($P > 0.05$) differences found among the treatments in the percent of small, medium, large, and extra large eggs produced.

VII. SUMMARY

The studies reported herein were designed to evaluate the quality of the protein in yellow corn, barley, and oats and combinations of corn and barley, or of barley and oats as the principal protein source in diets for laying pullets.

The same Single Comb White Leghorn pullets were used in two eight-weeks trials, with an eight-week recovery period between trials. At the end of the first trial the experimental diets were discontinued and the birds fed a 17 percent protein layer diet to permit them to recover sufficiently from the effects of the first trial. At that time pullets were fed the diets to be studied in trial 2.

Corn and barley, in trial 1, and barley and oats, in trial 2, were compared.

In both trial 1 and 2, six different diets were fed. They were calculated to contain 8.26 percent of crude protein and about 2966 kilocalories of metabolizable energy per kilogram. The diets were formulated so that 0, 20, 40, 60, 80, or 100 percent of the grain protein was supplied by corn and the remainder by barley in trial 1. In trial 2, 0, 20, 40, 60, 80, or 100 percent of the grain protein was supplied by barley and the remainder by oats. The diets were deficient, by calculation, in all the essential amino acids and were not supplemented. The 17 percent protein recovery diet was considered to contain adequate amounts of amino acids and was calculated to contain 2816 kilocalories of metabolizable energy per kilogram.

From the results of this study, the cereals were rated in the following order: for egg production - corn > barley > oats; for egg quality - barley = corn = oats; for egg weight - barley = oats, and barley > corn; for pounds of feed per dozen eggs - corn = barley > oats; and for preventing body weight loss - barley > corn, and barley > oats.

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