DIETARY PROTEIN AND ENERGY REQUIREMENTS OF CAGED LAYERS

By

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DECLARATION

I hereby declare that this thesis entitled "DIETARY PROTEIN AND ENERGY REQUIREMENTS OF CAGED LAYERS" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title, of any other University or Society.

Mannuthy,
29-4-1986.

A. Jalaludeen

CERTIFICATE

Certified that this thesis, entitled " DIETARY PROTEIN AND ENERGY REQUIREMENTS OF CAGED LAYERS" is a record of research work done independently by Sri. A.Jalaludeen under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to him.

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INTRODUCTION

Many programmes had been planned and implemented in the past with varying degrees of success for the socio-economic uplift of the weaker sections of society. Among them poultry farming has established itself as a viable enterprise for improving the rural economy. The remarkable progress made by the poultry industry in our country during the last two decades bears testimony to this fact. The poultry population increased from 115 millions in 1961 to 159.30 millions in 1977. Likewise, the egg production has risen from 2340 millions in 1961 to 13500 millions in 1983 and the value of poultry products has increased from 650 million rupees in 1961 to 8700 million rupees in 1983. Eventhough, India holds seventh position among countries of the world in total egg production, our percapita availability is only 18.9 eggs as compared to 300 to 350 in developed countries (Anon, 1984). In order to achieve the target recommended by the National Commission on Agriculture, we have to produce more than one lakh million eggs annually in addition. Such target can be achieved only by promoting large and small scale poultry farming in the country with precision knowhow to generate maximum production without waste of inputs.

Feed cost being the single major cost factor in any poultry production operation, efficient feed management will reflect itself in the profitability. It is accepted that feed cost alone accounts for about 70 to 75 per cent of the total cost of poultry production. During the last few years the feed prices in the country are increasing gradually. This increasing feed cost has not been matched by proportionate rise in egg prices. In order to contain this pressure on production continuous efforts have to be made for the production of efficient and economic poultry rations.

The efficiency of utilization of a feed is mainly governed by its energy and protein content. Likewise, the cost of feed is largely dictated by its protein content. In as much as the feed cost is the major expense item in producing egg and meat, a balance has to be struck at the economic energy and protein level in the ration.

The conventional deep litter rearing system is being rapidly replaced by the cage system due to the spatial and labour saving advantages of the latter system. Consequently, it has become necessary to reassess the nutrient requirements vis-a-vis the cage environment. While the nutrient requirements of chicken raised in deep litter system have been extensively studied and documented, similar attempts in respect of cage reared chicken are limited. The National Research Council (NRC), Agricultural Research Council (ARC) or Indian Standards Institution (ISI), the three major organisations which set standards of nutrient requirement for poultry for adoption by farmers and scientists, seems silent on the requirement for poultry raised in cages due to want of sufficient information for recommendation.

The requirement of nutrients is also reported to be partially influenced by the genetic makeup of the bird. This therefore means that for each genetic material that is being evolved for commercial exploitation there should be simultaneous assessment of its nutrient requirement atleast in respect of major nutrients before the new germplasm is released. The All India Co-ordinated Research Project (AICRP) on Poultry for Eggs, Mannuthy centre has identified a strain cross White Leghorn chicken viz., IWN x IWP as a possible cross for commercial exploitation for egg production. It is necessary to determine the energy and protein requirements of this strain cross so that when this is released the farmers can be advised on their nutrient needs for economic production. Thus, the present study was taken up with the twin objective of assessing the dietary protein and energy requirements of caged layers in general and that of the strain cross IWN x IWP in particular under the hot humid climatic conditions of Kerala.

Review of Literature

REVIEW OF LITERATURE

Protein rich feed ingredients are costlier among the feed sources used in poultry feed manufacture and therefore they have to be judiciously selected in the formulation of economic rations. Consequently, in recent years scientists working in the area of poultry nutrition have been attempting to arrive at biological optimum levels of protein in rations under various conditions for economic production. The protein requirements of laying hens are influenced by various factors. The size, breed and strain of layers, environmental temperature, stage of production, energy content of diet, type of housing system and the like influences feed intake and ultimately the dietary protein requirements. The following review is an attempt to throw light on the recent researches that have been conducted both in India and outside on the various factors which influence dietary protein and energy requirements of caged layers.

Requirement of Protein

The response of four strains of egg producing birds on diets containing three different protein levels viz., 13, 15 and 17 per cent was studied by Moreng et al. (1964) who claimed that strain differences existed in protein requirements. Quisenberry et al. (1964) observed that egg production was highest at 19 per cent protein level and body weight and egg size at 17 per cent. Internal egg quality in terms of Haugh unit scores was highest at 15 per cent protein level. When protein content was 15 per cent or lower, body weight, egg size and feed efficiency were depressed. Lowering protein level as laying advanced reduced the egg size and body weight significantly but tended to improve egg production and feed efficiency.

In an attempt to determine whether genetic differences, if any, exist in protein requirements between four strains of egg type stocks, Deaton and Quisenberry (1964) tried four different protein combinations under two housing types. The diets contained 17 and 14 per cent protein for 336 days and a 17 per cent protein decreased to 14 per cent with one per cent decrease every 56 days until 14 per cent was reached and 14 per cent increased to 17 per cent with an increase of one per cent every 56 days until 17 per cent was reached. The housing consisted of colony and individual cages. The results showed a highly significant strain x protein interaction for average hen-day production, egg weight and feed efficiency for birds in both housing types.

A highly significant strain x protein interaction was found for average body weight, Haugh unit score and shell thickness in individual cages. When only protein levels was considered, birds housed in individual cages receiving the increasing protein diet laid significantly more number of eggs with significantly heavier egg weight and better feed efficiency. Birds housed in colony cages laid more eggs with a better feed efficiency and significantly heavier eggs when receiving a constant 17 per cent protein diet.

Pepper _et_ _al_. (1967) conducted two experiments to investigate the possible inter-relationship between dietary protein and calcium for laying hens. In the first experiment four levels of protein viz., 12, 14, 16 and 18 per cent and two levels of calcium viz., 2.4 and 3.5 per cent and three levels of terephthalic acid (to potentiate cation) viz., 0, 0.25 and 0.50 per cent were employed. The 12 per cent protein diet resulted in significantly lower egg production, smaller eggs and poorer feed utilization than the higher levels of protein. In the second experiment, three protein levels viz., 13, 15 and 17 per cent and three calcium levels viz., 2, 3 and 4 per cent were tried in factorial design. No significant differences were noted for egg production, feed utilization or egg weight between three levels of protein tested. They could not observe any significant interaction between protein and calcium in both the experiments. However, the results suggested that the highest level of protein coupled with highest level of calcium gave optimum performance. Factors affecting the protein requirements of layers was studied by Speers and Balloun (1967) who concluded that there was a significant effect of strain on protein requirement.

Owings _et al._ (1967) studied the influence of dietary protein level and bird density in cages on egg production and liver fatty acids. White Leghorn pullets were housed in 10" x 16" cages at two and three birds per cage. They were fed with diets containing three protein levels viz., 16.0, 17.5 and 19.0 per cent. The performance of birds fed the above protein diets, respectively, was : mortality (%) - 9.03, 11.25 and 10.83; hen-day egg production (%) - 63.8, 63.2 and 65.8; pounds of feed per dozen eggs - 4.10, 4.25 and 4.14. There was no pronounced relationship between diets or concentrations of hens per cage on the distribution of fatty acids in the liver or the total amount of liver lipids.

While evaluating four cereal grains (barley, oats, wheat and corn) and three protein level (10, 12.5 and 15.0 %) combinations for layer performance, Lillie and Denton (1967) observed that higher the protein level, the greater the egg production and body weight gains, irrespective of the grain. Mortality was lower on 15 per cent than on lower protein levels. Feed consumed per dozen eggs was greater on 10 per cent than on higher protein levels. Blaylock et al. (1967) conducted three experiments to determine the protein requirement of the laying hen. Two experiments were started during summer and one during winter. Dietary protein levels ranged from 13 to 21 per cent. Daily feed intake was as low as 77 g per bird per day during summer months and as high as 118 g per bird per day during winter. This wide variation in daily feed intake due to environmental temperature resulted in a wide range of daily protein and energy intakes. The results also indicated that the protein requirement of layers was probably no higher than 14 g per bird per day at rates of lay upto at least 80 per cent. Egg weight was reduced only at protein intakes below 14 g per bird per day.

Significant strain difference in protein requirements was reported by Balloun and Speers (1969). In an attempt to study the effect of different protein levels viz., 14, 16 and 18 per cent on layer performance in two strains of White Leghorns, Smith et al. (1970) observed significant differences with respect to hen-day egg production, feed per kilogramme of eggs, average egg weight and 72 week body weight, whereas no significant differences were observed with regard to feed per dozen eggs and laying period mortality. Effect of protein level on production traits in the first and second halves of the 46 weeks laying period was measured in three strains (Hunt and Aitken, 1970). The birds were fed with diets having graded protein levels viz., 11, 13, 15 and 17 per cent having the same amino acid pattern. Birds from each protein level in the first half were randomly divided into four groups, each being placed on one of the four protein levels for the second half. Birds on 13 per cent protein throughout laid significantly fewer eggs than birds on 15 per cent throughout, while 15 and 17 per cent protein were comparable. Birds started on 15 per cent and switched to 13 per cent were comparable to 15 per cent protein throughout. Strain, protein and protein x strain interaction were significant for egg weight. A four per cent change in protein level affected egg weight while a two per cent change did not, except when the change resulted in feeding of 11 per cent protein in which case egg weight decreased. Mortality was inversely proportional to protein level.

In order to test the hypothesis that light weight birds require a different nutritional regime during the lay period than medium and heavy weight birds of the same strain, Fowler and Quisenberry (1971) conducted a trial and reported that hen-day production was significantly different between each weight class and was positively correlated to pullet body weight. Small birds were slower in attaining sexual maturity. Egg size was directly related to body weight. Livability was positively correlated to pullet body weight. They also reported that increasing the protein level resulted in a significant increase in hen-day egg production for the light weight birds but not with the medium and heavy weight birds. Cunningham and Butts (1972) conducted a study in which pullets were given for 17 weeks, diets with 2.83 Kcal metabolizable energy per g and 12.28, 14.21, 16.07 or 17.95 per cent protein. Egg production increased as dietary protein increased and with 12 per cent protein fewer and smaller eggs were produced than the other diets.

The effects of feeding different protein levels and of changing protein levels on egg production, egg weight, body weight and feed intake were investigated by Fernandez _et al._ (1973). It was concluded that a diet containing 13 per cent protein and supplemented with lysine and methionine was as effective as levels of 15, 17 and 18 per cent protein for supporting optimum egg production and egg size. The effect of protein level on body weight gains varied. It was also observed that egg production did not change significantly as a result of changing protein levels after eight or ten weeks of production from 18, 17 or 15 per cent protein to 15 or 13 per cent protein. Lowering the level of protein in the diet after 18 weeks of production had no adverse effects on egg production. The level of protein in the different treatments did not affect egg weights except when a diet with 11.5 per cent protein in which case it was inferior. Feed intakes for the different levels of protein fed birds were equal.

Reid and Weber (1973) conducted two experiments in laying hens to evaluate the effects of environmental temperature on methionine and total protein needs. In the first study, birds were housed at 21.1 or 32.2°C and fed diets containing 15.6 per cent protein with methionine plus cystine levels of 0.5, 0.55, 0.59 per cent or 20 per cent protein with 0.59 per cent sulphur amino acids. Birds housed at 21.1°C consumed 12.5 to 14.0 g protein per day when fed the 15.6 per cent protein diet, while those on the 20 per cent protein diet consumed 17.3 g protein per day. At higher temperature feed consumption was reduced. In the second trial, protein intakes were equalised for birds housed at 21 and 35 °C over a range of 12.7 to 20.5 g per day. Significant improvements in egg production were obtained with increased protein consumption at 21°C, while no such increase in production was obtained with increased protein intake at 35 °C.

Tkacev _et al._ (1973) opined that hens of six to eleven months age require a 17 per cent crude protein layer diet and that can be reduced to 15 per cent between 11 and 15 months and thereafter to 13 per cent provided that the limiting amino acids are in sufficient amounts and in particular lysine, S-amino acids and tryptophan. Kolstad and Lien (1974) tried four levels of protein viz., 12, 14, 16 and 18 per cent in layer diets and observed that the tendency to higher egg production with higher protein content of the diet was not significant,nor was there a significant effect of protein content of egg quality. Mean protein utilization was 28.3 per cent and varied considerably with protein content from 35.0 per cent with 12 per cent protein in the diet and 22.9 per cent with 18 per cent protein.

In a study, Singh and Talapatra (1974) employed five protein levels from 14 to 28 per cent with 2377 to 2473 Kcal ME per kg diet. The ratios of energy to protein varied from 8.6:1 to 17.7:1. Neither high nor low protein content favoured laying. The results indicated that about 20 per cent protein may give best egg production within diets of metabolizable energy around 2400 Kcal per kg. Zavgorodnyaya and Rodionova (1974) assessed the productive quality and nitrogen metabolism in purebred and crossbred hens on phased feeding. Leghorn hens of C and D lines, Moskovskaya of B and G lines and their crosses were used. During three phases of egg laying, from months one to three, four to nine and 10 to 12, each group of hens got a concentrate diet with 17 per cent protein (control) or a diet with 19, 19 or 15 per cent at phases one, two or three, respectively. Line C Leghorn and the hybrid hens given the control diet laid significantly more eggs and ate less protein per 10 eggs in all the phases than the other birds. Those birds on the control diet laid slightly more eggs during a year than the corresponding subgroup; for Leghorn D the opposite was true. During the third phase, birds on the 15 per cent protein diet gave more but lighter eggs than those on the control diet. Apart from at the 12th month of laying, with negative N balances, the Moskovskaya and Leghorn D hens on 15 per cent protein diet all the other trials had positive N balances of 0.12 to 2.33 g per day.

Thayer *et al.* (1974) conducted two feeding trials to assess the daily protein intake requirement of laying hens.

In the first trial 18 diets provided estimated protein intakes of 15 to 19.25 g and in the second 24 diets had four estimated energy densities of 1.00 to 1.32 MJ and six estimated protein intakes of 14 to 18 g given in a 4 x 6 factorial design. The protein intake did not affect egg production or weight, but weight gains at a daily protein intake of 14 g were significantly less than with intakes of 15 to 19 g. It was concluded that 14 g protein per day could be recommended as a minimum intake for such birds, but that 15 g per day might allow for varying conditions, no benefit being derived from higher intakes.

Chawla et al. (1975) studied the influence of climatic conditions on protein requirement of layers and suggested that for optimum egg production, the protein requirement of White Leghorn pullets lies between 18.5 to 21.6 per cent and 16.6 to 18.5 per cent protein in summer and winter months, respectively. Calculations based on egg production, feed consumption and average egg weight indicated that the requirement can be met by feeding rations containing 18 to 19 per cent and 15 to 16 per cent protein in summer and winter, respectively. Four feeding programmes with three different protein levels in isocaloric diets viz., programme one-16 per cent protein, programme two- 17 per cent protein, programme three - 18 per cent protein, all fed from 22 through 70 weeks of age and programme four = 18 per cent protein from 22 to 39 weeks, 17 per cent protein from 40 to 59 weeks and 16 per cent protein from 60 to 70 weeks, were evaluated in brown egg type birds housed in cages (Millar and Smith, 1975). A significant difference at five per cent probability level was observed with respect to egg production. Birds on programme one, two and four had five per cent greater production than birds on programme three. Feed consumed per dozen eggs was not statistically different between the four feeding regimes. Similarly there was no statistical difference in egg weight between the four feeding programmes.

In an experiment, four groups of White Leghorn layers were allotted four different protein diets viz., 12.5, 14.0, 15.5 or 17.0 per cent and protein increased from 12.5 to 17.0 per cent or decreased from 17.0 to 12.5 per cent during the year. There was no significant difference in weight among groups on the four constant protein contents, but egg production on the hen-day basis was greater with 14.0 per cent and also with the increase in protein than with 12.5 per cent protein throughout (Jongh and Rode, 1976). Babatunde and Fetuga (1976) conducted an experiment with White Leghorn and White Rock hens employing five levels of protein viz., 12, 14, 16, 18 and 20 per cent under tropical conditions and observed that hen-day production percentages increased upto the 16.0 per cent protein diet and then declined. Feed used for 12 eggs also declined upto the 16.0 per cent protein and then increased slightly. All the hens except those on the 18 per cent protein diet lost weight to varying degrees, those on the 12 per cent protein diet losing most. As dietary protein increased, there were significant decreases in the percentage of eggs weighing less than 40.0 g and those weighing between 40.0 and 49.0 g and increases in the percentage of eggs weighing between 50.0 and 59.0 g and 60.0 g and above.

Ross and Herrick (1976) observed the performance of hens fed 14 and 16 per cent protein layer diets from 20 to 74 weeks. Body weight gain, but not egg production, efficiency of production, egg weight or quality, was significantly greater with 16 per cent protein. With a view to identify the optimum protein level for caged layers, Krueger et al. (1976) graded commercial egg type pullets into 'A', 'B' and 'C' quality pullets based on degree of fleshing and each class of pullets were placed on three dietary regimes viz., 15 per cent protein phased upto 17 per cent protein, 17 per cent protein fed throughout the experiment and 18 per cent protein phased down to 16 per cent protein.

No significant differences in rate of egg production and livability could be attributed to the different feeding regimes employed in the study. Feed efficiency was consistently best in the groups receiving 17 per cent protein.

Reid (1976) designed a study to evaluate the dietary protein intake needs of the laying hen during three periods of three months each. Six experimental diets varying in protein content viz., 10.0, 11.5, 13.5, 15.5, 17.5 and 19.5 per cent were fed to pullets for a period of 36 weeks. The data were divided into three phases of 12 weeks. There was no statistical difference in egg production obtained with diets containing more than 13.5 per cent protein. The calculated daily protein needs was found to be 17.05, 17.84 and 14.94 g per day for the three phases to support egg production levels of 83.6, 78.1 and 69.3 per cent, respectively. For the entire 36 weeks of the experiment, 14.6 per cent dietary protein was adequate to support an egg production rate of 77 per cent at an average protein intake of 16.54 g per hen per day.

Chawla <u>et al</u>. (1976) studied the protein requirement of laying hens during summer (March to July) and in winter (September to January). White Leghorn pullets were offered diets having 12.8, 15.0, 16.6, 18.5 and 21.6 per cent protein.

In summer, birds on diets one to five reached 50 per cent production when they were 175, 174, 173, 169 and 171 days old and in winter 50 per cent production was reached when they were 198, 194, 195, 189,and 192 days old. In summer, cumulative egg production for the 122-day period after 50 per cent production was 52.1, 55.4, 56.4, 64.4 and 66.6 per cent and in winter it was 54.0, 66.0, 66.7, 70.6 and 73.2 per cent. Feed conversion efficiency was 3.48, 3.23, 2.83, 2.63 and 2.49 kg per kg egg in summer and 3.81, 3.31, 3.24, 2.94 and 2.92 kg per kg egg in winter.

An experiment with three protein levels viz., 12, 15 and 18 per cent each at three calcium levels viz., 2.5, 3.5 and 4.5 per cent on Rhode Island Red caged layers was conducted by Ameenuddin _et al._ (1976). Data on 100-day experimental period showed that the highest egg production was obtained at 18 per cent protein, which was significantly superior to that at the 12 or 15 per cent. Egg quality traits like albumen index, yolk index, shell thickness or Haugh units were not affected by the various protein levels tested. In three trials, Rojas-Deporta (1977) compared crude protein levels of 18, 15 and 12 per cent in layer diets. In the first and third trial egg production and feed efficiency were greatest with 18 per cent protein diet and significantly less with 12 per cent protein level. In the second trial 15 per cent protein fed birds performed better than 18 per cent protein diet.

The effect of varying proportions of protein in the diet on quality of hens eggs was studied by Scholtyssek (1977). The protein level of the diet ranged from 13 to 19 per cent. With increasing protein, egg quality differed little, the main changes being an increase in egg weight and a decline in albumen height. There were slight changes in other egg criteria. While studying the phase feeding of pullets and laying hens kept in cages, Iotsyus et al. (1977) opined that White Leghorn birds fed with 19 per cent crude protein showed best results from 154 to 336 days of age, 17 per cent crude protein from 337 to 430 days and 15 per cent crude protein afterwards. Control group given a diet with metabolizable energy 270 Kcal per 100 g and crude protein 17.5 per cent at 300 days laid 12 to 17 per cent fewer eggs. The test groups also gave seven to thirteen per cent more eggs at age 400 days. From 400 to 500 days, egg yield declined and crude protein in diet was reduced to 15 per cent with ME 300 Kcal per 100 g. Controls gave slightly heavier eggs, although the test groups produced eggs of first grade.

Hamilton (1978) studied the effects of dietary protein level on productive performance and egg quality of four strains of White Leghorn hens. The effects of a mid-laying period reduction in dietary protein level was also studied. The experiment was divided into two periods, from 143 to 325 days and from 326 to 507 days of age. The hens on treatments one and two received diets containing 17 and 15 per cent crude protein, respectively during both periods. For treatment three, the diets contained 17 and 13 per cent protein and for treatment four, 15 and 13 per cent protein during the first and second periods, respectively. The results of this experiment indicated that productive performance, egg quality and shell quality of White Leghorn hens were not affected when the level of dietary protein was decreased from 17 to 13 per cent at 325 days of age or when the birds received a 15 per cent protein diet from 143 to 504 days of age.

Laying hens were given isoenergetic diets with metabolizable energy 2800 Kcal per kg feed and with protein 11, 12, 14 or 16 per cent and the efficiency of utilization of feed protein was studied (Yamazaki et al., 1979a). Retention of nitrogen was estimated when hens were 35, 46 and 57 weeks old. Except for the diet with 11 per cent protein, there was no significant difference in performance among groups. The proportion of ingested N which was retained, decreased as dietary protein increased from 12 to 16 per cent and the decrease was greater in younger birds. Efficiency of protein utilization was affected by age and protein level. In younger hens metabolism of dietary energy was affected by dietary protein and it was suggested that the efficiency of protein utilization affected the utilization of dietary energy. Yamazaki et al. (1979b) conducted one more trial to assess the efficiency of feed protein utilization. White Leghorn laying hens were fed with diets having 2700 Kcal ME per kg and three levels of protein viz., 12, 14 or 16 per cent. Compared with the diet with 16 per cent protein, the efficiency of protein utilization was 13 per cent greater with 14 per cent protein and was 28 per cent greater with 12 per cent protein.

Richter et al. (1979) studied the crude protein requirement of hybrid laying hens. From 23 to 74 weeks, White Leghorn hens in cages were given diets with crude protein from 133 to 189 g per kg. Feed intake, laying performance and egg weight were not significantly affected by dietary protein, although crude protein at 133 and 150 g per kg was associated with slight reduction in laying performance. The intake of crude protein and intake per 100 g egg weight significantly increased as the protein in the diet increased. Live weight gain, mortality and egg quality were not affected by changes in the dietary protein level. These workers suggested mean crude protein requirements of 17.0 to 17.5 g daily for an output of 225 eggs per bird upto 500 days of age.

Sixteen dietary treatments including four protein, four energy and eight calcium levels were fed to pullets in an attempt to prevent the decline in shell quality as the hen ages by reducing the normal increase in egg weight while maintaining shell weight (Roland, 1980). Results showed that when pullets were fed diets varying in protein from 20 to 13.5 per cent with a minimum of 0.53 per cent sulphur amino acids and with varying energy and calcium levels, egg weight, shell weight, specific gravity and egg production were not significantly affected. However, egg production and egg weight were significantly reduced when the protein level was lowered to 11.5 per cent. It was concluded that the rate of decrease in shell quality can be reduced or prevented for atleast five months by reducing the normal increase in egg size.

Optimum protein level for egg production in three strains of White Leghorns was studied by Singh _et al._ (1980). Each of these strains were divided into four groups and provided with diets containing 2700 Kcal per kg of ME and 24, 21, 18 and 15 per cent protein,respectively. Egg production was significantly less on 15 per cent as compared to other protein levels and significantly more on 24 per cent as compared to 21 and 15 per cent. No significant difference could be observed between 24 and 18 per cent and between 21 and 18 per cent protein levels. Results indicated that 18 per cent protein level in the diet was adequate in supporting egg production as a 21 or 24 per cent protein diet. Mean egg weight was significantly less on 15 and 18 per cent protein than 21 and 24 per cent protein levels, there being no difference between 24 and 21 per cent protein levels. In all the strains egg weight increased with an increase in the dietary protein level. Feed consumption was significantly more on 15 per cent protein diet and there was no difference between 24, 21 and 18 per cent protein levels. Similarly feed efficiency was best with 24 per cent protein ration and decreased with decreasing level of protein in the diet.

In an experiment, egg type pullets were fed isocaloric diets containing 2710 Kcal ME per kg and 16 and 18 per cent protein each from three sources viz., plant plus animal, plant and plant plus methionine. Groundnut cake and fish meal were used as plant and animal protein supplements, respectively. Egg production, egg mass, body weight gain and feed efficiency but not egg weight, feed consumption and nitrogen retention were significantly higher on higher protein level (Rothe et al., 1981).

Yamazaki et al. (1982) studied the effect of dietary protein and age on N retention of layers by giving purified whole egg protein at 12 to 21 per cent as the protein source. At 30 weeks N retention increased with increasing daily protein intakes and reached a maximum of 1000 mg N per hen daily for an intake of about 14 g protein daily. At 37 weeks, maximum daily N retention was 1350 mg, requiring 17 g daily protein intake. At 46 weeks, N retention was 1340 mg with a daily protein intake of 18 g. At 61 weeks, maximum daily N retention was 1140 mg requiring a daily protein intake of 15 g. The N retention expressed as percentage was 42 at 30 weeks, 54 at 37 weeks, 54 at 46 weeks and 46 at 61 weeks of age.

Damian et al. (1982) carried out an investigation in which laying hens were supplied with 18, 17 or 16 per cent crude protein for the whole period or were given 20, 19 and 18 per cent crude protein for 20 to 42 weeks, then 18, 17 and 16 per cent crude protein for 43 to 60 weeks and finally 16, 15 and 14 per cent crude protein for 61 to 72 weeks, respectively. Egg production was greater for hens given 18 or 17 per cent crude protein throughout and for those given

20, 19 and 18 per cent or 18, 17 and 16 per cent crude protein than for hens given 16 per cent crude protein throughout or 16, 15 and 14 per cent crude protein. Egg weight was greater during the period when the greatest amount of protein was given. Mortality was greater for hens supplied with low protein diet than those given high protein diet.

Two experiments with nine strains of White Leghorn hens were made to compare laying performance of hens given a diet of uniform protein content or a phase feeding diet in which protein content was reduced from 156 to 148 and then to 140 g per kg at 273 and 414 or 273 and 384 days of age (Cave and Hamilton, 1982). Phase feeding allowed deductions of 4.2 and 4.3 per cent in protein intake without reducing egg production, mortality or except in one strain, body weight. There was an increase of 0.5 per cent in feed intakes but feed cost was reduced by 1.3 per cent. Phase feeding increased Haugh units by 0.3 per cent. Influence of housing systems, stocking density and protein levels on productive traits in chicken was investigated by Rao et al. (1983) who reported that irrespective of the housing systems and densities the birds with 18 per cent protein gave significantly better egg production than birds on 15 per cent protein. The protein level had a significant effect on feed consumption in that the 18 per cent protein fed birds consumed significantly more feed than those on 15 per cent protein level. In general the birds fed with 18 per cent dietary protein performed better than the birds fed with 15 per cent protein.

In an experiment, Vogt and Krieg (1983) observed the influence of different crude protein levels (20.5, 19.4 or 18.4 g daily) in the feed on the performance of laying hens and opined that with decreased protein intake, egg yield and feed efficiency were poorer but protein efficiency improved by about eight per cent. Laying hens were given practical diets with varying protein levels viz., 16, 18, 20 and 22 per cent and concluded that increasing protein from 16 to 18 per cent increased average hen-day egg production significantly. It was also reported that increasing protein beyond 18 per cent had no further significant effect (Onwudike, 1983).

While studying the factors influencing early egg size, Summers and Leeson (1983) opined that increasing dietary protein or methionine level had little or no effect on egg size. The effect of sorghum tannin (low and high) and protein level (11.5 and 14.5 per cent) on the performance of laying hens maintained in two temperate environments (22 and 28°C) were studied by Sell et al. (1983). Egg production and feed efficiency were reduced and weight loss was increased by 11.5 per cent protein as compared with 14.5 per cent protein.

The influence of dietary sand on the performance and egg shell quality of laying hens fed decreasing protein regimes were investigated by How-Hong Hsieh and Rowland (1983). Laying hens were fed with diets containing 2850 Kcal ME per kg at three protein levels viz., 15.0, 13.5 and 12.0 per cent, diluted with either zero or six per cent builders sand. There was a decrease in egg production as dietary protein levels were reduced. Egg size and body weight decreased significantly when dietary protein levels were reduced. When the zero and six per cent sand groups were combined, egg shell percentage and feed conversion values were increased when dietary protein levels decreased.

Prasad et al. (1984) observed significantly superior egg production (66.22 per cent) in 18 per cent dietary protein fed birds as compared to those fed 15 per cent dietary protein (61.52 per cent). The protein levels had no significant effect on feed consumption. The birds fed with 18 per cent dietary protein had significantly better feed efficiency as compared to 15 per cent dietary protein fed birds. It was also observed that there were no significant differences in body weight gains and per cent livability of birds due to different protein levels studied.

Requirement of Energy

Energy content is considered as the most critical nutritional factor of a ration since the feed intake and therefore indirectly the intake of other nutrients is influenced to a major extent by its energy content. Like protein, energy requirement of chicken is dictated by many factors like age, size, stage of production and environmental temperature.

Using three strains, Owings (1964) tested four levels of productive energy viz., 775, 850, 925 and 1000 Calories per pound of diet and one level of added L-lysine with a 13.5 per cent protein diet for ten 28-day periods. During first five periods there was a significant improvement in egg production due to increased dietary energy. Though this trend was also noted during the last five periods, the differences were not statistically significant. Increasing the dietary energy significantly reduced the feed required to produce one dozen eggs during the first five periods. This reduction was also observed during the last half of the experiment but the differences were not significant. Body weight was also significantly influenced by energy level.

Coligado and Quisenberry (1967) compared an energy phase feeding system with constant energy, using layers housed in cages of two sizes with three densities. The birds fed constant energy received a 16 per cent protein diet containing 932 Calories while the energy phase fed birds received diets with 1032 Calories for four, 28-day periods, 982 Calories for the next four and 932 for the remaining four. It was observed that feeding a high energy diet at the onset of production significantly depressed egg number and body weight gain but increased egg size and feed efficiency with no effect on mortality. Energy phase feeding did not change the carcass content of protein, fat, moisture, calcium and phosphorus but total ash was slightly lower on energy phase fed birds.

Bragg and Hodgson(1969) studied the effect of dietary energy level on the performance of caged layers. Dietary treatments included three levels of metabolizable energy viz., 2794, 2570 and 2354 Kcal per kg in isonitrogenous (16.1 per cent protein) wheat-soyabean meal laying rations. The ration containing 2354 Kcal per kg was divided into two parts and low energy was obtained by adding wheat bran or wheat straw at the expense of wheat, yielding two dietary treatments at the low energy level. The results showed no difference in egg production between the three levels of dietary energy or between low energy rations. Egg weight decreased slightly from high to low dietary energy but no change was observed between the two low energy rations. Feed consumption increased significantly as energy was decreased in laying rations with a concomitant change in efficiency of feed utilization. However, efficiency of energy utilization improved as dietary energy was decreased from 2794 to 2354 Kcal per kg of the ration.

Palafox and Flegal (1970) employed White Leghorn pullets raised under subtropical condition, from 20 through 74 weeks of age, to study the effect of 16 per cent protein ration containing graded concentrations of tallow to provide 2576, 2682, 2788, 2894 and 3000 Kcal ME per kg in the diet on efficiency of egg production. Pullets fed the 2894 Kcal ME per kg diet laid eggs at a significantly higher rate than those fed 2576 and 3000 Kcal ME per kg diets. The birds fed 2682, 2788 and 2894 Kcal ME per kg did not differ significantly with regard to egg production. Pullet body weight increased, whereas daily feed consumed per egg produced decreased linearly with increase in dietary energy level. For optimum overall efficiency, pullets fed the diet which contained 2894 Kcal ME per kg were superior to others fed other levels tested.

Relationship of dietary energy, egg number, fatty liver and tissue composition was studied by Palafox and Flegal (1971). The birds were fed with 16 per cent protein layer diets containing 0, 1.5, 3.0, 4.5 and 6.0 per cent tallow. Fatty liver increased linearly with increase in dietary energy. Liver fat score of pullets fed 4.5 and 6.0 per cent tallow was significantly higher than those of pullets fed zero per cent tallow. Correlation studies showed that liver fat score was positively correlated with egg number, liver total lipids and plasma total lipids.

The influence of various dietary energy levels on feed consumption, calorie intake and liver fat content of White Leghorn hens maintained at a temperature of 16.5°C was determined by Ivy and Nesheim (1971). The diets contained 1150, 1350 and 1550 Calories ME per pound with an identical calorie-protein ratio. Daily feed consumption increased initially when hens were switched to the high energy diet, then declined to below the intake of the intermediate energy group within 7-10 days. During the same period the feed intake of hens fed the low energy diet plateaued, although daily calorie intake was below for both higher energy treatments. The low energy fed birds had a significantly lower liver fat content than the other two treatments. No difference in liver fat content was observed between hens receiving intermediate and high energy diets.

Chauhan et al. (1972) conducted a study in which 18 hens were fed on diets with 15 to 16 per cent protein and 2950, 3150 or 3350 Kcal ME per kg for 54 days and reported that the different energy levels studied did not have any influence neither on egg production nor on egg quality. In order to relate egg production at high temperature to the daily energy intake, Wilson et al. (1973) conducted an experiment under controlled temperature conditions with Leghorn pullets. The birds were fed rations of either 2200, 2600, 2800 or 3500 Kcal per kg of ME and kept at temperatures of either 15, 26.7 or 32°C for either five or 14 days. The results obtained revealed differences in the energy intake on egg forming days in contrast with the intake of non-egg forming days. The layers did not adjust their calorie intake to the energy level of the feed. Based on the results obtained, the authors stated that the accuracy of estimates of energy requirements, based on averages when the temperature was not controlled appeared questionable.

In a factorial trial seven months old dwarf and normal laying hens were kept at 22° or 30°C and were given metabolizable energy intakes of 250 and 350 Kcal per 114 g feed. The higher energy content and the higher temperature each reduced feed intake by both types of hens. However, actual energy intake was not reduced by high energy feed but was reduced by heat. Egg production was adversely affected by high energy diet (Ahmad et al., 1974). The influence of different levels of energy viz., 2800 or 3010 Kcal ME per kg and lysine viz., 0.63, 0.75 or 0.85 per cent on the egg yield of laying hens was investigated by Gondos et al. (1975). Egg production was not significantly affected by different diets but tended to increase for hens given 3010 Kcal per kg. Feed intake for unit weight of eggs produced tended to be less in those given 3010 Kcal per kg. There were more deaths among hens given 3010 than among those given 2800 Kcal per kg.

In a trial, Petersen (1975) reduced the energy intake of hens by the addition of high fibre, low energy ingredients such as barley, wheat bran and barley hulls, from 300 to 340 Kcal ME per bird daily to 230 to 240 Kcal. Laying house temperatures differed. There were little differences in egg production or egg size. In a further five years study, all birds got the same daily intake of all nutrients and quantity of feed, the only variable being average daily intake of energy. Energy intake was 200 to 300 Kcal ME per bird and house temperatures were 50, 60, 70 and 80°F. Egg production ranged from 46.7 to 80.1 per cent. Results were poorest with the lowest energy intake at lowest temperatures. When the daily intake of energy was 260 Kcal ME per bird, egg production was 75.5, 75.8, 77.2 and 80.1 per cent at house temperatures of 50, 60, 70 and 80°F, respectively. Corresponding values for egg weight were 56.5, 56.7, 56.3 and 55.7 g.

Luke et al. (1975) conducted an experiment with four White and six brown breeds kept in deep litter or cages on diets of 2650 or 2800 Kcal ME per kg to assess their performance. The low energy diet resulted in a doubled mortality rate and surprisingly there were more deaths due to fatty liver syndrome. There was only very little difference between the different energy fed birds in respect of the number of eggs, the egg mass and the laying percentage. Feed consumption per egg unit was not significantly different between different diets. The possible influence of different energy levels on fat deposition in the liver of laying hens was investigated by Hartfiel and Tuller (1975). For 24 weeks the birds were given feeds with ME 2500, 2700 or 2900 Kcal per kg. With the low energy feed they lost 90 g body weight each and laying decreased by five per cent. Energy consumption per unit egg substance was fairly similar. Energy intake per bird was 284, 299 and 305 Kcal, so that the extra-energy available above egg production was 209, 219 and 222 Kcal, which might explain the increase in liver fat.

Lillie *et al.* (1976) determined the dietary energy requirements of caged layers as influenced by relative humidity and temperature variations. All birds were exposed to a 14 hour light regime and to one of four relative humidity levels viz., 50, 60, 70 and 80 per cent and one of three dry bulb temperatures viz., 13.0, 21.5 and 29.5°C. Isonitrogenous diets of varying energy levels viz., 3080, 2648 and 2220 Kcal ME per kg were fed *ad libitum*. Egg production was significantly greater on the low energy diet than on the high energy diet ($P<0.01$). The intermediate energy diet did not differ significantly from the other two dietary energy levels in this respect. The high energy diet resulted in lower egg weights ($P<0.05$) than did the intermediate and low energy diets. Specific gravity score and Haugh units were unaffected by dietary energy, an inverse relationship was observed between dietary energy and feed intake that was consistent among three energy levels. The differences were significant.

Khoo (1976) conducted an experiment in which laying hens of 47 weeks of age were offered four isoenergetic diets either full fed or about seven, 14 and 21 per cent less than fully fed control hens. Restricting the energy intake by seven per cent, giving an estimated daily energy intake of 273 Kcal ME resulted in egg production and egg mass output equivalent to the control. Greater restriction depressed egg production and egg mass output. Feed efficiency was improved by energy restriction. Egg weights were not affected by energy restriction. In the restricted hens body weight gains were less.

Palafox (1977) observed the effect of increasing dietary energy levels on performance of laying pullets. White Leghorn pullets were given diets with 16 per cent crude protein and metabolizable energy 2576, 2682, 2788, 2894 or 3000 Kcal per kg. As metabolizable energy increased body weight also increased, but daily intake of feed and protein and per egg decreased. Best overall efficiency was observed with ME 2894 Kcal per kg diet. Two levels of bird density viz., four and five birds per 16" x 16" cage and six levels of energy concentration viz., 3000, 2925, 2850, 2775 and 2625 Kcal ME per kg were tried in commercial pullets to assess their performance (Minners et al.,1977). Per cent hen-day egg production (77.7) was the highest and per cent mortality (9.12), feed consumed per dozen eggs (1.79 kg) and Kilocalories of ME (414) per egg were lowest at the 2775 Kcal level. Feed consumed per hen per day (112.8g) was the lowest at the highest energy level, but Kilocalories consumed per hen per day (311.3) was the lowest at the lowest energy level.

To determine the energy and protein requirements of laying hens, Summers and Leeson (1978) carried out a study in which White Leghorn pullets were fed diet with 17.8 per cent crude protein and varying metabolizable energy levels of 3080, 2860, 2640 and 2420 Kcal per kg. It was reported that egg production, egg weight and conversion of feed to egg mass was not affected by the diet. Pullets on the diets with most energy took 42 Kcal more daily than those on the diet with least energy and this resulted in a difference of 15 per cent in body weight. Increased protein intake associated with the low energy diet did not improve performance.

The production performance of hens as influenced by dietary energy at varying temperatures was studied by Vohra et al. (1979). Diets containing 2830 and 1980 Kcal per kg (high and low energy, respectively) were fed to Leghorn hens kept at 15.6 and 26.7°C ambient temperatures. The average metabolizable energy intakes per day were 231 and 287 Kcal at 15.6°C and 200 and 242 Kcal at 26.7°C for the low and high energy diets respectively. Within this temperature range, the feed intake decreased by 1.21 and 1.41 per cent per one degree C rise in ambient temperature for the low and high energy diets respectively. Neither egg production nor shell thickness was influenced by the treatments, but egg weight was significantly depressed at 26.7°C as compared to those at 15.6°C. The energetic efficiency was increased for the conversion of ME intake to egg energy either by increasing the ambient temperature or by lowering the dietary ME.

Effect of dietary energy concentration on the performance of heavy egg type hens at various densities in cages was studied by Carew et al. (1980). Three dietary energy levels viz., 2737, 3003 and 3322 Kcal ME per kg were employed at densities of 1320, 660 and 440 cm^2 of floor area per hen. Dietary energy levels tested did not significantly alter overall hen-day egg production. However, egg production on the highest dietary energy level declined more rapidly in the latter months. Therefore, a high dietary energy content was not conducive to sustained egg production. There was no significant interaction between hen density and dietary energy level. As dietary energy level increased, feed intake decreased and feed efficiency increased. The highest dietary energy caused an increase in egg size during the mid part of the experiment. Otherwise, energy level did not affect egg weight, shell strength, Haugh units or blood and meat spots. It was concluded that feeding of high energy rations to hens housed at high densities in cages may not be advisable, since egg production consistently got lowered under these conditions.

Fotoohi et al. (1980) investigated the biological and economic impact of certain feeding regimes on commercial egg type hens. Two isonitrogenous diets, viz., 15.7 per cent protein and 2728 or 2828 Kcal ME per kg fed to large and small body sized hens from the same cross produced similar rates of egg production, feed per dozen eggs, egg weight and livability. Hens on the high energy diet produced eggs with the thickest shells. An economic evaluation suggested that smaller sized hens performed more profitably on the low energy diet, while large hens produced greater profit when fed the high energy diet. Rowland et al. (1980) studied the effect of varying energy levels viz., 2650, 2725 and 2800 Kcal ME per kg on the caloric efficiency and indicated that with an increase in the caloric content from 2650 to 2800 Kcal there was a 5.5 per cent improvement in caloric efficiency.

Four strains of White Leghorns were given 100 g diet daily with protein 16 per cent and metabolizable energy 2800 or 3000 Kcal ME per kg. Eggs were collected randomly throughout the laying period and stored in groups of 200 for zero, three, seven or fourteen days at 23°C. It was observed that egg quality and yolk cholesterol were not significantly affected by energy level of the diet (Campos and Ferreira, 1981).

In two experiments, Elwinger (1981) tried different energy levels viz., 10.7, 11.2, 11.7 or 12.2 MJ per kg with three strains on egg production. It was observed that increasing the dietary energy content resulted in a linear increase in energy intake, heavier eggs, improved feed conversion efficiency but poorer energy conversion efficiency, increased body weights and more abdominal fat and poorer feather condition.

Energy : Protein ratio

The importance of protein and energy and their interrelationship have been fairly well established. Several studies have been conducted under a variety of experimental conditions with a view to arrive at optimum calorie-protein levels for best production performances. Inspite of the voluminous research findings, one cannot possibly pinpoint the exact requirements of these well established nutrients, probably due to the existing micro and macro-environments in the experimental flocks. In order to highlight the available information, works related to energy-protein ratios are reviewed here.

Mc Daniel _et al._ (1959) studied the effect of dietary fat, calorie intake and protein level on the performance and occurrence of fatty liver syndrome in caged layers. Three levels of protein viz., 15, 20 and 25 per cent were employed and each level was fed at energy levels of 750 and 960 Calories productive energy per pound. The 15, 20 and 25 per cent protein levels were also fed at energy levels of 940, 860 and 800 Calories PE per pound, respectively. Results showed that the three protein levels fed at energy levels from 750 to 960 Calories per pound did not show any significant influence on egg production. Significant differences in serum cholesterol were found to exist between protein levels fed and to be significantly correlated (positively) with total liver fat, per cent liver fat, serum lipid phosphorus, total serum protein and total serum albumen. Dietary protein and energy levels studied did not have any effect on total serum lipid levels.

Three intake levels each of protein, energy and vitamin-mineral mixture upon the performance of laying hens were investigated by Gleaves et al. (1967). For maximum egg production, energy consumption approximated 328 kilocalories of ME during the first 52 weeks of egg production, 294 Kcal from 53 to 76th week of egg production and an overall intake of 318 Kcal of ME per hen per day during the entire 76 weeks egg production period. Protein intake per hen per day for the same time intervals were 17.6, 15.9 and 17.1 g, respectively. A slight increase in egg weight was observed as energy and protein consumption were increased. Maximum egg weight was not obtained with those energy and protein consumption levels which supported maximum levels of egg production. However, these differences were relatively small. A gain in body weight was observed with those energy consumption levels which produced maximum levels of egg production.

Speers and Balloun (1967) reported that there was a distinct difference of protein requirements between different strains of White Leghorn hens. Two strains performed well on a 15 per cent protein at an energy level of 2860 Kcal ME per kg, whereas another strain required only a 13 per cent diet. When energy was increased to 3190 Kcal, all the strains required higher protein levels.

Quisenberry et al. (1967) compared energy and protein phase feeding with constant diets using commercial pullets housed in cages. Protein levels of 16, 17 and 18 per cent and productive energy of 927, 932, 936, 946, 982, 1000 and 1032 Calories were used. It was observed that a combination of energy and protein phase feeding was superior to either alone. Protein phase feeding resulted in higher egg production, lower weight, same egg size, daily feed and protein consumption, but fewer calories than energy phase feeding.

Creek (1970) explained the mathematical analysis of protein and energy requirements. Calculations revealed that the slope of the calorie-protein ratio for a corn-soyabean meal blend varies considerably more with respect to change in nutrient quality with adult birds or laying hens than it does in the broiler range. Thus the calorie-protein ratio does not have a constant meaning at practical points. Expression of energy-protein relationships in terms of "per cent protein per megacalorie" showed quite clearly that the slope is relatively constant and has equivalent meaning. It was recommended that protein be expressed as "per cent per megacalorie" rather than the calorie-protein ratio.

Three experiments were conducted to examine the effects of three levels of dietary protein viz., 13, 16 and 19 g, three levels of dietary energy, viz., 250, 275 and 300 Kcal ME, volume, weight and environmental temperature upon feed consumption and certain production characteristics in laying chickens (Gleaves and Dewan, 1971). Dietary protein and energy did not exert a significant influence on feed consumption. As dietary energy was increased feed intake decreased, but the effect was not significant because of the small range of levels used. Dietary protein and energy significantly influenced livability. Livability was generally best among hens that were fed the two higher levels of dietary protein ie., 16 and 19 g. Livability was significantly influenced by dietary energy only in the summer experiments, in that case as dietary energy was increased, livability decreased. As dietary protein was increased egg production increased significantly, along with a significant increase in body weight gain. The effect of energy was significant only in the energy x volume factorial trial. In this case body weight gain increased as dietary energy was increased.

Gardner and Young (1971) studied the effect of four dietary protein and two energy levels on the chemical and physical composition of the egg and reported that increasing the dietary protein level from 12 to 18 per cent resulted in an increase in total egg weight and in the weight of all egg components. Increasing the dietary energy level from 947 to 1003 Calories per pound produced only minor effects on relative weight of egg component parts.

Sadagopan *et al.* (1971) investigated the effect of different levels of protein, energy and their relationship on egg production and feed conversion on diets containing medium and high energy levels with four levels of protein viz., 12, 15, 18 and 20 per cent in White Leghorn pullets. There was no significant difference on egg production with diets containing 15, 18 and 20 per cent protein with medium and high energy levels ie., widening the calorie-protein ratio from 135:1 to 179:1 (Kcal ME per kg to per cent protein). But widening the ratio from 179:1 to 206:1 at 15 per cent protein level showed a slight decrease in egg production. Feed required to produce one kilogramme and one dozen eggs was progressively decreased as the protein content of the diet increased. Though increasing the energy content in the same protein series did not affect the egg production the feed efficiency was improved. However, maximum feed efficiency was observed with rations containing 148:1 to 161:1 ratios at 18 and 20 per cent protein levels.

Yoshida and Hoshii (1972) reported that abdominal fat of hens increased with the high energy diets and decreased with the low energy diets. Dietary protein level had little effect on abdominal fat. With chickens the diets with less energy resulted in less abdominal fat and the extra protein in the diet also reduced abdominal fats. The protein and energy requirements of laying hens in summer temperature was determined by Rybina and Reshetova (1972). The hens were fed rations containing protein ranging from 13.0 to 19.9 per cent and energy from 260 to 304 Kcal ME per 100 g. Average monthly temperature for the trial was above 20° from June to October and from 26.7° to 32.4°C in July and August. The groups given protein 19.6 per cent and energy 304 Kcal had the highest average summer egg yield at 72 per cent, with 73 and 75.5 per cent,respectively, in July and August. Egg production for the groups given 17 per cent protein and 271 Kcal energy or the normal protein and energy levels for caged layers, was from 5.6 to 10 per cent less than yield for the groups given high protein and energy levels. There was a definite positive relation between weight of egg and level of protein in the feed. The groups given protein 16.9 per cent and energy 301 Kcal had the lowest feed intake.

Karunajeewa (1972) studied the effect of two protein levels viz., 15 and 17 per cent each with two energy levels viz., 2660 and 2840 Kcal ME per kg on the performance of three strains of different body weights. Birds of either level of protein laid at similar rates and had similar egg production on hen housed basis. Birds given more energy laid more eggs on hen housed basis than those given less energy. Egg size of different strains differed. There was a significant interaction between protein and energy content on egg weights. Eggs were lighter when 17 per cent protein was given with less energy. Birds fed 15 per cent crude protein with 2840 Kcal ME per kg was the most efficient in this trial.

Gleaves _et al._ (1973) conducted two experiments to estimate the maintenance levels of protein and energy and the effect of egg production upon feed consumption of laying hen. Twentyeight week old pullets were fed nine different 120 g diets containing all combinations of

10, 13 and 16 g protein and 200, 250 and 300 Kcal of ME. The first experiment included normal and overiectomized pullets under controlled environmental temperature. The second experiment included normal and progesterone injected pullets under controlled environmental temperature. Average production was 0.189, 0.086 and 0.740 eggs per hen per day for the overiectomized, progesterone injected and normal hens, respectively. Body weight gain was 0.66, 0.69 and 1.14 g per hen per day for the respective treatments. Feed intake levels were significantly different at each energy level. There was no significant effect of protein upon feed intake. Egg production for normal and "non-laying" hens increased significantly with each increase in dietary protein.

An experiment was conducted to compare the laying performance of seven strains of White Leghorns housed in cages under two different intensities when fed seven diets differing in protein (ranged from 11.1 to 16.9 per cent) and energy (ranged from 2590 to 2860 Kcal ME per kg) levels (Aitken et al., 1973). It was concluded that protein intake was the dietary factor most closely associated with large effects of diets on gains in body weight, egg production, egg size, feed conversion and albumen height.

Average daily crude protein intake of 17 g for the laying year appeared adequate and there was no significant strain difference in dietary effects. Effect of ration on egg quality at 450 days of age was relatively minor. The low level of protein was associated with smaller egg size, a lower rate of production and hence with higher albumen height and Haugh unit score.

With the objective of determining dietary protein and energy requirement of laying hens in the tropic, Khoo (1974) conducted a trial in which birds were freely offered six diets with protein 15, 17 or 19 per cent and metabolizable energy 2.6 or 2.8 Kcal per g. It was found that for highest egg production daily intake of 290 to 300 Kcal ME per hen was required. A diet with protein 15 per cent and ME 2.8 Kcal per g was found to be adequate for good egg production and feed efficiency expressed as kg feed per dozen eggs or g feed per g egg. Protein or energy content of the diet had no significant effect on egg production, albumen height or shell quality; however, there was an interacting effect of protein and energy on egg weight. Mean body weight gain was greater with 2.8 than with 2.6 Kcal per g diet.

The effect of three energy levels, viz., 2650, 2750 and 3050 Kcal ME per kg each with two protein levels viz., 15 and 18 per cent on the performance of caged layers in the tropics has been investigated by Sugandi *et al.* (1975). The trial lasted for one year and the average monthly temperatures during the laying year ranged from 25.6° to 26.9°C. Pullets on higher protein levels laid significantly more eggs ($P < 0.01$) than those on the lower protein level. The groups fed the higher protein levels consumed 17 to 18 g of protein per bird per day and those fed the lower level consumed 13 to 15 g. Egg production at the highest energy level as significantly lower ($P < 0.05$) than at the two lower energy levels which did not differ from each other. Feed conversion was significantly better ($P < 0.01$) with the higher protein level than the lower one. Increasing the dietary energy level resulted in a highly significant decrease ($P < 0.01$) in feed consumption. Feed consumption of birds fed the higher protein was greater ($P < 0.01$) than that of birds fed the lower levels. Egg weights increased slowly during the year and reached a plateau with no sharp decrease at any time. Shell thickness and Haugh units declined some what during the year. Egg weight, shell thickness and Haugh units were similar to reported temperate zone values. This experiment supported the use of 17.5 per cent rather than 15 per cent protein and an energy level of 2650 or 2850 Kcal of ME per kg.

Ivy and Gleaves (1976) conducted an experiment to estimate the minimum protein and energy requirements of laying hens at different production levels. Egg production levels of 4.2, 29.8, 49.1 and 70.5 per cent were actually obtained with progesterone therapy. The effects of egg production level and dietary energy level on feed consumption were statistically significant. As egg production increased feed intake increased and as energy level increased feed intake decreased. The protein and energy consumption at egg production levels of 4.2, 29.8, 49.1 and 70.5 per cent were 9.3 and 182, 11.4 and 227, 12.5 and 250 and 13.5 g and 269 Kcal ME per kg, respectively. The maintenance requirement was estimated to be 6.1 g of protein and 156 Kcal ME per hen per day. It appeared that 15 g of protein and 299 Kcal ME per hen per day would be adequate for birds producing 80 per cent or more. As egg production declined to 70 per cent, 13.5 g of protein and 269 Kcal ME seemed adequate. Finally, when production declined to 50 per cent, 12.5 g of protein and 250 Kcal ME per hen per day appeared to be sufficient.

Mather et al. (1976) carried out an experiment to study the influence of dietary energy, protein and environmental temperature on feed intake and hen performance. The treatments consisted of three levels each of energy viz., 200, 250 and 300 Kcal ME and protein viz., 13, 16 and 19 g in 120 g feed and two environmental temperatures viz., 14 and 30°C. There was a significant inverse relationship between dietary energy level and feed intake and protein intake and a positive relationship with body weight change. The energy intake of hens on the low energy diets was significantly lower than for the medium and high energy diets. The treatments did not significantly influence egg production, albumen height, Haugh units and livability.

Hybrid laying hens were offered for eight weeks with one of the three diets, with crude protein 17, 17.7 or 18.3 per cent and metabolizable energy 2750, 2860 or 2930 Kcal per kg, each containing three, four or five per cent calcium (Malaj and Kovac, 1976). With increasing protein and energy egg weight tended to fall but calcium content had no effect.

The effect of three levels of calcium viz., 1.8, 3.6 and 5.4 g, three levels of protein viz., 13, 16 and 19 g and three levels of ME viz., 200, 250 and 300 Kcal in 120 g feed on feed intake, egg shell quality and hen performance was studied by Gleaves et al. (1977). Average egg production was best with diets containing 19 g protein, 200 Kcal ME and 5.4 g calcium. Voluntary feed intake was influenced significantly by dietary energy and protein. As protein level was increased, egg production increased and consequently feed intake increased. Protein was the only variable that significantly affected egg weight. Hens fed the low level of protein produced eggs that were 0.8 to 1.5 g lower in weight than hens fed the other two protein levels. The hens on the high levels produced lighter weight eggs than those fed the intermediate level, but the effect was not significant. There was a gradual but significant improvement in albumen height as dietary protein increased.

Vyas et al. (1977) tried two levels of dietary energy viz., 2650 and 3400 Kcal ME per kg diet each with two levels of protein viz., 16 and 22 per cent in caged layers. It was observed that the diet with less energy and more protein gave fewer eggs than the others in the cold month of January and more than others in October and March. Hens given it required more protein per 12 eggs than the other groups. Diet had no significant effect on size of eggs.

Mohan et al. (1977) had taken up a 4 x 4 factorial experiment with 11, 13, 15 and 17 per cent dietary protein levels, each with 2550, 2650, 2750 and 2850 Kcal ME per kg to find out the relationship of protein and energy in caged layers. The results showed a significantly better egg production and feed efficiency on 15 and 17 per cent dietary protein level as compared to 11 or 13 per cent dietary protein level. The protein x energy interaction or increase in energy level in diet did not have any significant effect on feed efficiency but affected the egg production. The average egg weight and body weight gain increased with corresponding increase in protein level. With the increase in protein level from 11 to 13 per cent there was a decrease in albumen quality. However, an increase in albumen quality was noticed when the energy level was increased from 2550 to 2750 Kcal ME per kg. Both albumen quality and average egg weight were affected by protein x energy interaction. An increase in dietary protein level resulted in increased carcass moisture and carcass protein content, while an increase in dietary energy level resulted in decreased moisture and protein content with simultaneous increase in fat content of carcass. It was concluded that a calorie-protein ratio of 177:1 with 15 per cent dietary protein and 2650 Kcal ME per kg appears to be adequate for optimum performance of caged layers.

Khoo and Beh (1977) conducted an experiment in which three levels of dietary protein viz., 15, 17 and 19 per cent each with two levels of metabolizable energy viz., 2.61 and 2.85 Kcal per g were tried to find out the performance and nutritional requirements of dwarfs and non-dwarf layers. It was noticed that although the output from neither genotype was significantly affected by the diet there was a tendency for the dwarfs to produce more eggs from the diet with more protein and 2.85 Kcal ME per g.

White Leghorn hens, previously having a restricted intake of feed for three weeks, were fed with diets containing various levels of energy (MEK), viz., 930, 1100, 1270 or 1435 kJ daily and protein viz., 14.3, 17.6, 21.2 or 24.5 g daily (Voreck and Kirchgessner, 1979) and reported that with increasing energy or protein laying increased progressively from about 88 to 94.95 per cent. Egg weight was increased considerably by increasing protein supply although not with 24.5 g daily. Body weight of hens was increased most by increasing the intake of energy, although increasing the protein also had a positive effect. The effect of four levels of N-corrected metabolizable energy (ME) viz., 930, 1100, 1270 and 1440 kJ daily and four levels of crude protein viz., 14.3, 17.6, 21.2 and 24.6 g daily on the nitrogen balance of caged layers was studied by Voreck and Kirchgessner (1980a). It was noted that the N balance was slightly negative even with 24.6 g crude protein, although the daily protein loss decreased from 0.16 to 0.04 as the protein supply increased. Greater dietary energy did not reduce N loss even when dietary protein supply was suboptimal.

In another study, Voreck and Kirchgessner (1980b) reported that depending on the energy and protein intakes, the mean daily protein retention by 96 hybrid laying hens varied from 4.7 to 7.1 g. Retention was more influenced by the protein intake than by the total energy intake. The crude protein utilization ranged from 24.0 to 36.0 per cent. Increasing the crude protein intake decreased the utilization, while increasing the energy intake increased the utilization. The crude protein utilization for egg production was 40 per cent of the total.

The effects of four levels each of dietary energy (ranged from 930 to 1440 kJ per hen daily) and crude protein (ranged from 14.3 to 24.5 per cent) on the metabolisability of dry matter and organic contents of the diets were investigated (Voreck and Kirchgessner, 1980c). With increasing levels of protein the utilization of both dry matter and organic matter decreased, but increased with an increase in the energy supply. Treatment effects are ascribed to the varying degrees of utilization of dietary protein with different energy and protein intakes.

Voreck and Kirchgessner (1980d) conducted another experiment in which laying hens at the peak of their egg production were given diets with varying energy and protein levels that were similar to the previous trial. The high energy content of the diet resulted in a feed consumption per kg eggs of less than two kg, even when the hens had large gains in body weight. They also observed that supplementation of diets with extra protein did not influence the feed and energy intakes per kg of eggs, or the energy utilization. Results with 14 g crude protein were less favourable than with higher levels.

In a study taken up by El Boushy et al. (1980) caged birds were fed one of the five diets, in which the energy-protein ratio was constant. Diets one to five had crude protein 12.0, 12.9, 14.0, 15.0 and 16.0 per cent and metabolizable energy 8.71, 9.57, 10.27, 11.10 and 11.70 MJ per kg. From 24 to 64 weeks old, egg production of hens given diets one to five was 71.46, 71.31, 72.51, 71.13 and

69.99 per cent respectively. Corresponding values of mean egg weight, weekly feed intake and efficiency of feed conversion were 60.51, 60.47, 61.11, 61.02, 61.07 g ; 157.16, 147.56, 142.03, 130.37, 126.72 g; 3.674, 3.460, 3.262, 3.031, 3.014 kg feed per kg egg, respectively.

Doran et al. (1980) observed the response of 30 strains of egg type pullets to four layer diets differing in protein and energy levels. Diet one contained 15.1 per cent protein and 2770 Kcal ME per kg of feed; diet two, 15.1 per cent protein and 3010 Kcal ME per kg; diet three, 17.2 per cent protein and 2770 Kcal ME per kg and diet four, 17.2 per cent protein and 3010 Kcal ME per kg of feed. The hens on diet four laid at a significantly higher rate than the hens on diets one or two. Hens receiving 17.2 per cent protein laid 2.19 per cent more eggs than hens receiving 15.1 per cent protein. The higher caloric level improved egg production by only 0.96 per cent. As protein level increased and caloric level (within each protein level) increased, egg size increased, feed required to produce a unit of egg decreased and body weight increased. Type of diet fed had no statistically significant effect on interior egg quality expressed as Haugh units or upon mortality. Protein level of the diet increased egg size more significantly than caloric level.

The effect of four levels of metabolizable energy (nitrogen-corrected) viz., 930, 1100, 1270 and 1440 kJ daily, each with four levels of crude protein viz., 14.3, 17.6, 21.2 and 24.5 g daily on the body composition of laying hens was studied by Kirchgessner and Voreck (1980). At the start of the experiment, hens had an initial body weight of about 1600 g and contained an average of 45.5 per cent dry matter, 23.3 per cent crude protein, 18.2 per cent total fat and 12.5 kJ energy per g live weight. During the 40 days of experiment, the varying energy and protein supply resulted in major changes of body composition, depending on whether the hens gained or lost weight. Dry matter varied from 41 to 49 per cent, crude protein from 20 to 24 per cent and total fat from 13 to 24 per cent of the whole body in relation to the differences in energy and protein supply. Differences in final body composition of the hens were almost exclusively affected by the varying energy intake. Lower energy intake resulted in a reduction in fat content, decreased body weight and accordingly increased protein content. Conversely, higher energy intake brought about a lower protein content of the whole body because of the increased deposition of fat.

Reid and Maiorino (1980) investigated the effects of dietary protein and metabolizable energy on the layer performance employing four levels of energy viz., 2.42, 2.64, 2.86 and 3.08 Kcal per g of diet and three levels of protein viz., 14, 16 and 18 per cent in a 4 x 3 factorail design. At the 14 per cent protein level, increasing the dietary energy produced a progressive decrease in egg production rate, but an improvement in feed conversion efficiency. The protein intake levels for birds fed these diets varied from 18.3 to 15.0 g per bird per day as the dietary energy was increased. Birds fed 16 per cent protein showed increased egg production as the energy of the diet was increased. Regression analysis suggested a 2.25 per cent increase in egg production for each 0.22 Kcal ME increase per g feed. Protein intake varied from 19.4 to 17.0 g per bird per day in this series. The 18 per cent protein diet resulted in protein intakes of 19.2 to 22.1 g per bird per day and less response in egg production than was obtained at 16 per cent protein with increased levels of energy. The calculated protein intake requirement during the first twelve weeks was 17.92 g per bird per day to support 84.8 per cent egg production. During the second twelve weeks, the requirement was estimated at 16.5 g protein per bird per day at 77.2 per cent egg production, while during the last twelve weeks a requirement of 13.0 g per bird per day was determined at a

61.7 per cent egg production rate. Calculations of g of protein needed per egg during each of the three periods yielded values of 21.1 to 21.4 g.

In a study, four levels of protein viz., 12, 14, 16 and 18 per cent each with four levels of metabolizable energy viz., 2540, 2640, 2740 and 2840 Kcal per kg were tried to find out the production traits of caged layers (Reddy *et al.*,1980). There was significant improvement in per cent hen-day egg production, feed consumption, feed efficiency and egg weights with increase in each level of dietary protein. Increase in dietary energy levels significantly decreased egg production, feed consumption, feed efficiency and egg weight. A maximum productive response was obtained with 18 per cent protein diet in combination with dietary energy levels of 2540 and 2640 Kcal per kg in respect of egg production and feed efficiency. The 14, 16 and 18 per cent protein diets were similar in affecting the egg weights. Increasing levels of dietary protein resulted in decline in both albumen and yolk quality, while increasing levels of dietary energy improved albumen quality with no effect on yolk quality. Protein x energy interactions were significant with all the traits. It was concluded that calorie-protein ratios of 141 and 147 with 18 per cent dietary protein and energy levels of 2540 and

2640 Kcal per kg appeared to be satisfactory for optimum performance of caged layers.

Doran et al. (1981) conducted an experiment to study the effect of four grower-layer dietary feeding systems on caged layer performance. The feeding systems were as follows: System A - 16 per cent protein, 2950 Kcal ME per kg from 12 to 16 weeks of age, 19 per cent protein, 2900 Kcal ME per kg from 17 to 21.5 weeks of age, 16 per cent protein in the layer phase; System B - 18 per cent protein in the layer phase; System C - 16 per cent protein, 2750 Kcal ME per kg from 12 to 16 weeks, 19 per cent protein, 2700 Kcal ME per kg from 17 to 21.5 weeks and 16 per cent protein in the layer phase and System D - 18 per cent protein in the layer phase. Hen-day egg production for the dietary systems, A, B, C and D were 74.25, 75.25, 73.51 and 74.95 per cent, respectively. Corresponding values for egg weight were 57.85, 58.86, 58.04 and 58.75 g, respectively. Analysis of the data revealed that birds subjected to system B had a significantly higher rate of lay and feed efficiency when compared with system C. The increased protein level during the laying period increased egg size significantly. It was also observed that feeding system had little effect on body weight during the laying phase.

An experiment was conducted to find out the effect of dietary protein and energy content on laying hens exposed to mean daily maximum temperatures from 33.3° to 42.2°C (Thatte et al., 1981a). Dietary protein levels ranged from 14 to 28 per cent and energy levels from 2511 to 2811 Kcal ME per kg diet. The protein and energy levels employed in this trial did not have any significant influence on egg production, egg weight and body weight gain/loss. However, egg production was higher on higher protein levels and egg weight increased upto 20 per cent protein level, but not beyond. Most birds lost weight to the extent of nine to 15 per cent regardless of energy or protein level or protein quality. It was observed that inadequate energy intake rather than protein, appeared to result in depression in egg production, egg weight and loss of body weight. The authors also suggested that protein requirements appeared to be 18 per cent or higher.

In another study, Thatte et al. (1981b) employed varying protein levels from 14 to 24.5 per cent and energy levels from 2511 to 2811 Kcal ME per kg under the tropical climatic conditions to estimate their requirements. No significant difference could be observed in average egg production, egg weight, egg mass and body weight gain between varying protein and energy levels, except that 14 per cent protein diets resulted in significantly lower egg production and egg mass. In general, egg production, egg weight and body weight gain were higher on higher protein levels. Lower energy diets showed higher egg production but egg weight and body weight were higher on higher energy levels. Feed conversion efficiency (feed per dozen eggs as well as feed per kilogramme egg mass) was better on higher protein and higher energy levels. Protein conversion was higher on lower protein levels and higher energy levels. Energy conversion showed the reverse trend. An average daily ME intake of 301 to 303 Kcal supported high production. Daily intake of 18 to 20 g protein supported higher egg production, egg weight and body weight.

Madrid _et_ _al_. (1982) carried out three experiments to evaluate the effects of body weight, age, dietary protein and tallow levels on performance, nutrient intake and energy utilization of laying hens. Old, moulted and young hens (72, 106 and 27 weeks of age, respectively), divided into heavy and light body weight groups were employed for the study. They were fed with 10 diets containing 12, 14, 16, 18 and 20 per cent dietary protein in combination with one or four per cent supplemental fat. Egg output was increased with the supplementation of tallow in only the young birds.

Estimated daily protein intake requirements were 16.8, 13.3 and 12.8 g per day to support production levels of 84, 64 and 66 per cent for the young, old and moulted birds, respectively.

The effects of feeding three protein levels viz., 16, 18 and 20 per cent, each at three metabolizable energy levels viz., 2400, 2600 and 2800 Kcal per kg diet in the tropics were studied with brown egg type layers (Olomu and Offiong, 1983). Dietary protein had no significant effects on hen-day egg production, egg weight, Haugh units, feed intake, feed conversion, feed cost per dozen eggs, calorie intake, egg weights and final body weight. Protein consumption on all levels of dietary protein was over 20 g per bird per day and increased significantly with increases in dietary protein. Mortality was lowest on the highest protein level. The highest energy level significantly depressed egg production and feed and protein intake. The feed costs per dozen eggs increased significantly with increases in dietary energy level. Caloric intake and final body weights were similar for the medium and highest energy levels but significantly higher than that obtained on the lowest energy level. Egg weights, Haugh units, feed per dozen eggs and mortality were not significantly affected by energy levels. Inspite of the average maximum monthly temperatures, ranging from 26.8 to 35.2°C, annual egg production was about 71 to 73 per cent for the best groups, figures comparable with those obtainable in temperate climate. Egg weight and Haugh units were similar to reported temperate zone values. This experiment supported the use of 16 per cent protein and a ME level of 2400 Kcal per kg diet for brown egg type layers.

In two factorial trials, laying hens were fed on diets with metabolizable energy 11.7, 11.3 or 10.9 MJ per kg diet, or with 11.7, 11.3, 10.9 or 10.5 MJ per kg and crude protein 21.8, 20.8 or 19.9 g per hen daily (Vogt, 1983). It was observed that decreasing energy in diet had no effect on laying performance but it increased feed intake and decreased feed efficiency. Decreasing the protein intake from 21.8 to 19.8 g per hen daily decreased the laying rate slightly and decreased feed efficiency and energy efficiency by 3.5 per cent, but increased the crude protein efficiency by 6.8 per cent.

Khan and Baghel (1983) conducted an experiment in which dwarf pullets were fed with diets containing three protein levels viz., 14, 16 and 18 per cent each with three energy levels, viz., 2600, 2800 and 3000 Kcal ME per kg diet in a factorial design to examine their performance. Egg production improved from 62 to 73 when crude protein was increased from 14 to 18 per cent but decreased from 73 to 58 eggs when dietary energy increased. The protein x energy interaction effects were not significant.

In a factorial trial, Neumann and Kirchgessner (1983) studied egg yields of laying hens given varying energy concentrations, viz., 1070, 1240 or 1410 kJ (nitrogen corrected metabolizable energy) and crude protein viz., 16.2, 17.7 or 19.2 g daily. Individual egg weight and composition were not changed by the protein or energy intake, so differences in total daily output of energy and protein depended on the number of eggs. With increasing intake the production of eggs was 68, 71, and 77 per cent. Protein intake of 17.7 g or over gave maximum egg production.

Musharaf and Scheele (1983) conducted a 2 x 3 x 2 factorial trial, employing metabolizable energy at two levels, 2605 and 2915 Kcal per kg; metabolizable energy (Kcal per kg): crude protein (%): and lysine (%) at three levels, 1000:5.9:0.19, 1000:5.9:0.24 and 1000:7.5:0.24; and ME : fat (%) at two levels, 1000:1.9 and 1000:3.5. During the study the ambient temperature was cyclic 38°C by day and 27°C by night at 50 per cent constant relative humidity.

High energy diets reduced feed consumption, improved feed efficiency but had no effect on egg weight. Increasing protein level improved feed efficiency and egg weight but no effect on feed consumption.

Dammert and Giessler (1982) conducted an experiment employing three levels of metabolizable energy viz., 10.5, 11.3 or 12.1 MJ per kg and three levels of crude protein viz., 14, 16 or 18 per cent, to study the egg yield and feed intake of laying hens. With decreasing energy, feed intake increased, so that daily ingestion of ME was fairly similar at all levels. Egg number and egg weight were not affected by energy level. Protein level affected feed intake only with ME at 11.3 MJ per kg. Egg number and weight were less with 14 than with 18 per cent protein and feed required per kilogramme egg produced was more. Performance with 16 per cent protein was also sub optimal. For practical laying feeds ME at 10.5 to 12.1 MJ per kg was recommended. With about 11.5 MJ, protein at all stages should be about 18 per cent.

The results of studies presented in the foregoing section clearly reveal that the energy and protein requirements are governed by multiplicity of factors, the major ones being the genetic potentiality, climatic profile of the region in which the birds are grown and stage of production.

With the development of commercial hybrids for higher egg production we have almost reached a plateau in genetic improvement and therefore the efficiency of utilization of nutrients is the area that needs attention to make poultry farming economically viable. Further the change in systems of rearing as for example from deep litter to cages also affects efficiency and therefore recommended nutrient allowance henceforth has to be more precise for specific situations.

Materials and Methods

MATERIALS AND METHODS

An experiment was designed and conducted at the Department of Poultry Science, College of Veterinary and Animal Sciences, Kerala Agricultural University, Mannuthy, to evaluate the dietary protein and energy requirements of caged White Leghorn strain cross layers under the prevailing environmental conditions of Kerala.

One hundred and ninety two strain cross (IWN x IWP) Single Comb White Leghorn pullets of same hatch maintained at the All India Co-ordinated Research Project (AICRP) on Poultry for Eggs, at the Mannuthy centre were selected at random for the experiment. They were 176 days of age at the commencement of the trial. The birds were wing badged and housed in 64 California type colony cages with three birds in each. The cage dimensions were 60 cm x 45 cm x 40 cm size providing 900 cm^2 area per bird. The cages had been erected in a well ventilated and well lighted poultry house. Four levels of protein viz., 14, 16, 18 and 20 per cent and four levels of metabolizable energy of 2400, 2500, 2600 and 2700 Kcal per kg were employed in a factorial design. Thus, in all, there were 16 treatments and each treatment was replicated four times and each replicate had three birds. The allotment of pullets to different treatment groups as well as to the different cages were made at random.

The birds under the different treatment groups were fed different layer rations varying in protein and energy content as outlined earlier. The composition of the different treatment diets is given in table 1. The ingredients required for the formulation of the diet were procured in one lot and were analysed for proximate composition. The feed was mixed four times during the entire period. However, after each mixing the mixed feed was analysed for its protein and energy content. Of the ingredients, the level of fish meal, being the animal protein source, was kept constant in all the diets. However, marginal adjustments were made in all the other ingredients to obtain the required protein and energy levels of the diets. The individual ingredients as well as the mixed rations were analysed each time for their crude protein and energy levels. The metabolizable energy values of the ingredients and rations were calculated using the prediction equation suggested by Carpenter and Clegg (1956). The available carbohydrate was estimated by the application of anthrone reagent (Clegg, 1956). The proximate composition of ingredients as well as rations was estimated according to the procedure described in A.O.A.C. (1970).

Feed and water were provided ad lib. The routine managemental practices were followed throughout the experimental period.

The meteriological variables of macroclimate such as temperature and relative humidity of the region where the experiment was conducted were recorded monthly.

The general observations were made for 12, 28-day periods and were subsequently pooled to form four phases, each phase representing a specific season of the year, based on the climatic profile reported by Somanathan and Rajagopalan (1983) for Mannuthy.

Individual body weights were taken at the beginning and end of the experimental period to study the pattern of body weight gain under the different feeding regimes.

Daily egg production, under the different treatment groups was recorded during the entire experimental period. From this data, hen-day egg production was calculated for each phase.

Feed intake data was recorded at the end of each 28-day period and was calculated phase wise.

Feed efficiency was calculated based on both egg number (kilogramme feed per dozen eggs) as well as egg mass (kilogramme feed per kilogramme egg).

The layer house mortality during the experimental period was recorded for assessing the livability of each treatment group.

During the last three consecutive days of each 28-day period, four eggs from each treatment were saved at random every day for egg quality studies. They were marked, weighed individually and stored in a refrigerator for internal quality studies on the next day. The height and width of albumen, height and diameter of yolk and shell thickness were recorded. From these data albumen index, yolk index and Haugh unit were calculated as per USDA procedure (Anon, 1975). While breaking open the eggs for quality evaluation the incidence of blood spot and meat spot, if any, was also recorded.

At the end of the experimental period, four birds from each group were chosen at random for estimation of total serum lipids, serum inorganic phosphorus and total serum protein, albumen and A:G ratio. For the estimation of blood parameters blood was collected from the brachial vein. Total serum lipid was estimated according to method described by Josyln (1970). The estimation of serum inorganic phosphorus was done by the method of Fiske and Subbarow (1925). Biuret method (Gornall et al., 1949) was employed for the determination of total serum protein and albumen and based on the above A:G ratio was calculated.

The haemoglobin of the experimental birds was estimated (four birds from each treatment) employing the traditional acid haematin method using Sahli's haemoglobinometer. The values were corrected by using the following correction factor as recommended by Rao (1981).

$$\text{Corrected haemoglobin value} = \frac{\text{Sahli's value} + 1.57}{0.96}$$

Ethylene diamine tetra acetate (EDTA) was used as the anti-coagulant. The packed cell volume was also measured centrifuging a sample of blood (2500 x g for 30 min) and calculating the per cent volume occupied by the packed red cells (Wintrobe, 1961).

During the last day of the twelfth, 28-day period, one bird from each treatment was selected at random for carcass analysis studies. The birds were fasted for six hours and killed by cervical dislocation. The procedure outlined by Mohan et al. (1977) was employed for the preparation of carcass for chemical analysis. The carcass was made into a homogenised material and an aliquot was used for estimating moisture content. The remaining portion was dried and finely ground and used for estimation of proximate principles as per A.O.A.C. (1970).

During slaughter of birds for carcass analysis studies, one piece of liver from each bird was saved, marked and sealed in polythene bag and was stored in deep freezer for subsequent estimation of protein and lipids. The liver samples were thawed, dried and finely ground before analysis. Estimation of protein and ether extractives of the liver samples were made employing the procedure described in A.O.A.C. (1970).

During the last phase of the experiment, excreta collection was made for 24 hours for nitrogen balance studies from two cages from each treatment. The droppings were weighed and a sample was taken for moisture determination. The balance quantity was placed in a polythene bag, sealed and kept in a deep freezer for nitrogen determination. This procedure was repeated. Nine birds in three cages were kept without any feed for two days for estimating the endogenous nitrogen loss. Using the data on nitrogen content of droppings, feed and egg, feed intake, egg production and endogenous nitrogen loss, the nitrogen balance was calculated.

The data collected were subjected to statistical analysis (Snedecor and Cochran, 1967).

Table 1. Percentage composition of experimental diets.

Ingredients	Energy	2400 Kcal ME/kg				2500 Kcal ME/kg			
	Protein (%)	14	16	18	20	14	16	18	20
Groundnut oil cake		7.00	12.00	17.00	22.00	7.00	12.00	17.00	22.00
Yellow maize		49.00	45.00	40.50	36.00	53.50	49.50	45.00	40.50
Fish meal		8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Rice bran		32.00	31.00	30.50	30.00	27.50	26.50	26.00	25.50
Shell meal		2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
[1] Mineral mixture		1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75
Salt		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
[2] Rovimix AB_2D_3 (g)		25	25	25	25	25	25	25	25
[3] Liv. 52 (g)		100	100	100	100	100	100	100	100
<u>Analysed Value</u>									
Energy (Kcal ME/kg)		2409	2422	2414	2407	2503	2512	2520	2508
Protein (%)		14.20	16.17	18.14	20.10	14.13	16.20	18.10	20.11

Contd.......

Table 1. Contd.......

Ingredients	Energy	2600 Kcal ME/kg				2700 Kcal ME/kg			
	Protein (%)	14	16	18	20	14	16	18	20
Groundnut oil cake		7.00	12.00	17.00	22.00	7.00	12.00	17.00	22.00
Yellow maize		58.00	54.00	49.50	45.00	62.50	58.50	54.00	49.50
Fish meal		8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Rice bran		23.00	22.00	21.50	21.00	18.50	17.50	17.00	16.50
Shell meal		2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
[1]Mineral mixture		1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75
Salt		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
[2]Rovimix AB_2D_3 (g)		25	25	25	25	25	25	25	25
[3]Liv. 52 (g)		100	100	100	100	100	100	100	100
Analysed Value									
Energy (Kcal ME/kg)		2608	2621	2628	2625	2718	2724	2711	2705
Protein (%)		14.26	16.12	18.20	20.16	14.23	16.17	18.24	20.19

1. Poultrymin (Aries Agro-Vet Industries Private Ltd.) contained Calcium (Min) - 32.00%, Phosphorus (Min) - 6.00%, Copper (Min)-100 ppm, Cobalt (Min)-60 ppm, Manganese (Min)-2700 ppm, Iodine - 100 ppm, Zinc - 2600 ppm, Iron - 0.1% and Magnesium - 1000 ppm.
2. Rovimix $A+B_2+D_3$ (Roche Products Ltd.) contained vitamins A, B_2 and D_3 at levels of 40,000 I.U., 20 mg and 5,000 I.U. per g. respectively.
3. Liv. 52 powder (The Himalayan Drug Co.).

Results

RESULTS

A 4 x 4 factorial experiment with different dietary levels of protein and energy, as outlined in the Materials and Methods, was conducted to decipher variation, if any, in the requirement of energy and protein for layers housed in cages. The results obtained are presented in this chapter.

The mean minimum and maximum temperature as well as relative humidity (monthwise) from October 1983 to August 1984 (period of experiment) of the campus where the experimentation was undertaken is depicted in table 2.

Table 2. Mean monthly temperature and relative humidity during the period of experiment.

Month	Temperature (°C)		Relative humidity (%)
	Maximum	Minimum	
October '83	31.8	23.2	80.9
November '83	31.0	22.3	75.1
December '83	30.2	23.7	70.7
January '84	31.6	22.7	64.8
February '84	33.9	24.1	65.0
March '84	34.5	24.0	71.0
April '84	33.9	23.9	75.3
May '84	34.8	25.8	71.9
June '84	28.6	23.1	88.0
July '84	28.1	23.0	88.0
August '84	29.0	23.0	86.2

PRODUCTION PARAMETERS

Body weight gain

The gain in body weight of the birds fed varying dietary levels of energy and protein (Table 3) showed a numerical increase as the level of these two nutrients were increased. However, the statistical analysis of the data presented in table 4 revealed that the magnitude of difference observed in either case was not significant. It could also be seen from the analysis of variance table (Table 4) that there was no interaction effect. Of the various combinations of energy and protein, the lowest gain in weight of 149.38 g was observed in 14:2700 combination and the highest gain of 497.5 g for 18:2700 protein-energy combination. The initial and final body weight of the experimental birds is shown in appendix I.

Table 3. Body weight gain of layers fed varying levels of protein and energy (g).

Protein (%)	Energy (Kcal ME/kg diet)				Mean
	2400	2500	2600	2700	
14	281.82	347.78	325.50	149.38	281.05
16	286.67	316.43	441.11	428.33	379.35
18	285.50	361.67	342.27	497.50	357.22
20	333.33	336.67	337.92	467.50	369.00
Mean	296.53	342.06	358.21	385.15	

Table 4. Analysis of variance of body weight gain of layers fed varying levels of protein and energy.

Source	df	MSS	F
Protein	3	144869.05	2.43 NS
Energy	3	119373.71	2.01 NS
Interaction	9	30635.65	0.51 NS
Error	129	59719.41	
Total	144		

NS - Non significant

Egg production

Egg production of the experimental birds over a period of 12, 28-day periods calculated as per cent hen-day egg production is presented in table 5 and the statistical analysis thereto in table 6. If energy level alone is considered, the lowest egg production of 65.75 per cent was observed among birds fed a diet containing 2700 Kcal ME per kg and the highest of 67.15 per cent for the diet containing 2600 Kcal ME per kg. Likewise, when protein alone is considered the lowest rate of 58.48 per cent production was observed in those birds fed 14 per cent protein, while the highest value of 71.15 per cent was observed in the group fed 18 per cent protein diet (Fig. 1). It could be seen from the analysis of variance data (Table 6) that the differences observed in per cent hen-day egg production among various dietary energy levels employed were not statistically significant, whereas the differences observed among the protein levels were statistically significant ($P<0.01$). Egg production was significantly lower among birds fed a diet containing 14 per cent protein while it was significantly higher for the birds fed a diet containing 18 per cent protein. However, the egg production obtained from birds fed 16 per cent and 20 per cent were not statistically different. Likewise, those between 18 and 20 per cent was also not significant. Statistical analysis of the egg production data also revealed that there was no interaction effect between protein and energy.

In as much as the period of experimentation lasted about eleven months the possible influence of season over egg production and interaction effects with season was studied. The data when classified according to the four seasons prevalent in Kerala showed statistically significant difference ($P<0.01$) in hen-day egg production among the four seasons (Table 6). It was also observed that the interaction effect between energy and season was not significant whereas

Table 5. Per cent hen-day egg production of layers fed varying levels of protein and energy.

Protein (%)	Energy (Kcal ME/kg diet)				Mean
	2400	2500	2600	2700	
14	64.03	56.50	58.20	55.21	58.48^{a}
16	67.82	66.43	65.51	65.36	66.28^{b}
18	71.44	71.49	70.80	70.89	71.15^{c}
20	63.18	71.92	74.08	71.53	70.18^{bc}
Mean	66.62	66.59	67.15	65.75	

Values bearing the same superscript do not differ significantly.

<u>Critical difference</u>

Protein - 5.13

Season - 3.19

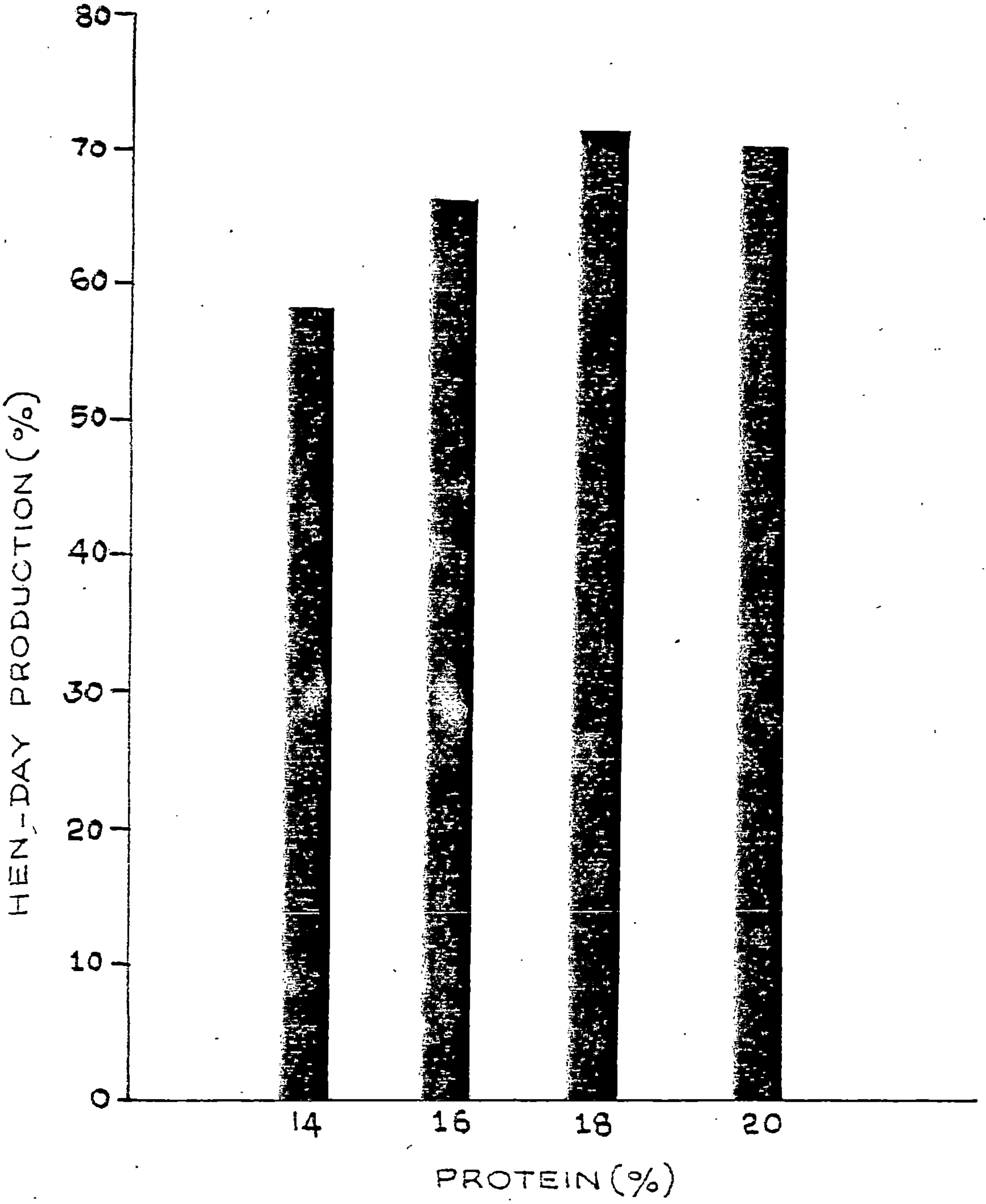
Season x Protein - 6.38

Table 6. Analysis of variance of per cent hen-day egg production of layers fed varying levels of protein and energy.

Source	df	MSS	F
Protein	3	2122.17	10.19**
Energy x Protein	9	204.14	0.98 NS
Energy	3	21.46	0.10 NS
Error A	48	208.50	
Season x Protein	9	199.51	2.35*
Season x Energy	9	61.33	0.72 NS
Season	3	2342.21	27.59**
Interaction	27	50.67	0.60 NS
Error B	144	84.88	

* Significant at 5% level
** Significant at 1% level
NS Non Significant

FIG. 1 : PER CENT HEN-DAY EGG PRODUCTION INFLUENCED BY VARYING DIETARY PROTEIN LEVELS



that between protein and season was significant ($P < 0.05$). On further analysis it was revealed that during warm wet and warm dry periods a dietary protein level of 18 per cent resulted in optimum egg production, while 16 per cent dietary protein would be sufficient during hot dry and cold wet seasons.

It could also be seen from the data on egg production categorised based on seasons, that the maximum hen-day egg production of 73.93 per cent was obtained during warm dry period. Egg production during hot dry, cold wet and warm wet seasons were 68.25, 64.22 and 59.69 per cent, respectively. The statistical analysis of the means revealed that the egg production was significantly highest during the warm dry period and the lowest during warm wet period. The egg production during the other two seasons was intermediate eventhough production was significantly higher during hot dry when compared to cold wet season (Appendix II and III).

Feed intake

Data on mean daily feed intake of birds fed varying levels of protein and energy is given in table 7. The range of mean daily feed intake per bird varied from 99.77 g to 120.96 g. When the data were subjected to statistical analysis, the magnitude of difference in daily feed intake per bird among various protein levels or among energy levels was not found to be different (Table 8). However, the daily feed intake per bird between various seasons showed statistically significant differences (Appendix IV and V). It was significantly lower for the warm wet season (100.30 g) and significantly higher for the cold wet season (119.84 g). The differences in feed consumption during warm dry and hot dry seasons were not statistically significant eventhough these were significantly higher than the warm wet season.

Table 7. Mean daily feed intake per bird fed varying levels of protein and energy (g).

Protein (%)	Energy (Kcal ME/kg diet)				Mean
	2400	2500	2600	2700	
14	120.32	108.52	99.77	100.26	107.22
16	104.77	105.53	114.74	109.55	108.65
18	116.78	113.22	115.69	108.52	113.55
20	112.06	120.96	113.96	116.09	115.77
Mean	113.48	112.06	111.04	108.61	

<u>Critical difference</u>

Season - 3.83

Table 8. Analysis of variance of feed intake per bird per day fed varying levels of protein and energy.

Source	df	MSS	F
Protein	3	1039.25	1.92 NS
Energy x Protein	9	664.50	1.22 NS
Energy	3	270.00	0.50 NS
Error A	48	541.72	
Season x Protein	9	217.25	1.78 NS
Season x Energy	9	157.92	1.29 NS
Season	3	4257.17	34.88 **
Interaction	27	129.56	1.06 NS
Error B	144	122.04	

** Significant at 1% level.

NS-Non significant

Feed per dozen eggs

Feed per dozen eggs is one of the parameters which indicates the efficiency of a ration as well as the biological efficiency of the bird. Therefore a critical evaluation of this ratio will enlighten the economic superiority or otherwise. The data calculated for feed per dozen eggs for the varying combinations of energy and protein employed in the study is set out in table 9. The statistical analysis of the data presented in table 10 revealed that the level of protein in the diet as well as the season influences the feed efficiency, whereas the level of energy does not seem to affect the feed efficiency at the levels tested. It was also revealed that there is no interaction effect either between energy and protein nor between season and nutrients.

The lowest ratio of 1.94 was obtained with a diet containing 18 per cent protein, while the highest ratio of 2.36 was obtained with a diet containing 14 per cent protein (Fig. 2). The differences observed in the ratios among 16, 18 and 20 per cent dietary protein levels were not statistically significant. Likewise, the difference obtained between 14 and 16 per cent was also not significant.

When the feed per dozen eggs was calculated based on seasons (Appendix VI and VII) it was observed that the lowest ratio (1.89) was obtained for the warm dry season and the highest ratio (2.41) for the cold wet season. The difference in ratios observed between warm dry and hot dry (1.98) seasons was not statistically significant. Likewise, that between hot dry and warm wet (2.14) was also not significant.

Table 9. Feed per dozen eggs of layers fed varying levels of protein and energy (kg).

Protein (%)	Energy (Kcal ME/kg diet)				Mean
	2400	2500	2600	2700	
14	2.31	2.82	2.08	2.22	2.36^{b}
16	2.04	2.06	2.17	2.15	2.10^{ab}
18	2.00	1.93	1.98	1.87	1.94^{a}
20	2.17	2.05	1.87	1.97	2.01^{a}
Mean	2.13	2.22	2.03	2.05	

Values bearing the same superscript do not differ significantly.

Critical difference

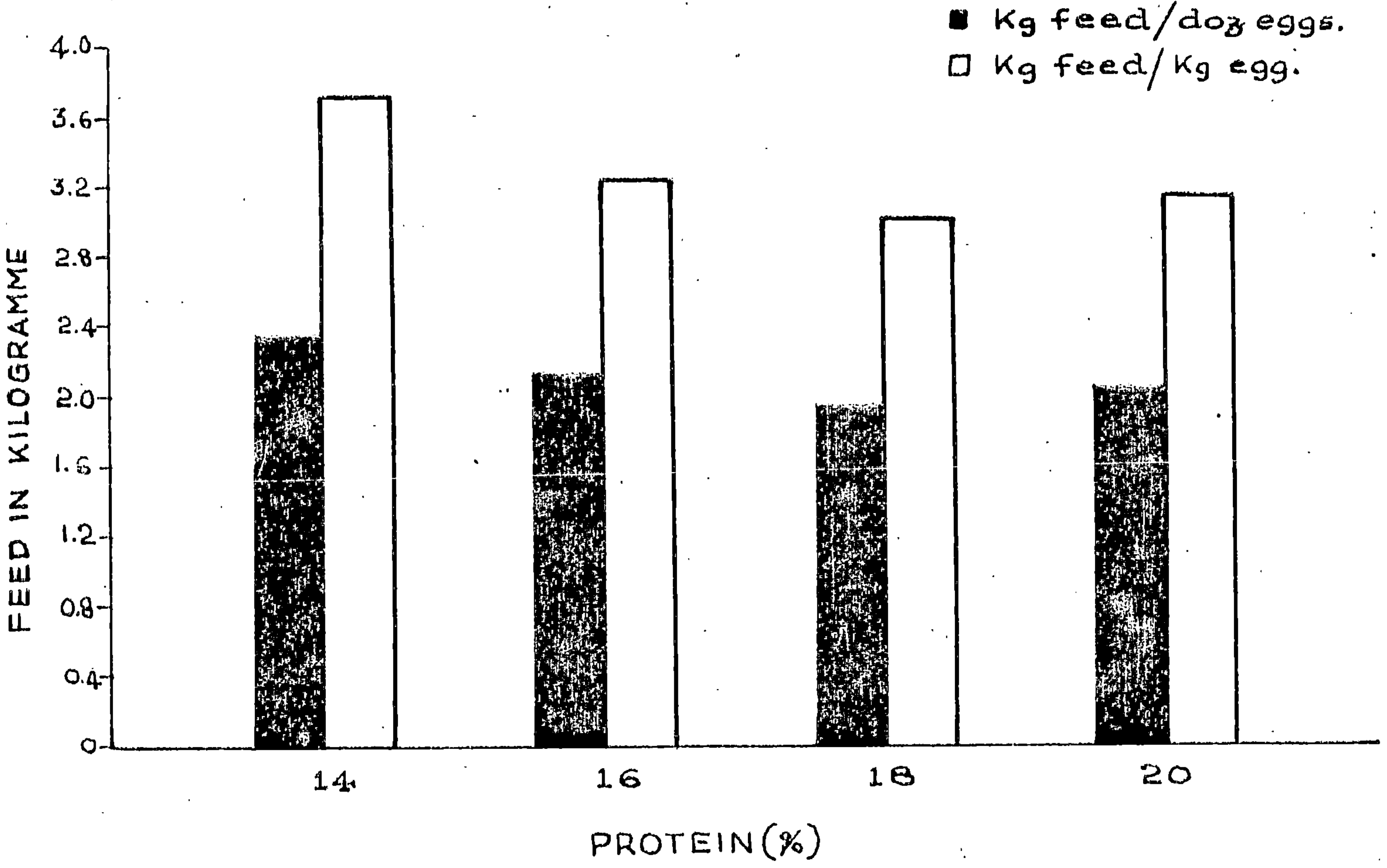
Protein - 0.26 Season - 0.23

Table 10. Analysis of variance of feed per dozen eggs of layers fed varying levels of protein and energy.

Source	df	MSS	F
Protein	3	2.12	3.95 *
Energy x Protein	9	0.53	0.98 NS
Energy	3	0.47	0.87 NS
Error A	48	0.54	
Season x Protein	9	0.58	1.36 NS
Season x Energy	9	0.51	1.20 NS
Season	3	3.31	7.77 **
Interaction	27	0.35	0.83 NS
Error B	144	0.43	

* Significant at 5% level.
** Significant at 1% level.
NS -Non significant.

FIG.2. FEED CONVERSION EFFICIENCY OF LAYERS FED VARYING DIETARY PROTEIN LEVELS



Feed per kilogramme egg

Information on the efficiency of feed to produce unit weight of a product is another measure to indicate the efficiency of the feed as well as the bird. The increased consciousness for eggs with higher weight than number necessitates that efficiency be measured in terms of both number and weight. Thus the productive efficiency is to be decided based on the comparison of efficiency of production both in number and weight of the product.

The feed required to produce one kilogramme of egg presented in table 11 indicated that protein content of the diet influenced this parameter, while the energy content did not show any significant influence. When the data was classified and analysed according to season it was observed that the feed per kilogramme of egg was influenced by the season too. However, specific energy-protein combinations or specific season-nutrient combinations exerted no influence on this parameter.

The mean values presented in table 11 and the statistical analysis of the data presented in table 12 revealed that the lowest ratio of 3.08 was obtained with a diet containing 18 per cent protein, while the higher ratio of 3.74 was obtained with a dietary protein level of 14

Table 11. Feed per kilogramme of egg of layers fed varying levels of protein and energy (kg).

Protein (%)	Energy (Kcal ME/kg diet)				Mean
	2400	2500	2600	2700	
14	3.59	4.42	3.28	3.68	3.74^{b}
16	3.19	3.24	3.33	3.32	3.27^{a}
18	3.11	3.07	3.15	3.00	3.08^{a}
20	3.40	3.19	2.91	3.10	3.15^{a}
Mean	3.32	3.48	3.17	3.28	

Values bearing the same superscript do not differ significantly.

Critical difference

Protein - 0.40 Season - 0.35

Table 12. Analysis of variance of feed per kilogramme of egg of layers fed varying levels of protein and energy.

Source	df	MSS	F
Protein	3	5.72	4.44 **
Energy x Protein	9	1.15	0.89 NS
Energy	3	1.08	0.84 NS
Error A	48	1.29	
Season x Protein	9	1.41	1.39 NS
Season x Energy	9	1.35	1.34 NS
Season	3	6.40	6.32 **
Interaction	27	0.89	0.88 NS
Error B	144	1.01	

** Significant at 1% level.

NS - Non significant.

per cent. The differences observed among dietary levels of 16, 18 and 20 per cent protein was not statistically significant.

When the data were analysed based on the seasons it was revealed that the lowest ratio of 3.02 was obtained during the warm dry period, whereas the highest ratio of 3.59 was obtained during cold wet season (Appendix VIII and IX). However, the differences in feed efficiency calculated as feed per kilogramme of egg between warm dry and hot dry (3.05) season was not statistically significant. Similarly, the differences between cold wet and warm wet (3.58) season were also not significant.

EGG QUALITY PARAMETERS

Egg weight

The mean egg weights obtained from the birds fed different dietary protein and energy levels is presented in table 13 and the connected statistical analysis in table 14. The overall egg weight irrespective of the protein level or energy level seems to be reasonable. When egg weight is classified according to the dietary protein levels, it was found that the highest weight of 54.66 g was obtained at 16 per cent protein level and the lowest of 53.30 g with 14 per cent protein level. The statistical analysis of the data revealed that the egg weight between protein levels 14 and 18 per cent is homogenous and that between 18 and 20 per cent is also homogenous. Likewise, when the egg weight data are analysed in relation to the energy content of the diet, it was observed that birds fed a diet containing 2700 Kcal ME per kg laid eggs with lowest egg weight (53.23 g), whereas the birds fed a diet containing 2400 Kcal ME per kg laid eggs with highest weight (54.29 g). The statistical analysis of the data revealed that the egg weight obtained from birds fed diet containing energy level of 2400 and 2600 Kcal ME per kg were not significantly different. Likewise, that between 2500 and 2700 Kcal ME per kg were also not significant.

The statistical analysis further revealed the existence of a significant difference in an interaction between protein and energy. An examination of the data in the light of this indicated that the highest egg weight obtained with a dietary protein-energy combination of 18:2400, 16:2600 and 16:2700 are homogenous. The mean egg weight of birds influenced by period, dietary protein and energy is shown in appendix X.

Table 13. Mean egg weight of layers fed varying levels of protein and energy (g).

Protein (%)	Energy (Kcal ME/kg diet)				Mean
	2400	2500	2600	2700	
14	54.48	53.38	54.19	51.15	53.30^{a}
16	54.03	53.49	55.68	55.46	54.66^{c}
18	54.87	53.39	53.03	52.75	53.51^{ab}
20	53.79	54.31	54.15	53.58	53.96^{b}
Mean	54.29^{b}	53.64^{a}	54.26^{b}	53.23^{a}	

Values bearing the same superscript do not differ significantly.

Critical difference

Period	- 0.81	Energy	- 0.47
Protein	- 0.47	Protein x Energy	- 0.94

Table 14. Analysis of variance of egg weight of layers fed varying levels of protein and energy.

Source	df	MSS	F
Period	11	1396.23	84.76 **
Protein	3	209.17	12.70 **
Period x Protein	33	18.23	1.11 NS
Energy	3	151.00	9.17 **
Period x Energy	33	18.83	1.14 NS
Protein x Energy	9	162.11	9.84 **
Period x Protein x Energy	99	19.96	1.21 NS
Error	2112	16.47	
Total	2303		

** Significant at 1% level.

NS- Non significant.

Shell thickness

The shell thickness of the eggs produced by the birds fed different dietary regimen is presented in table 15 and the analysis of variance in table 16. The effect of protein and energy on shell thickness recorded periodwise is presented in appendix XI. The mean shell thickness of all the eggs examined was 0.332 mm. When the shell thickness data were analysed in relation to the protein content of the diet, it was found that the eggs laid by hens fed a dietary protein level of 14 per cent had the thickest shell (0.337 mm) while that obtained from those fed 18 per cent protein diet had comparatively thinner shells (0.326 mm). When the magnitude of difference was tested statistically it was revealed that the thickness of shell of eggs obtained from birds fed dietary protein level of 14 and 16 per cent and 16 and 20 per cent were not significant.

When the relationship between energy level and shell thickness was considered the eggs obtained from birds fed diet containing 2600 Kcal ME per kg had comparatively thicker shells (0.335 mm) and that obtained from birds fed diet containing 2500 Kcal ME per kg had thinner shells (0.331 mm). Statistical analysis revealed that the differences in shell thickness observed among various energy levels were not significantly different.

Table 15. Mean shell thickness of layers fed varying levels of protein and energy (mm).

Protein (%)	Energy (Kcal ME/kg diet)				Mean
	2400	2500	2600	2700	
14	0.338	0.341	0.337	0.332	0.337^{c}
16	0.325	0.337	0.338	0.340	0.335^{bc}
18	0.328	0.325	0.326	0.326	0.326^{a}
20	0.335	0.322	0.337	0.332	0.332^{b}
Mean	0.332	0.331	0.335	0.333	

Values bearing the same superscript do not differ significantly.

Critical difference

Period - 0.0057 Protein x Energy - 0.0065

Protein - 0.0032

Table 16. Analysis of variance of shell thickness of layers fed varying levels of protein and energy.

Source	df	MSS	F
Period	11	0.0306	37.57 **
Protein	3	0.0128	15.71 **
Period x Protein	33	0.0010	1.23 NS
Energy	3	0.0011	1.35 NS
Period x Energy	33	0.0004	0.58 NS
Protein x Energy	9	0.0047	5.85 **
Period x Protein x Energy	99	0.0006	0.83 NS
Error	2112		
Total	2303		

** Significant at 1% level.

NS- Non significant.

Table 17. Mean Haugh unit score of layers fed varying levels of protein and energy.

Protein (%)	Energy (Kcal ME/kg diet)				Mean
	2400	2500	2600	2700	
14	83.08	82.65	85.00	82.35	83.27^{d}
16	83.00	81.08	81.97	83.28	82.33^{c}
18	81.13	77.15	79.44	80.42	79.53^{b}
20	80.38	77.74	79.42	76.23	78.44^{a}
Mean	81.89^{c}	79.66^{a}	81.46^{bc}	80.57^{ab}	

Values bearing the same superscript do not differ significantly.

Critical difference

Period	- 1.58	Energy	- 0.91
Protein	- 0.91	Protein x Energy	- 1.83

Table 18. Analysis of variance of Haugh unit score of layers fed varying levels of protein and energy.

Source	df	MSS	F
Period	11	4148.36	66.15 **
Protein	3	2989.00	47.66 **
Period x Protein	33	82.55	1.32 NS
Energy	3	567.67	9.05 **
Period x Energy	33	60.21	0.96 NS
Protein x Energy	9	233.00	3.72 **
Period x Protein x Energy	99	52.38	0.84 NS
Error	2112	62.71	
Total	2303		

** Significant at 1% level.

NS- Non significant.

The Haugh unit score for eggs obtained from hens fed an energy level of 2400 Kcal ME per kg had the highest score (81.89) while that for 2500 Kcal ME per kg was 79.66 which was lowest. The magnitude of difference obtained between energy levels of 2500 and 2700 and that between 2600 and 2700 and between 2400 and 2600 were not statistically significant. The possible influence of period on Haugh unit score as affected by various dietary protein-energy combination is presented in appendix XII.

The protein x energy interaction which revealed statistical significance indicated that a protein x energy combination of 16:2700 and 14:2600 resulted in comparatively better Haugh unit score than others.

Albumen index

Albumen index is another measure of the internal egg quality of eggs similar to Haugh unit score. The albumen index of the eggs received from layers fed varying levels of protein and energy were computed and are presented in table 19 and statistical analysis thereto in table 20. Irrespective of the consideration for energy levels, when protein levels alone are considered, the mean albumen index score ranged from 0.084 to 0.093, the former being the lowest representing 20 per cent protein and the latter the highest representing 14 per cent protein diet. The overall trend indicated an inverse relationship between albumen index and protein percentage in the diet. Statistical analysis also confirmed this trend.

When the effect of energy level in the diet on albumen index was considered without concern to protein level, the range observed was from 0.084 to 0.091. There was no specific trend in relation to energy. The lowest albumen index score was 0.084 observed with a dietary energy level of 2500 Kcal ME per kg which was significantly different from the other energy levels. The highest score of 0.091 was observed with an energy level of 2400 and 2600 Kcal ME per kg and a medium value of 0.089 was observed with an energy level of 2700 Kcal ME per kg. However, the numerical differences observed among the above three levels of energy were not significant statistically.

The statistical analysis of the data further revealed that significant differences exist among values obtained for the parameters among the different periods (Appendix XIII). Further, interaction effects between protein and period and between protein and energy were also significant. Inorder to decipher the best combination of protein and energy for obtaining optimal albumen index, the mean values

Table 19. Mean albumen index score of layers fed varying levels of protein and energy.

Protein (%)	Energy (Kcal ME per kg diet)				Mean
	2400	2500	2600	2700	
14	0.093	0.089	0.099	0.090	0.093^{c}
16	0.090	0.085	0.095	0.100	0.092^{c}
18	0.092	0.081	0.088	0.087	0.087^{b}
20	0.091	0.080	0.084	0.080	0.084^{a}
Mean	0.091^{b}	0.084^{a}	0.091^{b}	0.089^{b}	

Values bearing the same superscript do not differ significantly.

Critical difference

Period	- 0.0043	Energy	- 0.0024
Protein	- 0.0024	Protein x Energy	- 0.0049
Period x Protein	- 0.0086		

Table 20. Analysis of variance of albumen index score of layers fed varying levels of protein and energy.

Source	df	MSS	F
Period	11	0.02804	60.19 **
Protein	3	0.01114	23.92 **
Period x Protein	33	0.00138	2.98 **
Energy	3	0.00795	17.07 **
Period x Energy	33	0.00058	1.26 NS
Protein x Energy	9	0.00256	5.50 **
Period x Protein x Energy	99	0.00046	1.01 NS
Error	2112	0.00046	
Total	2303		

** Significant at 1% level.
NS-Non significant.

were screened employing critical difference. It revealed that the protein-energy combination of 16:2600, 16:2700 and 14:2600 were shown to be the ideal combination for obtaining optimum albumen index values under the conditions of the experiment.

Yolk index

The results of evaluation of yolk index of eggs collected from layers fed varying levels of energy and protein is presented in table 21 and its statistical analysis in table 22. The analysis reveals that the yolk index is influenced by period, protein, energy, period x protein, period x energy, protein x energy and period x protein x energy.

The influence of protein on yolk index indicated that there is an inverse relationship between protein levels and yolk index values, highest (0.455) with 14 per cent protein, lowest (0.440) with 20 per cent protein and the others intermediary. However, the values obtained with 14 per cent protein level was significantly higher than those obtained with other protein levels. Likewise, that obtained with 18 and 20 per cent level of protein was significantly lower when compared to 14 and 16 per cent protein levels.

Table 21. Mean yolk index of layers fed varying levels of protein and energy.

Protein (%)	Energy (Kcal ME/kg diet)				Mean
	2400	2500	2600	2700	
14	0.449	0.456	0.459	0.456	0.455^{c}
16	0.451	0.449	0.447	0.448	0.449^{b}
18	0.449	0.423	0.449	0.447	0.442^{a}
20	0.441	0.445	0.439	0.437	0.440^{a}
Mean	0.447^{ab}	0.443^{a}	0.448^{b}	0.447^{ab}	

Values bearing the same superscript do not differ significantly.

Critical difference

Period - 0.0064
Protein - 0.0037
Period x Protein - 0.0130
Energy - 0.0037
Period x Energy - 0.0130
Protein x Energy - 0.0074

Table 22. Analysis of variance of yolk index of layers fed varying levels of protein and energy.

Source	df	MSS	F
Period	11	0.04309	42.15 **
Protein	3	0.02533	24.77 **
Period x Protein	33	0.00448	4.38 **
Energy	3	0.00321	3.14 *
Period x Energy	33	0.00370	3.62 **
Protein x Energy	9	0.00849	8.30 **
Period x Protein x Energy	99	0.00525	5.14 **
Error	2112	0.00102	
Total	2303		

* Significant at 5% level.
** Significant at 1% level.

But the values obtained for 16 per cent protein was significantly intermediery.

The yolk index values when considered on the basis of energy levels alone did not reveal any specific trend. The highest value of 0.448 was obtained with a diet containing 2600 Kcal ME per kg which was statistically similar to those obtained with a dietary energy level of 2400 and 2700 Kcal ME per kg. Similarly, the lowest value of 0.443 obtained with a dietary level of 2500 Kcal ME per kg was statistically not different from the values obtained with an energy level of 2400 and 2700 Kcal ME per kg.

Combination effect indicated that significantly better yolk index could be obtained with a protein level of 14 per cent and an energy level of 2500, 2600 or 2700 Kcal ME per kg diet. Any other combination had significantly lower values for this parameter. The influence of period of yolk index is set out in appendix XIV.

BIOCHEMICAL PARAMETERS

Serum lipid

The influence of the different dietary regimes employed on the serum lipid of the layers is presented in table 23 and the statistical analysis thereto in table 24. It could be seen from the table that the lowest serum lipid level of 1.68 g per cent was obtained with a diet of 20 per cent protein and 2400 Kcal ME per kg and the highest level of 2.88 g per cent for a diet with 20 per cent protein and 2700 Kcal ME per kg. The statistical analysis of the data revealed that the level of dietary protein did not influence the serum lipid levels whereas the dietary energy level had an influence (P∠0.01). The mean serum lipid levels for the four different dietary energy employed in the study revealed that there is an increasing trend as the energy level in the diet is increased. The serum lipid levels with a dietary energy of 2700 Kcal ME per kg was

Table 23. Mean serum lipid of layers fed varying levels of protein and energy (g %).

Protein (%)	Energy (Kcal ME/kg diet)				Mean
	2400	2500	2600	2700	
14	2.18	2.08	2.45	2.68	2.34
16	2.13	2.40	2.43	2.83	2.44
18	2.43	2.25	2.55	2.63	2.46
20	1.68	1.93	2.35	2.88	2.21
Mean	2.10^{a}	2.16^{ab}	2.44^{b}	2.75^{c}	

Values bearing the same superscript do not differ significantly.

Critical difference

Energy = 0.29.

Table 24. Analysis of variance of serum lipid of layers fed varying levels of protein and energy.

Source	df	MSS	F
Protein	3	0.22	1.30 NS
Energy	3	1.42	8.37 **
Interaction	9	0.14	0.84 NS
Error	48	0.17	
Total	63		

** Significant at 1% level.
NS-Non significant.

significantly highest (2.75 g %) whereas it was significantly lowest with a diet containing 2400 Kcal ME per kg (2.1 g %). The differences observed in the mean serum lipid values between the diets containing 2400 and 2500 Kcal ME per kg was not significant. Likewise, the values for 2500 and 2600 Kcal ME per kg was homogenous.

Serum inorganic phosphorus

The serum inorganic phosphorus levels as influenced by the different dietary treatments is set out in table 25 and analysis of variance in table 26. The lowest serum inorganic phosphorus of 5.00 mg per cent was obtained for the dietary combination of 20 per cent protein and 2400 Kcal ME per kg and the highest level of 6.38 mg per cent for the combination of 14 per cent protein and 2700 Kcal ME per kg. Neither protein nor energy levels seemed to influence the serum inorganic phosphorus levels.

Table 25. Mean serum inorganic phosphorus of layers fed varying levels of protein and energy (mg %).

Protein (%)	Energy (Kcal ME/kg diet)				Mean
	2400	2500	2600	2700	
14	5.53	5.80	6.07	6.38	5.94
16	5.90	5.49	5.02	6.04	5.61
18	6.07	5.84	5.97	5.73	5.90
20	5.00	5.50	6.14	6.27	5.73
Mean	5.62	5.66	5.80	6.10	

Table 26. Analysis of variance of serum inorganic phosphorus of layers fed varying levels of protein and energy.

Source	df	MSS	F
Protein	3	0.38	0.47 NS
Energy	3	0.77	0.95 NS
Interaction	9	0.69	0.85 NS
Error	48	0.81	
Total	63		

NS - Non significant.

Table 28. Analysis of variance of serum protein of layers fed varying levels of protein and energy.

Source	df	MSS	F
Protein	3	0.16	0.41 NS
Energy	3	0.35	0.93 NS
Interaction	9	0.39	1.03 NS
Error	48	0.38	
Total	63		

NS - Non significant.

Table 29. Albumen : Globulin ratio of layers fed varying levels of protein and energy.

Protein (%)	Energy (Kcal ME/kg diet)			
	2400	2500	2600	2700
14	0.39:1	0.42:1	0.54:1	0.40:1
16	0.38:1	0.47:1	0.62:1	0.58:1
18	0.46:1	0.53:1	0.71:1	0.70:1
20	0.52:1	0.53:1	0.64:1	0.63:1

Packed cell volume

The packed cell volume of layers as influenced by different dietary combinations employed in this study is presented in table 30, which showed a lowest value of 28.0 per cent in dietary combinations of 16 per cent protein, 2500 Kcal ME per kg; 18 per cent protein, 2600 Kcal ME per kg and 18 per cent protein, 2700 Kcal ME per kg and a higher value of 31.0 per cent in 14 per cent protein, 2400 Kcal ME per kg dietary combination. In general, the values are under normal range which is an indication of normal physiological conditions of birds subjected to varying dietary regimes. The statistical analysis of the data presented in table 31 showed neither protein nor energy have any significant influence.

Table 30. Packed cell volume of layers fed varying levels of protein and energy (%).

Protein (%)	Energy (Kcal ME/kg diet)				Mean
	2400	2500	2600	2700	
14	31.00	29.00	28.75	29.50	29.56
16	29.00	28.00	28.75	29.25	28.75
18	28.50	28.25	28.00	28.00	28.19
20	28.25	28.00	28.25	29.00	28.38
Mean	29.19	28.31	28.44	28.94	

Table 31. Analysis of variance of packed cell volume of layers fed varying levels of protein and energy.

Source	df	MSS	F
Protein	3	5.94	1.97 NS
Energy	3	2.73	0.91 NS
Interaction	9	1.16	0.39 NS
Error	48	3.01	
Total	63		

NS - Non significant.

Haemoglobin

The effect of varying protein and energy levels upon haemoglobin of layers is set out in table 32. A low haemoglobin value of 9.71 was observed with a dietary combination of 20 per cent protein and 2500 Kcal ME per kg, while high value of 10.7 was observed with 14 per cent protein and 2400 Kcal ME per kg combination. The statistical analysis of the data presented in table 33 showed both energy and protein did not have any significant influence on haemoglobin.

Table 32. Haemoglobin values of layers fed varying levels of protein and energy (g %).

Protein (%)	Energy (Kcal ME/kg diet) 2400	2500	2600	2700	Mean
14	10.70	10.15	10.10	10.44	10.35
16	10.57	9.89	10.00	9.89	10.09
18	10.21	10.00	10.02	10.13	10.09
20	10.05	9.71	10.10	10.52	10.09
Mean	10.38	9.94	10.05	10.24	

Table 33. Analysis of variance of haemoglobin of layers fed varying levels of protein and energy

Source	df	MSS	F
Protein	3	0.27	0.95 NS
Energy	3	0.62	2.20 NS
Interaction	9	0.20	0.70 NS
Error	48	0.28	
Total	63		

NS - Non significant.

Liver lipid

The total liver lipid of random birds fed different levels of energy and protein revealed that both nutrients influenced this parameter. The liver lipid values presented in table 34 and its analysis of variance in table 35 indicated that as the energy levels increased the liver lipid content also showed an increasing trend. However, the differences observed in the percentage of liver lipids on a diet containing 2400 and 2500 Kcal ME per kg were not statistically significant. Similarly, that obtained on a diet containing an energy level of 2400 and 2600 Kcal ME per kg were also not significant. The highest level (50.72%) obtained in the group fed a dietary energy level of 2700 Kcal ME per kg was statistically not different from those obtained with 2600 Kcal ME per kg.

The mean liver lipid per cent pooled based on protein level alone were 54.26, 42.39, 28.00 and 33.69 per cent for diets containing 14, 16, 18 and 20 per cent protein, respectively. The numerical differences in the values for liver lipids were statistically not different in respect of diets containing 14 and 16 per cent, 16 and 20 per cent and 18 and 20 per cent.

Table 34. Per cent liver lipid of layers fed varying levels of protein and energy.

Protein (%)	Energy (Kcal ME per kg diet)				Mean
	2400	2500	2600	2700	
14	39.18	53.21	70.26	54.38	54.26^{c}
16	44.39	33.90	39.60	51.68	42.39^{bc}
18	21.86	10.02	29.74	50.39	28.00^{a}
20	20.28	25.00	43.06	46.43	33.69^{ab}
Mean	31.43^{ab}	30.53^{a}	45.67^{bc}	50.72^{c}	

Values bearing the same superscript do not differ significantly.

Critical difference - 14.98

Table 35. Analysis of variance of liver lipid of layers fed varying levels of protein and energy.

Source	df	MSS	F
Energy	3	413.00	4.71 *
Protein	3	523.70	5.97 *
Error	9	87.74	
Total	15		

* Significant at 5% level.

Liver protein

The percentage liver protein in birds fed varying levels of energy and protein is presented in table 36 and the statistical analysis in table 37. It could be seen that liver protein is influenced both by the level of protein and energy in the diet. When protein level in the diet alone was considered, it showed a linear trend with 39.76 per cent as the lowest with 14 per cent protein and 55.59 per cent with 20 per cent protein. The values obtained with 16, 18 and 20 per cent dietary protein were not statistically different, so also those with 14 and 16 per cent.

Level of liver protein as dictated by energy level did not show any specific trend. The highest value (57.47%) was obtained with an energy level of 2400, while the lowest value was with a diet containing 2500 Kcal ME per kg (32.50%).

Table 36. Per cent liver protein of layers fed varying levels of protein and energy.

Protein (%)	Energy (Kcal ME/kg diet)				Mean
	2400	2500	2600	2700	
14	50.96	42.54	25.92	39.61	39.76^{a}
16	47.32	56.59	54.96	33.90	48.17^{ab}
18	65.63	70.11	51.96	44.72	58.11^{b}
20	65.95	59.87	49.92	46.61	55.59^{b}
Mean	57.47^{c}	32.50^{a}	45.67^{b}	41.21^{ab}	

Values bearing the same superscript do not differ significantly.

Critical difference = 11.74

Table 37. Analysis of variance of liver protein of layers fed varying levels of protein and energy.

Source	df	MSS	F
Energy	3	272.12	5.06 *
Protein	3	272.70	5.07 *
Error	9	53.83	
Total	15		

* Significant at 5% level.

MORTALITY

The mortality among the experimental birds which occurred during the whole period of experimentation is tabulated and presented in table 38. The overall mortality of 25.5 per cent over a period of 12, 28-day period can be considered as normal.

Eventhough, there are numerical higher values in mortality at certain energy x protein combinations, the autopsy of the birds had not revealed anything suggestive of the influence of these nutrients.

Table 38. Mortality pattern of layers fed varying levels of protein and energy (number).

Protein (%)	Energy (Kcal ME/kg diet)			
	2400	2500	2600	2700
14	1	3	2	4
16	6	5	3	3
18	2	3	1	6
20	3	3	0	2

CARCASS ANALYSIS

The results obtained on the analysis of the carcasses of birds fed varying levels of protein and energy are presented in table 39. The values did not show any effective trend because of the energy or protein levels. The values obtained are well within the normal biological limits.

Table 39. Carcass analysis of layers fed varying levels of protein and energy(%).

Protein-energy combination	Crude protein	Crude fibre	Ash	Ether extractives	Nitrogen free extract
14:2400	44.08	1.07	7.99	40.68	6.18
14:2500	42.92	2.39	9.65	38.57	6.47
14:2600	31.31	0.75	6.24	58.43	3.27
14:2700	42.23	1.21	6.75	42.77	7.04
16:2400	38.72	1.35	6.63	49.91	3.39
16:2500	45.56	1.15	6.41	44.69	2.19
16:2600	48.66	1.64	10.21	34.99	4.50
16:2700	28.27	1.19	5.01	59.24	6.29
18:2400	43.15	3.18	6.85	39.41	7.41
18:2500	49.76	1.86	7.82	34.56	6.00
18:2600	44.48	2.42	6.54	43.12	3.44
18:2700	38.96	2.83	5.34	49.54	3.33
20:2400	45.52	1.53	6.96	40.64	5.35
20:2500	50.08	2.30	6.64	29.18	11.80
20:2600	39.62	1.74	6.67	48.23	3.74
20:2700	35.43	1.09	6.33	55.56	1.59

NITROGEN BALANCE

The nitrogen balance studies of birds fed with different dietary protein-energy combinations are presented in table 40. On examination of the nitrogen retention data it was observed that all the birds showed a positive nitrogen balance irrespective of the protein or energy level in the diet. As the level of protein in the diet increased there was an apparent increase in the retained nitrogen. With respect to energy levels in the diet the pattern did not show any specific trend.

Table 40. Nitrogen retention value of birds fed varying levels of protein and energy (g).

Protein (%)	Energy (Kcal ME/kg diet)				Mean
	2400	2500	2600	2700	
14	1.57	1.06	0.86	0.77	1.07
16	1.59	1.26	1.33	0.53	1.18
18	1.53	2.03	1.03	1.43	1.51
20	1.31	2.01	1.36	1.49	1.54
Mean	1.50	1.59	1.15	1.06	

Discussion

DISCUSSION

PRODUCTION PARAMETERS

Body weight gain

The mean body weight gain ranging from 281 to 379 g for the four levels of protein and from 296 to 385 g for the four energy levels is well within normal limits for layers. The statistical analysis of the data revealed that neither protein nor energy levels influenced this parameter. Thatte et al. (1981b) using an energy level from 2511 to 2811 Kcal ME per kg diet and a protein level from 14 to 24.5 per cent also reported that no significant difference could be obtained in body weight gain. After conducting an experiment to study the effect of four grower-layer dietary feeding systems on caged layer performance, Doran et al. (1981) also reported that feeding system had little effect on body weight during laying phase. Mohan et al. (1977) reported that the weight gain was highest in birds given 17 per cent protein diet while it was the least in birds on 11 per cent protein diet. They further observed that there was no significant difference between 11 and 13 per cent protein levels. Olomu and Offiong (1983) and Prasad et al. (1984) also observed that body weight gain was not influenced by protein level in the diet. Thus considering results in the present study and those reported by other workers it is reasonable to presume that satisfactory physiological well being could be achieved with a protein level of 14 per cent and an energy level of 2400 Kcal ME per kg in the diet of caged layers.

Egg production

Per cent hen-day egg production at all protein levels except with 14 per cent protein and with all levels of energy used in the experiment appears to be in the optimal range. Diet containing 18 per cent protein resulted in significantly higher egg production (71.15 per cent) and that with 14 per cent protein resulted in significantly lowest egg production (58.48 per cent). The absence of any statistically significant difference in egg production between 18 and 20 per cent protein and between 16 and 20 per cent diet suggest that birds will be able to deliver satisfactory egg production with a diet containing 16 per cent protein. The present results confirm the observations of Deaton and Quisenberry (1964), Sadagopan _et al_. (1971), Quadratulla (1976), Babatunde and Fetuga (1976), Mohan _et al_. (1977), Reid and Maiorino (1980) and Olomu and Offiong (1983) who reported satisfactory egg production in caged layers with dietary protein less than 18 per cent. Though, Sadagopan *et al.* (1971) suggested that the protein requirement of caged layers lies between 14 and 16 per cent, observations made in this study with 14 per cent protein does not subscribe to the lower limit suggested. It could be possible that the conflicting reports on the lower level of protein might be due to the bio-availability of amino acids from the feed ingredients used in the formulation of diet. In developing countries like India where ingredient quality control does not exist it is safer to rationalise on a slightly higher level of protein than lower level *per se*.

Egg production was not affected when energy level alone was considered without taking cognisance of protein. Increasing the energy content in the same protein level in the diet also did not significantly affect egg production. Miller *et al.* (1957) reported a non significant effect on egg production when metabolizable energy : protein ratio varied from 36 to 81 (This suggest that the energy level in the diet is not as critical as protein level in caged layers). Hochreich *et al.* (1958) and Mc Daniel *et al.* (1959) reported that varying the energy level on 16, 17 or 18 per cent protein diet did not show any effect on egg production. Bragg and Hodgson (1969), Petersen (1975), Lillie *et al.* (1976) and Summers and Leeson (1978) also reported that lowering the energy level did not affect egg production. In fact, Lillie *et al.* (1976) could observe significantly higher egg production at an energy level of 2220 than at 3080 Kcal ME per kg in the diet. Thus it could be safely surmised that a diet containing 16 per cent protein and 2400 Kcal ME per kg diet can bring about satisfactory egg production.

The analysis of the data revealed that season of the year exerted appreciable effect on egg production. Seasonal influence on protein requirement of layers has been reported by Reid and Weber (1973) and Chawla *et al.* (1975). The analysis further revealed that while season x energy interaction is not significant, the interaction effect of season x protein is significant ($P \angle 0.05$). The egg production was highest (73.93 per cent) during warm dry season and was significantly different from other seasons. It was significantly lowest during warm wet season (59.69 per cent) comprising of October and November months. It is difficult to draw positive conclusion on the best season for egg production in as much as comparable layers were not started during other seasons inorder to decipher critically the effect of season. However, the trend seems to suggest that warm dry period being ideal for egg production.

Feed intake

The overall mean feed intake was 111.29 g per bird per day. The daily feed intake by the layers was not shown to be influenced by the levels of either protein or of energy employed in the study. The daily feed intake due to varying levels of energy and protein in the diet as reported by various workers are quite conflicting. Reddy et al. (1980) reported that daily feed consumption per bird increased significantly with increasing levels of protein and decreased with increasing levels of energy. However, Reid and Maiorino (1980) observed higher feed intake with lower protein diet. With high energy diet feed intake was lower. Olomu and Offiong (1983) opined that dietary protein had no effect on feed intake whereas high energy diets reduced feed intake. After studying two protein levels, Prasad et al. (1984) also reported that protein had no effect on feed consumption. Wilson et al. (1973) studied the influence of temperature on energy intake and stated that layers did not adjust their calorie intake to the energy level of the feed. The results of the present study also agree with Gleaves and Dewan (1971) who reported that dietary protein and energy did not exert a significant influence on feed consumption.

The absence of any significant influence on feed intake due to varying energy levels employed in the present study might be due to smaller differences between levels used.

The feed intake per bird was influenced by season, being significantly highest during cold wet and lowest during warm wet season. This is quite reasonable in as much as during cold wet season, the bird requires more energy for maintaining its body temperature which is accommodated by increased feed intake.

Feed per dozen eggs

The mean values for feed efficiency expressed as feed per dozen eggs ranged from 1.87 to 2.82 for the varying energy protein combinations. The figures are well within the normal range acceptable for egg producing stock. This gives a positive indication on the genetic as well as biological efficiency. The feed per dozen eggs considered on the basis of protein content alone showed that 18 per cent protein is the best (1.94) among the protein levels tested while the feed per dozen eggs of 2.36 for 14 per cent protein diet was the poorest. However, a 16 per cent protein diet was a borderline level in so far as feed per dozen eggs is considered. Likewise, 20 per cent protein diet had not shown improvement in the feed efficiency over

18 per cent protein diet. Therefore, the results tend to suggest that under conditions of the present experiment, 16 or 18 per cent protein diet is ideal in so far as feed per dozen eggs is considered. Sadagopan et al. (1971) observed that it required less feed to produce one dozen eggs with diets containing 18 or 20 per cent protein level when compared to 12 or 15 per cent protein. The feed per dozen eggs between 18 and 20 per cent protein level was not significant. Prasad et al. (1984) confirmed that 18 per cent dietary protein fed birds had significantly superior feed efficiency as compared to 15 per cent protein. Reddy et al. (1980) also reported higher feed efficiency with 18 per cent protein at all energy levels tested by them.

Similar results have also been reported by Hochreich et al. (1958), Miller et al. (1957), Quisenberry and Bradley (1962) and Mohan et al. (1977).

The energy range from 2400 to 2700 Kcal ME per kg, eventhough showed a numerical improvement with increasing energy, was not statistically significant. Again for a given protein level to increase in energy did not result in significant improvement in feed efficiency. Thus it is evident that protein rather than energy is more critical in improving feed per dozen eggs. However, Sadagopan et al. (1971), Reid and Maiorino (1980), Doran et al. (1980) and

Thatte *et al.* (1981b) reported that increased energy content in the diet reduced the feed required per dozen eggs. Whereas, the results of the present study is in close agreement with Mohan *et al.* (1977) and Olomu and Offiong (1983) who reported that energy levels in the diet did not have any effect on feed required to produce one dozen eggs.

Feed per kilogramme egg

Expressing feed required to produce kilogramme egg is a better measure over feed per dozen eggs in as much as the nutrient deposition in egg is quantitatively measured in terms of weight than number. In the present experiment when data on feed intake and egg weight are analysed as feed per kilogramme of egg, the value ranged from 2.91 to 4.42. The statistical analysis of the data revealed that the trend of results was very similar to those obtained when feed efficiency was calculated based on egg number (feed per dozen eggs). However, it was observed that the feed per kilogramme egg among protein levels of 16, 18 and 20 per cent were statistically similar, while that for the diet containing 14 per cent protein was significantly poorer than other protein levels. Similar results have been reported by Sadagopan *et al.* (1971) and Thatte *et al.* (1981b). Thus when the overall results on feed efficiency (both per dozen and per kilogramme) is considered a protein level of 16 per cent seems to be sufficient for supporting good egg production.

The results of the present experiment also revealed that varying energy levels employed in the present trial did not exert any significant influence. This is in agreement with Summers and Leeson (1978), who tried varying energy levels from 2420 to 3080 Kcal ME per kg and reported that conversion of feed to egg mass was not affected by the diet. However, Thatte et al. (1981b) reported that feed per kilogramme egg mass was better on higher energy levels. In the absence of any significant effect on feed efficiency by energy levels in the present investigation, it is reasonable to surmise that a diet containing 16 per cent protein with 2400 Kcal ME per kg can be considered as economical.

EGG QUALITY PARAMETERS

In meeting the requirements of nutrients for production of large number of eggs is also essential to examine its efficiency in producing eggs with sound quality. Furthermore, certain of egg quality characteristics are also known to be influenced by the housing system employed which can be to a great extent corrected by judicious feeding management.

Thus, sound egg quality traits not only influence its acceptability by the consumer but also affects the marketability of eggs.

The mean egg weight obtained from layers during the course of experiment without consideration of energy or protein was 53.86 g which is an acceptable market weight for Leghorn type of layers.

The egg weight was influenced both by protein and energy levels (Table 14). The results on the basis of protein level in the diet alone indicated that 16 per cent protein in the diet resulted in eggs with highest egg weight (54.7 g). The difference in egg weight between 14 and 18 per cent and that between 18 and 20 per cent diet were not statistically significant. MacIntyre and Aitken (1957) noticed that higher level of protein are necessary for maximum egg weight. Similar to that of protein, the influence of energy did not also show any definite trend. Diet containing 2400 Kcal ME per kg resulted in eggs with highest weight which was statistically not different from that obtained when a diet containing 2600 Kcal ME per kg was fed. Likewise, the difference between egg weights on 2500 and 2700 Kcal ME per kg was also not significantly different. These erratic difference could be due to an interaction between nutrients. That this is so evident from the statistical analysis of the data, which indicate that there is highly significant ($P \angle 0.01$) interaction or combination effect. It appears, therefore, that the protein-energy combination of 16:2600 or 2700 Kcal ME per kg or 18:2400 Kcal ME per kg is ideal under the conditions of present experiment for obtaining satisfactory egg weight.

It has been estimated that a shell thickness of atleast 0.33 mm is needed if the egg is to have a better than 50 per cent chance of moving through normal market handling without breaking (Stadelmann, 1977). Judging by this yardstick the mean shell thickness obtained in this study can be safely adjudged as normal and acceptable.

The statistical analysis of the data revealed that protein as well as a specific level of protein and energy had influenced this trait. However, it is paradoxical to note that shell thickness is better (0.337 mm) with lower protein levels than higher protein levels. This could be possibly due to better efficiency of utilization of protein at lower levels. The best protein-energy combination appears to be 14 per cent crude protein with 2400 Kcal ME per kg, 16 per cent protein with 2600 Kcal ME per kg and 18 per cent protein with 2400 Kcal ME per kg.

One of the major indicators of interior egg quality is Haugh unit score and the auxiliary measure is albumen index. The overall mean Haugh unit score of 81.0 and mean albumen index of 0.089 indicates that irrespective of treatment all eggs examined had good albumen quality. However, there was a statistically significant decrease in Haugh unit score as well as albumen index as the dietary protein levels increased. These results are in agreement with Harms and Douglas (1960); Harms et al. (1962) and Mohan et al. (1977) who reported an increase in albumen quality with decrease in dietary protein. This could be an indirect effect due to lowered egg production at lower levels of dietary protein.

The other measure of internal quality is the yolk quality as indicated by yolk index. The yolk index value in the present trial ranged 0.44 to 0.45. Average values for fresh egg falls between 0.42 to 0.40. Yolk index values of 0.25 or lower indicates a weak yolk (Nesheim et al., 1979). The overall yolk index obtained in the study can be considered satisfactory. The yolk index decreased with increase in dietary protein as with Haugh unit score. The trend in respect of dietary energy level on yolk index is inconsistent. Scanning the literature no evidence was available relating either dietary protein level or energy level as factors either directly or indirectly affecting yolk index. Yolk index being a measure of standing up quality of yolk is governed more by storage condition than dietary factors.

BIOCHEMICAL PARAMETERS

The results of biochemical parameters such as levels of haemoglobin, serum protein, serum lipids, serum inorganic phosphorus, packed cell volume, liver protein and liver lipids obtained revealed that the values recorded are within the normal range for healthy birds indicating thereby that the dietary energy or protein levels tested had not adversely affected the physiological well being of the birds under experimentation. The variation in values obtained in serum lipid as a consequence of change in dietary energy levels is also a normal phenomenon. No definite conclusion can be drawn from values for liver protein, liver lipids and carcass analysis since the observations were based on a small sample.

NITROGEN BALANCE

Nitrogen retention is an indication of sufficiency of dietary protein for tissue growth, feather development, egg production as well as formation of protein reserve.

Thus the positive nitrogen balance noticed in this study for all dietary combinations indicated that all the diets supplied sufficient protein and energy for normal physiological processes. The trend of result is in agreement with Zavgorodnyaya and Rodionova (1974).

Summary

SUMMARY

A 4 x 4 factorial experiment designed to study the dietary requirements of protein and energy for caged egg type layers under the hot humid conditions of Kerala is reported in this thesis.

One hundred and ninetytwo Single Comb White Leghorn strain cross pullets (IWN x IWP) of the Mannuthy centre of AICRP on Poultry for Eggs formed the experimental animals. The birds were randomly alloted to 16 dietary protein-energy combination groups with each treatment having four replicates and each replicate having three birds. The dietary protein levels employed were 14, 16, 18 and 20 per cent and that of energy levels were 2400, 2500, 2600 and 2700 Kcal ME per kg. The observations of the experiment were recorded over 12, 28-day periods.

Feed and water were provided ad libitum. The routine managemental practices were followed throughout the experimental period. Daily egg production was recorded and from this data hen-day egg production was arrived at. Feed intake data was recorded at the end of each 28-day period. Feed efficiency was calculated based on both egg number (kilogramme feed per dozen eggs) as well as egg mass (kilogramme feed per kilogramme egg).

Data on egg quality traits such as egg weight, shell thickness, albumen index, yolk index and Haugh unit were recorded period wise.

The biochemical parameters such as serum lipids, serum inorganic phosphorus, serum protein, packed cell volume, haemoglobin, liver protein and liver lipids were also estimated during the course of the experiment to assess the physiological status of the birds.

The overall performance of the birds fed different dietary regimen in respect of the production parameters, egg quality traits and biochemical observations are presented in table 41, 42 and 43, respectively. The following observations were made from this investigation.

1. The varying levels of protein and energy employed in this study did not have any significant influence on body weight gain.

2. Birds fed 18 per cent dietary protein had significantly higher hen-day egg production and egg production was significantly lower ($P<0.01$) for birds fed 14 per cent dietary protein. However, the egg production observed between 16 and 20 per cent and that between 18 and 20 per cent protein were not statistically significant.

3. Hen-day egg production was statistically similar among various dietary energy levels employed.

4. The daily feed intake per bird per day was not influenced by the levels of protein and energy employed in this experiment.

5. A dietary protein level of 16, 18 and 20 per cent showed significantly superior ($P<0.01$) feed efficiency, when expressed both in terms of feed per dozen eggs as well as feed per kilogramme egg than 14 per cent protein level. The differences observed among 16, 18 and 20 per cent protein were statistically not different.

6. Feed per dozen eggs as well as feed per kilogramme egg were not influenced by varying energy levels employed.

7. The mean egg weight (53.86 g) obtained from birds irrespective of the protein level or energy level seems to be reasonable.

8. The egg weight was significantly influenced ($P<0.01$) both by protein and energy levels. However, the change exerted due to feeding of various dietary combinations did not show any definite trend. The highest egg weight was obtained with a dietary protein x energy combination of 18:2400, 16:2600 and 16:2700.

9. In general, the mean shell thickness obtained in this trial can be considered as normal. The statistical

analysis showed that protein significantly influenced this trait whereas energy levels did not have any effect.

10. Irrespective of dietary treatments, all eggs examined had good albumen quality and Haugh unit score. However, there was a statistically significant decrease ($P<0.01$) in albumen index and Haugh unit score as the dietary protein levels increased.

11. Though, the Haugh unit score and albumen index was influenced significantly ($P<0.01$) by the energy level in the diet, it did not show any specific trend.

12. In general, the yolk index decreased with increase in protein content in the ration, whereas it was inconsistent with the dietary energy levels.

13. The data recorded for biochemical observations were within the normal range for healthy birds.

14. Biochemical parameters such as haemoglobin, serum protein, serum inorganic phosphorus and packed cell volume were not influenced either by protein or energy levels. The level of dietary protein does not influence the serum lipid levels whereas the dietary energy had influenced ($P<0.01$).

15. The level of protein and energy in the diet

significantly influenced ($P<0.05$) liver lipid and liver protein. However, the trend noted was not specific.

16. The values obtained on carcass analysis were well within the normal biological limits and did not show any specific effect either due to dietary protein levels or energy levels.

17. Though mortality of birds among certain dietary protein-energy combinations were on a higher side, the autopsy of the birds did not reveal any findings suggestive of the protein and/or energy combinations as a cause for mortality.

18. All the birds showed a positive nitrogen balance irrespective of the protein or energy level in the diet.

19. Season of the year exerted appreciable effect on production parameters. However, it is difficult to draw positive conclusion on the best season in as much as comparable layers were not started during other seasons.

Considering the above observations it can be inferred that the level of dietary protein and energy required for optimum production for layers raised in cages are 16 per cent and 2400 Kcal ME per kg respectively. However, in practical feed formulation were amino acid balancing especially that of the critical amino acids being a tight rope walk in developing countries it is suggested that a dietary protein level of 18 per cent can be considered as optimal.

Table 41. Overall [redacted] production parameters of birds fed varying levels of protein and energy.

Protein-energy combination	Body weight gain (g) NS	Hen-day egg production (%)**	Feed intake (g/bird/day) NS	Feed per dozen eggs (kg) **	Feed per kilogramme egg (kg)**
14:2400	281.82	64.03	120.32	2.31	3.59
14:2500	347.78	56.50	108.52	2.82	4.42
14:2600	325.50	58.20	99.77	2.08	3.28
14:2700	149.38	55.21	100.26	2.22	3.69
16:2400	286.67	67.82	104.77	2.04	3.19
16:2500	316.43	66.43	105.53	2.06	3.24
16:2600	441.11	65.51	114.74	2.17	3.33
16:2700	428.33	65.36	109.55	2.15	3.32
18:2400	285.50	71.44	116.78	2.00	3.11
18:2500	261.67	71.49	113.22	1.93	3.07
18:2600	342.27	70.80	115.69	1.98	3.15
18:2700	497.50	70.89	108.52	1.87	3.00
20:2400	333.33	63.18	112.06	2.17	3.40
20:2500	336.67	71.92	120.96	2.05	3.19
20:2600	337.92	74.08	113.96	1.87	2.91
20:2700	467.50	71.53	116.09	1.97	3.10

** Significant at 1% level (For details refer analysis of variance table.

NS-Non significant (for details refer analysis of variance table.

Table 42. Overall [redacted] egg quality traits of birds fed varying levels of protein and energy.

Protein-energy combination	Egg weight (g) **	Shell thickness (mm) **	Haugh unit**	Albumen index**	Yolk index**
14:2400	54.49	0.338	83.08	0.093	0.449
14:2500	53.38	0.341	82.65	0.089	0.456
14:2600	54.19	0.337	85.00	0.099	0.459
14:2700	51.15	0.332	82.35	0.090	0.456
16:2400	54.03	0.325	83.00	0.090	0.451
16:2500	53.49	0.337	81.08	0.085	0.449
16:2600	55.68	0.339	81.97	0.095	0.447
16:2700	55.46	0.340	83.28	0.100	0.448
18:2400	54.87	0.328	81.13	0.092	0.449
18:2500	53.39	0.325	77.15	0.081	0.423
18:2600	53.03	0.326	79.44	0.089	0.449
18:2700	52.75	0.326	80.42	0.087	0.447
20:2400	53.79	0.335	80.38	0.091	0.441
20:2500	54.31	0.322	77.74	0.080	0.445
20:2600	54.15	0.337	79.42	0.084	0.439
20:2700	53.58	0.332	76.23	0.090	0.437

** Significant at 1% level (For details refer analysis of variance table.

Table 43. Overall biochemical observations of birds fed varying levels of protein and energy.

Protein-energy combination	Serum lipid (g)**	Serum inorganic phosphorus (mg%) NS	Serum protein (g%) NS	Packed cell volume (%) NS	Haemoglobin (g%)NS
14:2400	2.18	5.53	5.90	31.00	10.70
14:2500	2.08	5.80	6.20	29.00	10.15
14:2600	2.45	6.07	5.89	28.75	10.10
14:2700	2.68	6.38	5.29	29.50	10.44
16:2400	2.13	5.90	5.59	29.00	10.57
16:2500	2.40	5.49	5.53	28.00	9.89
16:2600	2.43	5.02	5.71	28.75	10.00
16:2700	2.83	6.04	5.77	29.25	9.89
18:2400	2.43	6.07	5.41	28.50	10.21
18:2500	2.25	5.84	5.29	28.25	10.00
18:2600	2.55	5.97	6.14	28.00	10.02
18:2700	2.63	5.73	5.59	28.00	10.13
20:2400	1.68	5.00	5.84	28.25	10.05
20:2500	1.93	5.50	5.84	28.00	9.71
20:2600	2.35	6.14	5.56	28.25	10.10
20:2700	2.88	6.27	5.23	29.00	10.52

** Significant at 1% level (For details refer analysis of variance table).

NS- Non significant (For details refer analysis of variance table).

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* Originals not consulted.

Appendix

APPENDIX

Appendix I. Initial and final body weight of layers fed varying levels of protein and energy (g).

Protein-energy combination	Initial body weight	Final body weight
14:2400	1383.33	1674.09
14:2500	1296.67	1647.78
14:2600	1366.67	1686.50
14:2700	1310.42	1465.63
16:2400	1282.50	1703.33
16:2500	1307.50	1633.57
16:2600	1300.42	1744.44
16:2700	1347.92	1821.67
18:2400	1298.75	1591.50
18:2500	1324.58	1690.56
18:2600	1368.75	1727.73
18:2700	1400.00	1878.33
20:2400	1312.50	1652.78
20:2500	1351.25	1675.56
20:2600	1405.42	1743.33
20:2700	1330.83	1792.50

Appendix II. Per cent hen-day egg production as influenced by season and dietary protein.

Protein (%)	Season				Mean
	warm wet	warm dry	hot dry	cold wet	
14	55.57	63.66	58.48	56.23	58.48
16	54.09	72.10	70.61	68.32	66.28
18	63.27	80.21	72.57	68.56	71.15
20	65.83	79.76	71.34	63.78	70.18
Mean	59.69	73.93	68.25	64.22	

Appendix III. Per cent hen-day egg production as influenced by season and dietary energy.

Energy (Kcal ME/kg)	Season				Mean
	warm wet	warm dry	hot dry	cold wet	
2400	58.06	76.22	68.45	63.74	66.62
2500	59.49	74.93	70.17	61.75	66.59
2600	61.83	72.66	68.30	65.81	67.15
2700	59.39	71.92	66.08	65.60	65.75
Mean	59.69	73.93	68.25	64.22	

Appendix IV. Mean daily feed intake per bird as influenced by season and dietary protein (g).

Protein (%)	Season				Mean
	warm wet	warm dry	hot dry	cold wet	
14	99.14	108.91	103.59	117.23	107.22
16	95.73	105.71	112.75	120.41	108.65
18	100.28	119.48	113.97	120.49	113.55
20	106.07	120.69	115.08	121.22	115.77
Mean	100.30	113.70	113.35	119.84	

Appendix V. Mean daily feed intake per bird as influenced by season and dietary energy (g).

Energy (Kcal ME/kg)	Season				Mean
	warm wet	warm dry	hot dry	cold wet	
2400	100.83	121.17	114.06	117.88	113.48
2500	102.50	109.71	113.33	122.68	112.06
2600	99.56	112.75	111.76	120.09	111.04
2700	98.33	111.16	106.24	118.70	108.61
Mean	100.30	113.70	111.35	119.84	

Appendix VI. Feed per dozen eggs as influenced by season and dietary protein (kg).

Protein (%)	Season				Mean
	warm wet	warm dry	hot dry	cold wet	
14	2.19	2.08	2.14	3.02	2.36
16	2.40	1.88	1.93	2.20	2.10
18	1.98	1.79	1.89	2.11	1.94
20	2.00	1.82	1.94	2.30	2.01
Mean	2.14	1.89	1.98	2.41	

Appendix VII. Feed per dozen eggs as influenced by season and dietary energy (kg).

Energy (Kcal ME/kg)	Season				Mean
	warm wet	warm dry	hot dry	cold wet	
2400	2.23	1.94	2.02	2.33	2.13
2500	2.15	1.87	1.94	2.91	2.22
2600	2.01	1.87	1.99	2.23	2.03
2700	2.18	1.89	1.95	2.18	2.05
Mean	2.14	1.89	1.98	2.41	

Appendix VIII. Feed per kilogramme of eggs as influenced by season and dietary protein (kg).

Protein (%)	Season				Mean
	warm wet	warm dry	hot dry	cold wet	
14	3.72	3.38	3.33	4.54	3.74
16	3.97	2.97	2.92	3.22	3.27
18	3.34	2.88	2.95	3.15	3.08
20	3.30	2.85	3.01	3.44	3.15
Mean	3.58	3.02	3.05	9.59	

Appendix IX. Feed per kilogramme of egg as influenced by season and dietary energy (kg).

Energy (Kcal ME/kg)	Season				Mean
	warm wet	warm dry	hot dry	cold wet	
2400	3.75	3.06	3.07	3.42	3.32
2500	3.57	2.95	3.02	4.39	3.48
2600	3.34	3.00	3.04	3.28	3.17
2700	3.67	3.08	3.08	3.26	3.28
Mean	3.58	3.02	3.05	3.59	

Appendix X. Mean egg weight of layers as influenced by period, dietary protein and energy (g).

Period	Protein (%)				Energy (Kcal ME/kg diet)				Mean
	14	16	18	20	2400	2500	2600	2700	
1	47.78	49.41	48.08	48.55	48.27	48.34	49.10	48.11	48.46
2	50.38	51.27	50.58	52.60	51.11	51.82	51.07	50.83	51.21
3	49.96	51.07	51.27	52.65	51.48	52.42	50.65	50.40	51.24
4	52.62	54.70	52.24	53.65	53.96	53.38	53.57	52.31	53.30
5	53.79	53.95	53.32	53.26	54.45	53.25	53.51	53.11	53.58
6	54.00	55.82	54.31	54.33	55.11	55.06	55.22	53.07	54.61
7	53.34	53.89	52.41	53.70	53.43	52.53	54.98	52.39	53.33
8	53.57	54.73	52.78	53.87	54.24	52.94	54.95	52.82	53.74
9	54.94	56.25	55.55	54.63	56.28	54.68	55.36	55.05	55.34
10	56.04	57.70	56.45	55.94	57.31	55.96	56.99	55.88	56.53
11	56.18	58.64	57.09	56.65	57.18	56.69	57.46	57.22	57.14
12	56.97	58.52	58.05	57.67	58.69	58.68	58.25	57.59	57.80
Mean	53.30	54.66	53.51	53.96	54.29	53.64	54.26	53.23	

Appendix XI. Mean shell thickness of layers as influenced by period, dietary protein and energy (mm).

Period	Protein (%)				Energy (Kcal ME/kg diet)				Mean
	14	16	18	20	2400	2500	2600	2700	
1	0.345	0.346	0.335	0.338	0.333	0.340	0.348	0.343	0.341
2	0.356	0.356	0.341	0.347	0.348	0.351	0.349	0.352	0.350
3	0.357	0.352	0.357	0.360	0.356	0.353	0.359	0.358	0.357
4	0.328	0.339	0.321	0.319	0.327	0.331	0.324	0.326	0.327
5	0.334	0.333	0.327	0.321	0.333	0.329	0.327	0.326	0.329
6	0.332	0.327	0.312	0.326	0.332	0.324	0.330	0.321	0.324
7	0.324	0.320	0.305	0.316	0.314	0.311	0.320	0.318	0.316
8	0.322	0.315	0.306	0.321	0.315	0.317	0.317	0.315	0.316
9	0.340	0.341	0.331	0.340	0.339	0.336	0.342	0.337	0.338
10	0.324	0.329	0.323	0.326	0.326	0.323	0.326	0.326	0.326
11	0.348	0.336	0.335	0.336	0.337	0.336	0.344	0.337	0.339
12	0.336	0.327	0.323	0.329	0.332	0.325	0.328	0.331	0.329
Mean	0.337	0.335	0.326	0.332	0.332	0.331	0.335	0.333	

Appendix XII. Mean Haugh unit score of layers as influenced by period, dietary protein and energy.

Period	Protein (%)				Energy (Kcal ME/kg diet)				Mean
	14	16	18	20	2400	2500	2600	2700	
1	89.40	91.48	87.15	87.44	90.71	87.56	89.56	87.63	88.86
2	87.75	87.60	84.31	83.58	87.69	85.19	85.48	84.90	85.81
3	89.71	90.13	87.65	87.42	90.17	86.33	90.77	87.63	88.72
4	84.96	84.54	80.67	79.92	83.50	80.56	83.75	82.27	82.52
5	82.19	79.25	77.33	80.04	79.83	78.58	80.88	79.52	79.70
6	81.81	79.25	78.88	77.52	79.35	78.29	78.96	80.85	79.36
7	81.19	80.04	75.92	75.25	79.98	76.06	78.83	77.52	78.10
8	81.75	80.44	79.08	78.29	80.38	79.35	79.27	80.56	79.89
9	82.13	81.38	79.69	73.81	80.27	77.10	79.33	80.29	79.25
10	78.15	75.98	74.44	70.79	74.88	73.85	74.98	75.65	74.84
11	78.60	78.23	75.10	72.44	79.04	74.71	76.60	74.02	76.09
12	81.60	79.69	74.21	74.81	76.94	78.27	79.08	76.02	77.58
Mean	83.27	82.33	79.53	78.44	81.89	79.66	81.46	80.57	

Appendix XIII. Mean albumen index score of layers as influenced by period, dietary protein and energy.

Period	Protein (%)				Energy (Kcal ME/kg diet)				Mean
	14	16	18	20	2400	2500	2600	2700	
1	0.109	0.116	0.100	0.100	0.112	0.102	0.109	0.101	0.106
2	0.103	0.104	0.094	0.092	0.104	0.096	0.097	0.096	0.098
3	0.116	0.117	0.108	0.108	0.116	0.104	0.120	0.110	0.112
4	0.100	0.099	0.089	0.085	0.095	0.089	0.097	0.092	0.093
5	0.091	0.081	0.075	0.080	0.080	0.081	0.085	0.081	0.082
6	0.089	0.084	0.080	0.077	0.082	0.080	0.082	0.086	0.083
7	0.096	0.096	0.080	0.080	0.091	0.083	0.091	0.087	0.088
8	0.094	0.093	0.088	0.086	0.091	0.087	0.090	0.092	0.090
9	0.096	0.094	0.086	0.074	0.089	0.082	0.088	0.090	0.087
10	0.080	0.076	0.071	0.072	0.078	0.069	0.074	0.078	0.075
11	0.069	0.072	0.079	0.075	0.077	0.063	0.082	0.073	0.074
12	0.070	0.076	0.090	0.075	0.082	0.066	0.081	0.083	0.078
Mean	0.093	0.092	0.087	0.084	0.091	0.084	0.091	0.089	

Appendix XIV. Mean yolk index value of layers as influenced by period, dietary protein and energy.

Period	Protein (%)				Energy (Kcal ME/kg diet)				Mean
	14	16	18	20	2400	2500	2600	2700	
1	0.461	0.455	0.456	0.454	0.455	0.459	0.460	0.452	0.457
2	0.451	0.438	0.379	0.431	0.435	0.383	0.437	0.444	0.425
3	0.463	0.452	0.459	0.452	0.455	0.455	0.458	0.459	0.456
4	0.442	0.440	0.433	0.437	0.439	0.440	0.441	0.430	0.438
5	0.458	0.447	0.446	0.434	0.446	0.443	0.446	0.451	0.446
6	0.440	0.437	0.433	0.425	0.437	0.438	0.427	0.433	0.434
7	0.435	0.435	0.431	0.419	0.432	0.430	0.433	0.426	0.430
8	0.433	0.427	0.431	0.424	0.428	0.430	0.432	0.426	0.429
9	0.463	0.463	0.462	0.447	0.459	0.457	0.460	0.461	0.459
10	0.460	0.457	0.454	0.441	0.454	0.452	0.452	0.455	0.453
11	0.476	0.478	0.465	0.467	0.468	0.460	0.477	0.472	0.471
12	0.474	0.456	0.455	0.452	0.462	0.462	0.459	0.455	0.459
Mean	0.455	0.449	0.442	0.440	0.447	0.443	0.448	0.447	

DIETARY PROTEIN AND ENERGY REQUIREMENTS OF CAGED LAYERS

By

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ABSTRACT OF A THESIS

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ABSTRACT

A 4 x 4 factorial trial designed to study the dietary requirements of protein and energy for caged egg type layers under the hot-humid conditions of Kerala is presented in this thesis. Single Comb White Leghorn strain cross pullets (IWN x IWP) of the Mannuthy centre of AICRP on Poultry for Eggs formed the experimental subjects. The birds were randomly alloted to 16 dietary protein-energy combination groups. The dietary protein levels employed were 14, 16, 18 and 20 per cent and that of energy levels were 2400, 2500, 2600 and 2700 Kcal ME per kg diet. General observations of the experiment were recorded over 12, 28-day periods.

The varying levels of protein and energy employed in this study did not have any significant influence on body weight gain. Birds fed 18 per cent dietary protein had significantly higher hen-day egg production and it was significantly lower for birds fed 14 per cent dietary protein. Egg production observed between 16 and 20 per cent and that between 18 and 20 per cent protein were not statistically significant. Hen-day egg production was not influenced by various dietary energy levels employed.

The daily feed intake per bird per day was not affected by the levels of protein and energy employed in this experiment. A dietary protein level of 16, 18 and 20 per cent showed significantly superior feed efficiency, when expressed both in terms of feed per dozen eggs as well as feed per kilogramme egg. Feed conversion efficiency was not influenced by varying energy levels employed. The egg weight was significantly influenced both by protein and energy levels. However, the change exerted due to feeding of various dietary combinations did not show any definite trend. The mean shell thickness was significantly influenced by dietary protein levels whereas energy did not have any effect. There was a statistically significant decrease in albumen index and Haugh unit score as the dietary protein levels increased. The Haugh unit score and albumen index was influenced significantly by the energy level in the diet. The yolk index decreased with increase in protein content in the ration, whereas it was inconsistent with the dietary energy levels. Biochemical parameters such as haemoglobin, serum protein, serum inorganic phosphorus and packed cell volume were not influenced either by protein or energy levels. The level of dietary protein did not influence the serum lipid levels whereas the dietary energy had influenced. The dietary-protein-energy combinations in the diet significantly influenced liver lipid and liver protein. The values obtained on carcass analysis were well within the normal biological limits and did not show any specific effect due to different dietary treatments. All the birds showed a positive nitrogen balance irrespective of the protein or energy level in the diet.

On the basis of these results it can be inferred that the level of dietary protein and energy required for optimum production for layers raised in cages are 16 per cent and 2400 Kcal ME per kg, respectively. However, in practical feed formulation where amino acid balancing especially that of the critical amino acids being a problem in developing countries it is suggested that a dietary protein level of 18 per cent can be considered as optimal.