EFFECT OF HOUSING SYSTEM ON PROTEIN AND ENERGY REQUIREMENTS OF WHITE LEGHORN

By

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THESIS

submitted in partial fulfilment of the
requirement for the degree

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1991

Dedicated
to
My Parents

DECLARATION

I Hereby declare that this thesis entitled "EFFECT OF HOUSING SYSTEM ON PROTEIN AND ENERGY REQUIREMENTS OF WHITE LEGHORN" 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.

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CERTIFICATE

Certified that this thesis, entitled "EFFECT OF HOUSING SYSTEM ON PROTEIN AND ENERGY REQUIREMENTS OF WHITE LEGHORN" is a record of research work done independently by Smt. P. Anitha under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Introduction

INTRODUCTION

The development of poultry through the application of modern science and technology will greatly contribute to improve the socio-economic conditions of rural masses. Poultry production, which made its beginning in 1960's has witnessed a phenomenal growth especially during the last two decades. Today the poultry industry has reached the level of a full fledged self-sufficient industry with complete sophistication within a short period of 20 to 25 years. Total layer population of India increased from 85 million in 1980 to 113 million in 1989. The previous production from a bird ie. 180 to 200 eggs per year has now reached a level of 280 eggs at many farms in India. The improved layer population increased from 56 million in 1980 to 96 million in 1989. Likewise, the egg production has risen from 12,500 million in 1980 to 23,000 million in 1989. Though, India holds 5th position among countries of the world in total egg production, our per capita availability is only 25 as compared to 300 to 350 in developed countries (Anon, 1990). It has been recognised that the major cause of undernutrition and malnutrition is the lack of adequate purchasing power among weaker sections of the Society. Poultry offers a profitable vocation for generating income in economically backward areas and for overcoming the problem of unemployment among the youth. By the application of Scientific management poultry can give the needed momentum and direction to the aspiration of large majority of people for better quality of life. According to a study made by the United State Agency for International Development (USAID), over 60 to 70 per cent of the population consume less protein and calories than the minimum requirement, protein being more limiting, leading to protein-calorie imbalance and consequent health problems (Anon, 1990). So the need to supplement diet with egg as affordable protein assumes added significance.

Housing and management play a dominant role in getting the full expression of the stock for egg production. The micro-environment of the house plays an important role in poultry production. Good housing provides optimum comfort to birds, keep them healthy and improve the efficiency of production. The type of house, conditions of housing in terms of temperature, humidity, air flow, lighting and space allowances of floor, feeders and waterers etc. influence production potential of the bird. In our country open sided poultry houses are the ones in vogue since the environment controlled houses, eventhough can give better comfort to birds and enhance production are not popular because of economic reasons. The open sided poultry houses may be the litter floor houses or cage houses. Deep litter system is a long standing and popular system for housing of layers. Slat floor, wire floor or combination of these with deep litter system may be of some advantage particularly for increasing the stocking density, yet they are not popular. Higher stocking density, inclusion of feeders and waterers with cages and dispensing requirement for nests make the cage system more economical compared to the deep litter system. Together, advantage of cleaner environment, lesser social stress, better supervision help a great deal in improving performance under this super intensive method. Cage system has gained much popularity in our country and will continue to do so in future.

The nutrient requirements of poultry depend on many factors such as breed and strain of bird, age, physiological status, body weight, environmental temperature, composition of the diet, type of housing system etc. Feed consumption is influenced by the energy content of the diet. It has been proved that macro environment greatly influences the production performance of layers especially those which have superior germplasm. Of the macro environment, housing condition is a major factor which influences productivity. This therefore means that a direct link exists between housing system and nutrient requirement. Therefore, it is necessary to study the energy and protein requirements of birds reared in common housing systems viz., cage and floor, thus helping feeding more exacting and economical. The nutrient intake, especially protein and energy during the growing stage of chicken has direct influence on the subsequent performance of layers. The studies on this aspect is limited merely to any one stage of chicken life viz. starter, grower and layer. The results of these studies will not give a correct picture on the optimum calorie protein requirements during the growing stage upon optimum production performance in the subsequent laying phase. Therefore, it was thought relevant to study the influence of housing systems viz. cage and floor on the optimum protein and energy requirements of egg type chicken from one day old to seventy two weeks of age. Since the genetic material proposed to be used in this study is the hybrid layer developed at All India Co-ordinated Research Project on Poultry Breeding at Mannuthy Centre (ILM-90), this information will also help to advise the farmers adequately when this hybrid is released for commercial exploitation.

Review of Literature

REVIEW OF LITERATURE

Housing system - Cage

Starter period

Haque and Agarwala (1975) conducted an experiment in chicks to determine the optimum level of energy protein ratio by feeding four levels of protein viz., 16, 20, 23 and 24 per cent. It was reported that the ration containing 23 per cent protein with 128:1 ratio of energy protein was found economical.

Rajasekhara Reddy *et al*. (1977) conducted two experiments to evaluate the protein and energy requirements of starter chicks. In experiment one, 18 and 20 per cent protein levels each at four energy levels viz., 2520, 2430, 2340 and 2250 Kcal ME/Kg were used. In experiment two, 22 and 24 per cent protein levels with similar energy levels as in experiment one were tried. Considering over all performance of both the trials, they concluded that a dietary protein level of 20% and energy level of 2300 Kcal ME/Kg to be optimum and economical for starter chicks. The efficiency of protein as well as energy utilization was better with 20 per cent protein level having 2430 ME Kcal/Kg than the other protein levels. No significant variation was noticed in the fat deposition in the body of chicks fed 22 and 24 per cent protein. Nagabhushanam et al. (1979) conducted two trials to determine the dietary protein and energy requirements of commercial starter pullets during two seasons namely, summer and winter. The experiment consisted a 4 x 4 factorial design with four dietary protein levels (18, 20, 22 and 24% CP) each having four dietary energy levels (2520, 2430, 2340 and 2250 Kcal ME/Kg). They observed that during summer, energy protein levels ranging from 2250 : 24 to 2520 : 24 supported maximum weight gain and feed efficiency, while during winter energy protein levels ranging from 2250 to 2430 : 22 supported adequate body weight gain and feed efficiency. The energy utilization was considerably better at 2430 Kcal ME/Kg level. The protein utilization was maximum with 18 and 22 per cent dietary protein levels during summer and winter, respectively. Matennai (1985) monitored the performance of pullet chicks fed diets with energy-protein ratios of 115, 130, 145 and 160 from day old to eight weeks of age. Birds which received rations with the narrowest ratio of 115 (2873 Kcal ME/Kg and 25% protein) made significantly better body weight gain than their counterparts on ration with widest ratio of 160 (3020 Kcal ME/Kg and 19% protein). When feed consumption and feed conversion ratio for birds during the first six weeks of age were considered, diet with a ratio of 115 was significantly better utilized than diets with high energy to protein ratio of 160.

Grower period

Blaylock (1956) carried out trials on the protein requirements of growing pullets being grown as replacement stock using two strains of leghorns. The diets used varied in calorie protein ratios from 46 in the 20 per cent protein to 85 in the 12 per cent protein diets. A graded series of protein levels at each 4 week period from day of age to 20 weeks was used. In the first trial, the various protein levels fed were 18, 16, 14 and 12 per cent. The feed efficiency of the groups was not affected. Lowering the protein levels to 12 per cent at 16 weeks of age had no effect on the time required to produce the first egg, to reach 50% production or on the feed consumption during the first month of lay. The results of the second test confirmed those previously obtained. It showed that even-though a 12% protein level was fed from 5 weeks on, the initial depression of growth was overcome by 20 weeks. They opined that the protein level required by light breed growing pullets was as low as 12% by 12 weeks of age.

In an experiment Jimmie *et al*. (1969) studied the effect of feeding two levels of dietary protein, three levels of dietary energy and three levels of dietary volume in growing egg type pullets. The two dietary protein levels were fed from the time the pullets were day-old until they were twenty weeks of age. The three dietary energy and dietary volume levels were introduced when the pullets were nine weeks of age and continued through twenty weeks of age. The two dietary protein levels fed during the first six weeks of the growing period resulted in statistically significant differences in feed consumption, protein consumption and body weight gain. From the nineth through eighteenth weeks, pullets fed different dietary energy levels consumed equivalent amounts of energy, but different amounts of protein. These differences in protein consumption during growing period were reflected in significant differences in subsequent egg production. Pullets that consumed 15 grams of protein per day from the nineth through eighteenth weeks matured earliest. A protein intake of 10 grams per day produced the greatest delay in sexual maturity.

Kapoor *et al*. (1985) conducted a study to find out the effect of dietary protein levels and limiting amino acids on the performance of growing egg type pullets.

In a 3 x 5 factorial study diets containing 16, 14 and 12 per cent protein each with supplements of lysine and methionine/cystine at 0.8 and 0.6, 0.7 and 0.5 or 0.6 and 0.4 per cent and two controls with vegetable protein alone or plus 8 per cent fish meal were employed. Average weight gains with dietary protein 16, 14 and 12 per cent were 694, 660 and 648 grams, respectively, and supplements of amino acids or fish meal had no effect. Corresponding feed conversion ratios were 7.37, 8.08 and 8.77; values were best with fish meal and with the two higher supplement groups.

Evaluation of protein and energy levels of growing commercial pullets in summer months was carried out by Thakur and Saxena (1985). Nine diets were tested having 14, 16 and 18 per cent protein levels and energy levels of 2800, 2900 and 3000 Kcal ME/Kg. Results of the study showed that ration containing 16 per cent protein and 2800 Kcal ME/Kg was better for optimal growth and feed efficiency in replacement pullets from 9 to 18 weeks in summer months.

Reddy et al. (1988) conducted studies on step-up and step down protein diecs for growing pullets on their laying house performance. White Leghorn chicken from one day to eight weeks old were given diets containing 12 or

22 per cent protein and metabolizable energy 2750 to 2800 Kcal/Kg. The grower diets contained 16 and 18 per cent protein and energy concentration of 2750 to 2800 Kcal. Thereafter a layer diet containing 18 per cent protein and metabolizable energy 2680 Kcal/Kg was given. Weight of chickens was significantly lower in those started on 12 per cent than in those on 22 per cent protein diets at 21 weeks old. Feed efficiency was not different between groups at 15 or 21 weeks of age.

Layer period

Miller *et al*. (1957) in an attempt to find out the minimum protein requirement of laying pullets at different energy levels obtained good egg production with an experimental diet containing 12.5 to 13 per cent dietary protein. It appeared that a wide calorie protein ratio of the diet can be tolerated by the laying pullet without affecting egg production, since the egg production was not affected by the level of energy at different levels of protein used in the experiment.

Mac Daniel *et al*. (1959) could not find any appreciable effect on rate of egg production by feeding caged layers three levels of protein viz., 15, 20 and 25 per cent at energy levels of 750 to 960 calories productive energy per pound.

High incidence of fatty livers was noted with all the diets except 15 per cent protein - 750 calorie diet. Large amounts of abdominal fat were found in approximately the same degree and incidence as the fatty liver condition. Hulett et al. (1960) studied the effect of dietary energy level on the performance of caged layers. For the first twenty weeks three groups of birds received each of three diets : 1027 calories productive energy per pound, 934 calories per pound or 823 calories per pound with a protein level of 17 per cent. After twenty weeks one group continued to receive each diet, while the other two were transferred to the remaining two diets, providing a total of nine treatment combinations. Altering the energy level of the diet did not significantly affect overall egg production or egg weight. There was a trend towards lowered egg production in birds fed high energy diets during the final twenty weeks, particularly where the initial diet was high in energy. The low energy diet gave poorer results during the first twenty weeks.

Studies were conducted to determine the effect of environmental temperature upon egg production as influenced by dietary protein level and protein intake (Bray and Gesell, 1961). Diets containing corn and soyabean meal were fed to White Leghorn pullets in climatic chambers maintained at 42 and 76°F in one experiment and 76 and 86°F in another experiment. At temperatures of 42 and 86°F rate of lay was not affected provided dietary protein levels of 11.5, 12 and 14 per cent were fed. The decline in egg production was more in pullets fed suboptimal protein diet at the higher temperature. The results showed that temperature exerted its effect through feed intake, rather than by altering the absolute protein requirement.

The effects of adding fat with and without concomitant increase in energy level, to the ration fed to eleven months old laying birds were reported by March and Biley (1963). Body weight, mortality, rate of egg production, albumen quality and shell thickness were not significantly affected by the level of fat in the ration. Egg size was reduced when 10 per cent of fat was added to the ration without increasing energy level. It was concluded that the reduction in egg size was related to the decrease in feed intake.

Deaton and Quisenberry (1964) in an attempt to examine the genetic differences in protein requirements exist between four commercial strains of egg production stocks, conducted trial with seven hundred and sixty eight birds which fed four different protein combination and reared in colony and individual cages. 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 for 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 for every 56 days until 17 per cent was reached. Statistical analysis showed a highly significant strain x protein interaction for average hen-day production, egg weight and feed efficiency, when only protein levels were considered birds housed in individual cages receiving the increasing protein diet laid significantly more eggs with significantly heavier egg weight and better feed efficiency than when receiving a constant 17 per cent protein diet.

Quisenberry _et al_. (1964) conducted an experiment to adjust the protein level to age and stage of production of laying stocks. Five duplicate groups of thirty six birds each received diets containing 19, 18, 17, 16 and 15 per cent protein. One group received each protein level for twelve, 28-day periods and the other was reduced as the production period advanced by varying intervals, reaching, with the exception of 19 per cent group, 14 per cent for the last six periods and the diets were isocaloric (992 calories productive energy). When the level of protein was 15 per cent or lower, body weight, egg size and feed efficiency were depressed. Lowering protein as the laying period advanced reduced significantly the egg size and body weight but tended to improve egg production and feed efficiency. Egg production was highest at 19 per cent and body weight and egg size at 17 per cent protein. Haugh units were highest at 15 per cent protein. Owings (1964) tested three strains of laying birds with 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 the first five periods there was a significant improvement in egg production due to increased dietary energy. Though this trend was also noticed during the last five periods, the differences were not statistically significant. Increasing the dietary energy significantly increased the feed conversion efficiency during the first five periods. Body weight was also influenced by energy level.

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 higher than 14 g per bird per day at rates of lay upto atleast 80 per cent. Body weight was reduced only at protein intakes below 14 g per bird per day.

Coligado and Quisenberry (1967) studied the effect of energy phase feeding, cage size and bird density on performance of commercial layers. In energy phase feeding birds were fed with diets containing productive energy of 1032 calories for four 28-day periods, 982 calories for the next four and 932 for the remaining four 28-day periods in comparison to constant energy feeding where the diets contained 16 per cent protein and 932 calories energy. Results showed 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.

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 Kcal of ME per hen per day 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 of 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 increased. Maximum egg weight was not obtained with those energy and protein consumption levels which supported maximum levels of egg production. A gain in body weight was observed with those energy consumption levels which produced maximum levels of egg production.

Speers and Balloun (1967a) conducted an experiment utilising three strains of White Leghorn hens, three dietary protein levels (13, 15 and 17%) and two dietary energy levels (2860 and 3190 Kcal ME/Kg). Two strains performed well on a 15 per cent protein diet at an energy level of 2860 Kcal ME/Kg. Whereas another strain required only 13 per cent protein diet. When energy was increased to 3190 Kcal all the strains required higher protein levels. Factors affecting protein requirement of layers was studied by speers and Balloun (1967b) and concluded that there was a significant effect of strain on protein requirement.

Quisenberry (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 levels 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 a higher egg production, lower weight, same egg size, daily feed and protein consumption, but fewer calories than energy phase feeding.

Bragg and Hodgson (1969) carried out an experiment to study the effect of dietary energy level on the performance of laying hens. Three levels of metabolizable energy viz., 2794, 2570 and 2354 Kcal/Kg in isonitrogenous (16.1 per cent protein) laying ration were employed. The ration containing 2354 Kcal/Kg was divided into two parts and low energy was obtained by adding wheatbran or wheat straw at the expense of wheat, yielding two dietary treatments at the low energy level. Results showed no differences in egg production between the three levels of dietary energy or between low energy rations. Feed consumption increased significantly as energy was decreased in laying rations with a concomitant change in feed utilization. However, efficiency of energy utilization improved as dietary energy was decreased from 2794 to 2534 Kcal/Kg of the ration.

The effect of changes in dietary energy level on energy consumption and liver fat content of laying hens was studied by Ivy and Nesheim (1971). White Leghorn hens maintained at a temperature of 16.5^{o}C were given diets containing 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 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 treatment. 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.

Sadagopan _et al_. (1971) studied 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. The eggs produced by hens fed with diets containing 15, 18 and 20 per cent protein levels did not show any significant difference with medium and high energy levels. Feed required to produce one kilogram and one dozen eggs were progressively decreased as the protein content of the diet increased. Though increasing the energy content in the same protein level did not affect the egg production, feed efficiency was increased. Maximum feed efficiency was observed with rations containing 148 : 1 to 161 : 1 ratios at 18 and 20 per cent protein levels.

Effect of feeding different protein levels and of changing protein level on egg production was studied by Fernandez et al. (1973). Treatments comprised of different levels of dietary protein viz., 13, 15, 18, 15, 18 and 16.3 per cent respectively. After ten weeks of production, treatments four and five were changed from diets with 15 and 18 per cent protein to diets containing 13 and 15 per cent respectively. Egg production did not change significantly as a result of changing protein levels after ten weeks of production. Lowering the level of protein in the diet, after 18 weeks of production had no adverse effect on egg production. The level of protein in different treatments did not affect egg weight. 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. Twenty eight weeks old pullets were fed nine different 120 g diet containing all combinations of 10, 13 and 16 g protein and 200, 250 and 300 Kcal of ME. The first experiment included normal and ovariectomized pullets under controlled environmental temperature. The second experiment included normal and progresterone injected pullets under controlled environmental temperature. Average production was 0.189, 0.086 and 0.074 eggs per hen per day for the ovariectomized-projesterone 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. Wilson et al. (1973) conducted an experiment to relate the egg production of pullets at high temperatures to the daily energy intake. The birds were fed rations of either 2200, 2600, 2800 or 3500 Kcal/Kg of ME and kept at temperatures of either 15, 26.7 or 32°C for either five or fourteen days. The results obtained revealed difference in the energy intake on egg forming days in contrast with the intake of non-egg forming days. The layers did not adjust their caloric intake to the energy level of the feed.

Effect of environmental temperature and dietary energy on dwarf and normal hens kept at 22 and 30°C was observed by Ahmad et al. (1974). The birds 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.

The protein requirements of White Leghorn pullets were evaluated in summer and winter seasons by Chawla et al. (1975). The dietary treatments were introduced either at eight weeks of age (Phase I) or at twenty weeks of age (Phase II) in both the seasons. The isocaloric rations containing 12.8, 15, 16.6, 18.5 and 21.6 per cent protein were formulated and offered to duplicate groups of twenty pullets each. The rate of lay was higher with higher levels of dietary protein in both seasons regardless of the age at which the treatments were initiated. Trend in egg production suggested that protein requirement of White Leghorn pullets lie between 18.5 to 21.6 per cent and 16.6 to 18.5 per cent in summer and in winter months respectively. Calculations based on egg production rate, feed consumption and average egg weight indicated that the requirements could be met by feeding rations containing 18 to 19 per cent and 15 to 16 per cent protein in summer and winter respectively.

Miller Smith (1975) evaluated four feeding programmes on brown egg type birds housed in cages. Three different protein levels were formulated in isocaloric diets and fed to these birds in a forty eight week laying experiment. The feed schedules were : programme one - 16 per cent protein, programme two - 17 per cent protein, programme three - 18 per cent protein (all fed from 22 weeks through

70 weeks of age) and programme four - 18 per cent protein through 39 weeks, decreased to 17 per cent protein from 40th week through 59th week and 16 per cent protein layer from the 60th week through the end of the experiment. A statistical analysis of hen-day egg production results showed a treatment difference at the 5% probability level. Birds on programme one, two and four had 5 per cent greater production than the birds on programme three. No statistical difference was noticed in the feed consumed per dozen eggs between the four feeding programmes. The birds on programme three consistently consumed less feed during the entire fourty eight weeks test period. Egg weights between the four feeding programmes were not statistically different. Results obtained indicated that brown egg type birds in cages do equally well on 18, 17 or 16 per cent protein laying ration. An experiment was conducted by Ameenuddin et al. (1976) in a 3 x 3 factorial design with Rhode Island Red pullets from the time 50 per cent egg production of the flock was reached to 100 days of laying. The dietary treatments consisted of three protein levels (12, 15 and 18 per cent) and three levels of calcium (2.5, 3.5 and 4.5). The average egg production data indicated a progressive and significant improvement in egg production as the level of protein in the diet was increased from 12 to 15 and 18 per cent. Egg production

was severely depressed at the 12 per cent dietary protein level and was highest at 18 per cent protein level. Maximum feed efficiency was recorded with ration containing 18 per cent protein.

Reid (1976) estimated daily protein requirements of laying hens. Six experimental diets varying in protein content from 10.0 to 19.5 per cent were fed to pullets in colony cages for a period of thirty six weeks. The data were divided into three phases of twelve weeks for the purpose of evaluating the protein requirement. During each of the three phases a diet containing 14.6 per cent protein was calculated to produce the optimum response in egg production and egg output. For the entire thirty six 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.

Effects of three levels of calcium viz., 1.8, 3.6 and 5.4, three levels of protein viz., 13, 16 and 19 per cent and three levels of ME viz., 201, 250 and 300 Kcal in 120 g feed on feed intake, egg shell quality and hen performance were studied by Gleaves _et al_. (1976). 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 increased, egg production increased and consequently protein intake increased. 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 fed 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.

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^{o}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. The intermediate energy diet did not differ significantly from the other two dietary energy levels in this respect. The high energy diet resulted in significantly lower egg weights than did the intermediate and low energy diets. Specific gravity 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.

Mather *et al.* (1976) conducted an experiment to study the influence of dietary energy, protein and environmental temperature on feed intake and hen performance. The treatments comprised three levels of energy viz., 13, 16 and 19 g in 120 g of 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 calcium 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.

Hinners *et al.* (1977) observed the effect of energy and density levels on performance of laying hens by providing two levels of bird density viz., four and five birds per 16" x 16" cage and five levels of energy concentration viz., 3000, 2925, 2850, 2775 and 2625 Kcal ME per kg to twenty two weeks old commercial pullets. 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 Kcal of ME (414) per egg were lowest at the 2775 Kcal level. Feed consumed per hen per day (112.8 g) was the lowest at the highest energy level, but Kilocalories (311.3) consumed per hen per day was the lowest at the lowest energy level.

Mohan et al. (1977) conducted a 4 x 4 factorial experiment with 11, 13, 15 and 17 per cent dietary protein levels each at 2550, 2650, 2750 and 2850 Kcal ME/Kg to find out the relationship between protein and energy in cage layer nutrition. The results showed a significantly better egg production and feed efficiency on 15 and 17 per cent protein levels as compared to 11 or 13 per cent levels. The protein energy interaction or increase in energy level in the diet did not have any significant effect on feed efficiency, but affected the egg production. The average egg weight and body weight gains 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/Kg. Both albumen quality and average egg weight were affected by protein x energy interaction. The effects of a mid-laying period reduction in dietary protein level on productive performance of caged White Leghorn layers were studied by Hamilton (1978). The protein levels applied were 17, 15 and 13 per cent and it was found that dietary protein level had no significant effect on feed intake, mortality, egg weight, egg production, specific gravity, Haugh units or blood spots.

Summers and Leeson (1978) determined the energy and protein requirements of laying hens. White Leghorn pullets were fed with diets containing 17.8 per cent crude protein and varying ME levels of 3080, 2860 and 2420 Kcal/Kg. Egg production, egg weight and conversion of feed to egg mass was not affected by the diets. Pullets on the diet with highest energy took 42 Kcal more daily than those on the diet with least energy and resulted in a difference of 15 per cent more in body weight. Increased protein intake associated with the low energy diet did not improve performance.

Carew *et al*. (1980) studied the effect of dietary energy concentration on performance of White Leghorn hens at various densities of cages. The birds were housed at cage floor densities of 660, 440 or 330 cm^2 and were fed diets with 2737, 3003 or 3322 Kcal ME/Kg. Dietary energy level did not significantly affect over all hen-day production. However, the highest dietary energy consistently resulted in the lowest egg production during the latter part of the experiment. It was concluded that for heavy egg type hens high dietary energy was not conducive to sustained egg production. Increasing the dietary energy level decreased feed intake and consequently increased feed efficiency. The highest dietary energy caused an increase in egg size during midpart of the experiment. Otherwise, energy level did not affect egg weight, shell strength, Haugh unit or blood and meat spots.

Response of thirty egg type stocks to four layer diets differing in protein and caloric levels was studied by Doran et al. (1980). Diet one contained 15.1 per cent protein and 2770 Kcal ME/Kg of feed, diet two-15.1 per cent protein and 3010 Kcal ME/Kg, diet three - 17.2 per cent protein and 2770 Mcal ME/Kg and diet four - 17.2 per cent protein and 3010 Kcal ME/Kg of feed. Hen-day production for the four combinations were 73.40, 74.38, 75.61 and 76.55 per cent for ration 1, 2, 3 and 4 respectively. 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 and caloric levels of the diets increased, average egg size, body size and feed efficiency increased. Protein level of the diet increased egg size more significantly than caloric level.

Reddy <u>et</u> <u>al</u>. (1980) conducted a 4 x 4 factorial experiment with 12, 14, 16 and 18 per cent dietary protein levels each at energy levels of 2540, 2640, 2740 and 2840 Kcal ME/Kg to find out the influence on production traits of caged layers. There was significant improvement in per cent hen-day egg production, feed consumption, feed efficiency and egg weight with each incremental level of dietary protein. An increase in the dietary energy level significantly decreased egg production, feed consumption, feed efficiency and egg weight. Maximum production response was obtained with 18 per cent protein diet in combination with dietary energy levels of 2540 and 2640 Kcal ME/Kg in respect of egg production and feed efficiency. The 14, 16 and 18 per cent protein diets were similar in their effect on 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. 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.

Reid and Maiorino (1980) investigated the effects of four dietary energy levels of 2.42, 2.64, 2.86 and 3.08 Kcal/g with three protein levels 14, 16 and 18 per cent on laying hen performance. At the 14 per cent protein level, the increasing dietary energy produced a progressive decrease in egg production rate, but an improvement in feed conversion (kg/dozen eggs). The protein intake levels for the birds fed those 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 ME of the diet was increased. 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 ME from added fat. Increasing the dietary ME with added fat produced an average of 5.1 to 8.3 g feed per bird per day for each increase of 0.22 Kcal ME/kg feed. These dietary changes also resulted in increased ME intakes amounting to 3.4, 10.8 and 9.9 Kcal per bird per day for the three protein levels.

Valencia *et al*. (1980) conducted a study in laying hens to evaluate the net energy of tallow and energetic efficiency of metabolizable conversion to net energy at 18.3 and 35^{o}C. The results showed that maintenance metabolizable energy needs were 20.3 per cent less at 35^{o}C than at 18.3^{o}C. Dietary energetic efficiency was the same at the two temperatures. There was a reduction in voluntary feed intake at higher temperature. The birds consumed 42.6 to 49.3 per cent less ME at 35°C. Those birds fed with 5 per cent fat diet and housed at 35°C consumed 15 per cent more metabolizable energy than those birds fed the unsupplemented basal diet at the same temperature. There was 13 per cent increase in ME intake with the feeding of 5 per cent fat at 18.3°C. Liver fat contents were not significantly different in any of the treatments in the study.

Rothe et al. (1981) studied the effect of level and source of dietary protein and methionine supplementation on the performance of laying hens. In a 2 x 3 factorial experiment, individual caged egg type pullets were fed isocaloric diets containing 2710 Kcal ME/Kg and 16 and 18 per cent protein each from three sources viz., plant plus animal, plant and plant plus methionine. Egg production was found satisfactory on all diets. Protein level significantly influenced egg production, which was higher on 18 per cent than on 16 per cent protein. Egg weight and egg grades were not significantly affected either by dietary protein level or protein source. Egg mass however, was significantly higher at 18 per cent than at 16 per cent protein level. Feed consumption was not significantly influenced either by level or source of protein.

Thatte _et al._ (1981a) conducted five experiments in White Leghorn birds to study the effect of dietary protein and energy content on laying hens exposed to mean temperatures from 33.3 to 42.2°C. The effect of only groundnut cake and groundnut cake with fish meal on egg production and other criteria in layer was also examined. The protein levels used in various experiments were from 16 to 24 per cent in first, 15.5 to 24.5 per cent in second, 14 to 20 per cent in third, 16 to 20 per cent in fourth and 16 to 28 per cent in fifth experiment. The ME level used for each protein level in the respective experiments were 2611 and 2811, 2559 and 2741, 2609 and 2803, 2718 and 2803 and 2584 and 2803 Kcal/kg. The results of the study showed that egg production, egg weight and body weight gain were not significantly affected by protein or energy levels. When fish meal was used as the only protein supplement, egg production was higher, egg weight significantly higher and body weight loss significantly lower than when groundnut cake plus fish meal was used.

Diets containing plant protein resulted in significantly lower egg production than with animal protein. Inadequate energy intake was the main cause of the weight loss which occured regardless of protein levels. The protein requirements appeared to be 18 per cent or higher for layers.

Energy and protein requirements of the individually caged White Leghorn pullets fed diets containing 14 to 24.5 per cent protein and 2511 to 2811 Kcal ME/kg were studied by Thatte et al. (1981b). The results showed no significant difference in average egg production, egg weight, egg mass and body weight gain except that 14 per cent protein diet resulted in significantly lower egg production and egg mass. The egg production was higher at lower energy levels, but egg weight and body weight gain were higher on higher protein levels. An average daily ME intake of 301 to 303 Kcal supported high egg production and daily intake of 18 to 20 g protein supported higher egg production, body weight and egg weight.

Douglas and Harms (1982) conducted two experiments, in which seven hundred and twenty Leghorn pullets were given dietary protein 9, 14 or 21 per cent from eight until twenty weeks old with metabolizable energy of 3320, 3197 and 3016 Kcal/Kg diet respectively. At twenty weeks thirty pullets from each treatment were caged at two hens per cage and all given the same commercial layer diet with protein 16.3 per cent, ME 2837 Kcal/Kg, calcium 3.5 per cent and phosphorus 0.75 per cent. Birds given 9 per cent protein had the lowest body weight at twenty weeks old and also throughout the subsequent laying period until sixty weeks old. About 6 per cent more large and extra large eggs were produced by birds given the grower diet with 21 per cent compared with those given 9 or 14 per cent.

The performance of brown egg type layers fed different protein levels viz., 16, 18 and 20 per cent each at three ME levels viz., 2400, 2600 and 2800 Kcal/Kg diet was studied by Olomu and Offiong (1983). It was found that dietary protein had significant effects on hen-day production, egg weight, Haugh units, feed intake, feed conversion, feed cost per dozen eggs, caloric intake, and final body weight. Protein consumption on all levels of dietary protein was over 20 g per bird per day and increased significantly with increase 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 (2600 Kcal/Kg diet) and highest energy levels (2800 Kcal/kg diet), but significantly higher than that obtained on the lowest energy level (2400 Kcal/kg diet). Egg weights, Haugh units, feed per dozen eggs and mortality were not significantly affected by energy levels. The experiment supported the use of 16 per cent protein and a metabolizable energy level of 2400 Kcal/Kg diet for brown egg type layers.

Three experiments were conducted by Summers and Leeson (1983) to investigate the influence of diet composition and body weight on early egg size. White Leghorn pullets were fed with corn-soya practical type diets-one containing 17 per cent protein (DL-methionine supplemented) to provide a level of 0.34 per cent methionine, a second diet similar but with a level of 0.44 per cent methionine and a third diet containing 22 per cent crude protein with methionine supplemented to a level of 0.44 per cent. All diets contained 2800 Kcal ME/Kg and equal levels of other major nutrients. It was observed that increasing dietary protein or methionine level had little or no effect on egg size for the first twelve weeks of production. Energy consumption was similar for all groups, although birds fed high energy-high protein diet, consumed significantly more energy than did birds fed the low energy-low protein diet.

Energy metabolism in laying hens kept at temperatures of 21 or 17°C and either singly in battery cages with an area of 2100 cm^2 or 3 in each cage having 700 cm^2/hen was studied by Chwalibog (1985). Feed intake was greatest in all trials at about 35 weeks and greatest egg production at 38 to 41 weeks old. Temperature had no significant effect on size or chemical composition of eggs.

Onwudike (1985) studied the effect of different protein levels on the performance of laying birds in tropical environment. One hundred and ninety two commercial laying hens were given diets with 16, 18, 20 or 22 per cent protein. All diets had similar concentration of energy, calcium and phosphorus. Increasing the protein concentration from 16 to 18 per cent led to a significant increase in the average laying rate, egg weight, feed intake and feed conversion efficiency. Protein at 20 or 22 per cent did not increase performance beyond the optimum.

Effect of the amount of protein in the diet on the performance of laying hens was observed by Franchini et al. (1986). From twenty two to forty one weeks old two hundred and eighty eight laying hens in two groups with sixteen replications were given diets equal in energy and calcium with protein 18.5 to 16.5 per cent. From forty two to sixty one weeks, old, two sub-groups in each group were given diets with protein 18.5 or 16.5 per cent. There was no significant difference in feed intake, egg production or feed conversion between groups to forty one weeks old. Decreasing protein in the diet from 18.5 to 16.5 from forty two to sixty one weeks old did not significantly affect production. Egg quality except for weight was not affected by treatments.

Saxena et al. (1986) observed the performance of commercial laying pullets on different protein and energy levels during winter months. From age nineteen weeks three hundred and fifty eight laying pullets in nine groups were given diet containing protein 15, 17 or 19 per cent and energy 2800, 2900 and 3000 Kcal/Kg for 100 days. There was no significant difference due to diet on age at sexual maturity, egg production, egg mass, feed efficiency, mortality or internal egg quality. It was concluded that optimum requirements of protein and energy for laying hens in winter were 15 per cent and 2800 Kcal ME/Kg diet respectively.

Tomova and Duneva (1986) conducted an experiment to study the effect of amount of metabolizable energy and protein in mixed feeds on the productivity of laying hens. From twenty six to sixty three weeks old, four groups of seventy two laying hens in battery cages were given diet with a protein level 17 per cent (group one and two) and 18 per cent (group three and four) and energy level of 2700 Kcal/Kg (group one and three) and 2800 Kcal/Kg (group two and four). Mean egg production was 78.7, 78.4, 77.93 and 81.22 per cent and mean egg weights were 48.38, 48.38, 47.71 and 49.61 g respectively. Feed intakes were 164, 168, 164 and 160 g per egg laid and 2676, 2729, 2680 and 2712 g per kg eggs. Effect of dietary protein levels and some limiting aminoacids on the performance of egg type commercial pullets were studied by Thakur _et al_. (1987). From twenty to forty weeks old pullets were given fifteen diets with crude protein 18, 16 or 14 per cent and lysine 0.75, 0.70 and 0.65 and methionine plus cystine 0.60, 0.55 and 0.50 per cent at each protein level. Each protein had a negative control with only vegetable protein and a positive control with vegetable protein plus 5 per cent fish meal. Percentage hen day egg production was maximum with 18 per cent dietary protein. Feed efficiency was least with 14 per cent crude protein and for hens given vegetable protein increased when amino acids were supplied; values were poor for diet with vegetable protein, fish meal and medium amounts of amino acids. Weight gains were similar for diets with vegetable protein, animal protein and low amounts of amino acids and were least with highest amounts of amino acids.

Jin and Craig (1988) while studying the effects of cage and floor rearing on commercial White Leghorn pullets during growth and first year of egg production reported that carry over effects from cage and floor pen rearing into the laying period were small and transient; pullets reared in cages attained sexual maturity two weeks earlier and had 6 per cent higher hen housed egg production for the first four weeks period. However, when compared for the full forty eight week laying period, no significant difference associated with rearing environments were found for livability, rate of lay, hen housed egg production, egg weight or egg mass. Although thirty two g heavier when housed at nineteen weeks, cage reared hens did not differ significantly in body weight from floor reared hens at 20, 50 and 67 weeks.

Reddy et al. (1988) conducted studies on step-up and step-down protein diets for growing pullets on their laying house performance. During the growing period the birds were fed with diets containing 12 or 22 per cent protein and ME 2750 to 2800 Kcal/Kg, thereafter a layer diet containing 18 per cent protein and ME 2680 Kcal/Kg. It was found that chickens started on 12 per cent protein reached sexual maturity ten days later than those started on 22 per cent protein. Per cent hen-day production was similar in all the dietary treatments regardless of protein fed during starter and grower period. Egg weight was reduced and albumen index increased in chickens started on 12 per cent compared with 22 per cent protein. Mortality was not affected by pre-layer protein intake.

Summers and Leeson (1989) carried out a 2 x 6 factorial experiment in which White Leghorn chickens were given maize-soybean meal diets with metabolizable energy 2800 or 3000 Kcal/Kg and protein 23, 21, 19, 17, 15 and 14 per cent. Daily protein intake was between 13.3 and 23.3 g from 18 to 32 weeks old and between 14.2 and 24.9 g from 32 to 56 weeks old. Performance decreased only at the lowest protein level. Energy intake was not different between diets, except for 23 per cent protein which increased energy intake by 8 per cent. It was concluded that since there was no difference in performance over the different protein levels with about 75 per cent variation in protein intake, energy intake was more likely to be a limiting factor than protein intake in the performance of chickens.

Jalaludeen and Ramakrishnan (1989a) conducted a study to assess the requirement of dietary protein and energy for layers maintained in cages. The protein levels employed were 14, 16, 18 and 20 per cent and energy levels were 2400, 2500, 2600 and 2700 Kcal ME/kg diet. The observations were made over twelve, 28-day periods. The varying levels of protein and energy employed did not have any significant influence on body weight gain. Neither protein nor energy influenced feed intake whereas hen-day egg production was influenced significantly by dietary protein but not by energy levels. Egg production was significantly highest with 18 per cent protein and lowest with 14 per cent protein. However, no significant difference in egg production was observed between 16 and 20 per cent and that between 18 and 20 per cent. Feed efficiency (both on egg number and egg weight) was significantly superior with diets containing 16, 18 and 20 per cent protein. Energy levels in the diet did not influence feed efficiency. The mean egg weight was influenced significantly by protein as well as energy, whereas shell thickness was influenced only by dietary protein.

Jalaludeen and Ramakrishnan (1989b) carried out another experiment with 108 strain cross White Leghorn Pullets from 20 to 40 weeks of age to study the optimum protein and energy requirements of caged layers. Three levels of protein viz., 14, 16 and 18 per cent CP and three levels of energy viz., 2300, 2500 and 2700 Kcal ME/Kg were employed. Maximum and minimum hen-day egg production percentages were observed with protein : energy combinations of 18 : 2500 and 14 : 2500 respectively. Daily feed consumption of birds subjected to different protein and energy diet did not differ significantly. Significantly better feed conversion efficiency was noted with 16 : 2700 group. Though significant differences were noted with egg weight among the various treatment groups, the results did not show a definite trend. The highest feed cost was observed with birds of 18 : 2500 group while the lowest was observed with 14 : 2300 group. From the results obtained it appeared that a crude protein level of 14 per cent with an energy level of 2300 Kcal ME/Kg feed was required for commercial egg production in caged layers.

Housing system - Deep Litter

Starter period

Hill and Danky (1950) studied the protein requirements of chicks and its relation to dietary energy level. Three protein levels (20, 25 and 30%) were fed in all possible combinations with graded levels of fish meal (0-4%). With adequate fish meal, all protein levels promoted equal growth; with inadequate fish meal, high protein level depressed growth. No improvement in growth of cross bred chicks to seven weeks of age was obtained by increasing the protein level above 20 per cent in a diet of relatively high productive energy content based on corn, wheat and heat extracted soybean flour. Reducing the protein level below 20 per cent in a similar diet high in productive energy reduced growth rate. In contrast, normal growth was obtained with protein levels under 20 per cent when dietary productive energy level was reduced by adding pulverised oat mill feed or oat hulls. The productive energy value of the ration was a major factor in controlling feed intake.

Leong _et al_. (1955) conducted two experiments to study the effect of energy - protein ratio on growth rate and feed efficiency of chicks. New Hampshire x White Leghorn crossbred chicks were fed diet with protein content varied from 12 to 42 per cent at 5 per cent intervals and energy levels of 700, 950, 1210 and 1450 Calories/lb. In experiment one, at five weeks best growth among the 700, 950 and 1210 Caloric diets obtained at 22, 27 and 32 per cent protein respectively. Weights of the three respective groups were 1162, 1165 and 1213 grams and feed conversion were 2.5, 2.1 and 1.9 gram feed per gram gain. In experiment two, best growth among the 950, 1210 and 1450 Caloric diets was obtained at 22, 27 and 32 per cent protein respectively. Weights of the three respective groups were 1162, 1165 and 1213 gram, and feed conversions were 2.5, 2.1 and 1.9 grams feed per gram gain.

Thornton *et al*. (1957) conducted experiments in batteries and floor pens to study the energy and protein relationships in male and female chicken. Two protein levels 20 and 24 per cent, and four energy levels 1110, 1245, 1375 and 1510 metabolizable Calories per kg feed were used. The energy level was changed by varying the corn soybean oil meal ratio. Females showed no growth response to additional protein at the four energy levels studied in both housing systems. In the floor trial both sexes showed additional growth with increased energy at each protein level. Feed efficiency was improved as the energy level increased.

Reddy *et al*. (1965) studied the growth response of White Leghorn hybrid chicks to three different protein supplements. About eight thousand chicks were randomly divided into three lots. Three different rations consisting of different combinations of animal protein supplements viz., non-fat dry milk, fish meal and liver residue were assigned to each lot. The rations contained energy levels of 1805, 1185 and 1110 Calories ME/lb and protein levels of 22.6, 24.6 and 23.7 per cent respectively. The level of non-fat dry milk in the three rations were 10, 10 and 15 per cent respectively.

Ration III was found consistently superior to both the rations I and II. Ration II was found to be slightly superior to ration I. The body weight of chicks fed ration III were significantly superior at 10 days, 17 days and 10 weeks of age. The superiority of ration III was indicated to be due to its higher level of non-fat dry milk with its higher biological value and its higher assimilable calcium content.

Quarles et al. (1981) conducted experiment in which single comb White Leghorn pullets were grown under three dietary regimes. One group (control) was fed a 20.1 per cent starter (S) from 0-8 weeks, a 15.1 per cent grower (G) from 9-12 weeks and a 13.8 per cent developer (D) from 13 to 20 weeks. A second group (Low) were fed (G) from 0-8 weeks and D from 9 to 20 weeks. A third group (MEDIUM) was fed S from 0 to 4 weeks and D from 5 to 20 weeks. An identical feeding programme was used in each group for the duration of laying period.

Control pullets was significantly heavier than birds fed lower amounts of protein at all ages examined during the growing period. Body weights at 20 weeks averaged 1383, 1246 and 1318 g in control, Low and MEDIUM birds respectively. The total feed as well as the protein and energy intake were also highest for control birds during the growing period. During lying phase hen housed production from 20 to 52 weeks of age was also highest in control birds.

Reddy et al. (1989) studied the effect of varying dietary protein levels during starter and grower stages on subsequent production performance of egg type chicken. Diets varying in protein levels viz., 22, 19.8, 17.6, 15.4 or 13.2 per cent with an energy content of 2700 Kcal ME/Kg were given to White Leghorn chicks maintained on the floor during starter period. Dietary protein content did not influence feed intake, energy intake and feed efficiency. Mortality was higher and financial returns were less for the birds started on 13.2 per cent protein.

Grower period

Lillie and Denton (1967) evaluated the dietary protein levels for White Leghorn in the grower and subsequent layer periods. The birds were reared on litter and fed different protein levels at two different ages and then transferred to layer cages. Diets one, two and three containing 21, 16 and 12 per cent protein respectively were used to supply the following levels of dietary protein during the growing period-One - 21 per cent 0-8 weeks and 16 per cent 8-20 weeks, two - 16 per cent 0-20 weeks, three - 16 per cent 0-8 weeks and 12 per cent 8-20 weeks.

The 21-16 per cent grower diet produced significantly heavier body weights than 16-12 per cent grower diet at eight and twenty weeks of age. The grower diets had no effect on the traits studied in the subsequent layer period, except that 21-16 per cent grower diet significantly increased egg production.

Saxena and Pradhan (1973) carried out a study on the requirement of protein for growing birds of different breeds. Two hundred and sixty four female chicks of ten weeks of age were grown diets containing 20, 16 and 12 per cent protein and kept in well-ventilated pens under deep litter system. They found that 16 per cent protein was optimum for growers of different breeds including White Leghorn at a dietary energy level of 2712 Kcal/Kg with a calorie protein ratio 170 : 1.

A study was conducted by Singh and Talapatra (1974) to find out the effect of varying levels of energy in the mash on growth and egg production in White Leghorn birds. Four isoproteinic mashes differing in ME contents viz., 2999, 2521, 2028 and 1536 Kcal/Kg were offered to two hundred day old chicks and at six weeks of age chicks were transferred from battery brooder to deep litter house. There was significant difference in weight of chicks observed upto eight weeks of age.

Layer period

Heywang (1947) conducted study to estimate the protein level of laying diets during hot weather. Data on the effect of the level of protein in the diet on mortality rate, feed consumption, egg production and live weight of laying White Leghorn pullets and hens were obtained in four experiments. One diet low in protein content (11, 12, 12.5 or 13.5 per cent), one diet 'standard' in protein content (15.5, 16.5 or 18 per cent) one diet moderately high in protein content (23, 25 or 25.5 per cent) and one diet extremely high in protein content (30, 31.5, 35 or 44 per cent) were fed in experiments. A diet slightly high in protein content (20.5 or 22.5 per cent) was also fed in two of the experiment. Combination of the results of all experiments showed that the total mortality was approximately greater in the groups receiving the diets moderately high in protein than it was in the group receiving the standard diet or diet low in protein. Average total feed consumption and average total egg production were greatest on the diet moderately high in protein and lowest on the diets low in protein. The poorest maintenance of live weight occurred in the groups fed the diets low in protein, the groups receiving the other classes of diets differed but little in their maintenance of live weight.

Heywang *et al*. (1956) in one experiment conducted during 112 days of hot weather and in another conducted during 120 days of hot and 153 days of relatively cool and moderate weather, laying White Leghorn pullets were fed diets containing varying quantities of Sardine meal and casein to bring their total protein content to about 11.5, 13, 15, 16.5, 18 and 19.3 per cent. The total protein content of the diet fed to three groups in the second experiment was different during hot than cool and moderate weather. It was found that average total egg production per pullet in the first experiment was less when the protein content of the diet was 11.5 per cent than when it was 13 per cent, but not greater when it was more than 13.0 per cent. The results in the second experiment both in the groups fed the same diets throughout the experiment and in the groups when the protein level of the diet was changed, indicated that optimum level of protein was 15.0 per cent during both hot and relatively cool and moderate weather. Considered collectively, the data from both experiments thus indicated that no increase in egg production would occur if protein level in the diet of laying chickens was greater than 15.0 per cent during hot weather.

Mac Intyre and Aitken (1957) conducted two feeding trials to determine the effects of high levels of dietary energy and protein on the performance of laying hen. Protein levels of 20.0 - 21.3 per cent were compared with levels of 15.4 to 16.5 per cent. Energy levels ranged from 700-940 Calories/pound. They found that neither high energy nor high protein had any influence on rate of egg production, egg weight, specific gravity of eggs, albumen height or blood and meat spots in the eggs. Feed consumption and feed per dozen eggs were markedly affected by the energy content of the diet. Body weight was highest when high protein and high energy were combined, but was the same for all other diets. Mortality was significantly higher on the high protein diets in the two experiments.

The effect of low and high energy in two experiments of ten months each was studied by Petersen et al. (1957). The low energy ration (660 calories) contained 61 per cent barley and the high energy ration (910 calories) contained 50 per cent corn. Each ration was fed to duplicate lots of seventy five pullets in both experiments. During the second experiment, the winter house temperature of one lot fed each ration was maintained at 55 $\pm$ 3°F. The temperature of other pens ranged from 40 to 60°F. During the first year, average egg production of the four lots fed the high energy ration was 2.5 per cent greater than lots fed low energy. Feed efficiency lb feed/doz. eggs) was influenced by energy level. The low energy diet required 10 per cent more feed. Egg production was not influenced by energy level during the second trial. Influence of energy upon feed efficiency was similar to the first experiment. However, production was improved when the house temperature was controlled during the winter months. Maintaining uniform temperature also resulted in 10 per cent improvement of feed efficiency with both energy levels.

Berg and Bearse (1958) conducted a study in which nine hundred strain cross White Leghorn pullets during the 8 to 20 week period were fed two rations, one of the diets contained approximately 15 per cent protein and 1100 calories of ME per pound, while the other ration contained 18 per cent protein and 1300 calories of ME per pound. When the pullets were 20 weeks old, the two laying rations which had the same approximate protein and energy content as the deceloping rations were formulated. Three of the laying house groups from each of the developing rations were continued on a laying ration of a similar protein and energy content. The other three groups were changed to the laying ration providing the other level of protein and energy, and the groups were continued on their laying diets for twelve, 28-day periods. The results showed that the above variation in developing ration had no effect on such subsequent laying period criteria as rate of lay, feed per dozen eggs, mortality, body weight gain, albumen quality or shell thickness. The birds fed the higher protein-higher energy developing diet produced slightly larger eggs at the onset of production. The effect of the growing ration on early egg size decreased as the laying year progressed.

The effect of dietary protein and energy levels upon production of single comb White Leghorn hens maintained on floor was studied by Hochreich *et al.* (1958). The six experimental diets included three levels of protein (calculated to contain 15.7, 17.0 and 18.35 per cent) with and without the addition of stabilised yellow greese. The average rate of egg production for the hens receiving diets containing 17 or 18.35 per cent protein was significantly higher than the rate of egg production with hens receiving 15.7 per cent protein in the diet. The feed efficiency per dozen eggs also gave the same results. A level of 17 per cent protein in the feed was required to maintain maximum egg production and feed efficiency when the feed contained at least 950 Calories of productive energy per pound.

An experiment was conducted by Pepper *et al.* (1959) involving about 1450 birds of seven different strains and crosses. One half of the birds were reared on range and the remainder in confinement. One half of each of these groups was fed high and the other low energy diets during the starting and growing periods and all groups received the same high energy diet during the laying period. The productive energy content of the high energy diets was 916, 929, 944 and 973 Calories per pound for the 0-4, 5-8, 9-14 and 15-20 weeks periods respectively, while for the same periods low energy diets contained 872, 874, 877 and 879 Calories per pound. Results revealed that birds reared on range laid slightly, but not significantly better than those reared in confinement. There was no difference in egg production or feed required per dozen eggs between birds reared on high and those reared on low energy diets.

Thornton and Whittet (1959) tested the adequacy of low protein levels for egg production under various conditions. Four levels of protein (17, 15, 13 and 11 per cent) were tested under several conditions viz., different strains of birds, cage and floor management and high and low dietary energy levels. In all cases it was evident that the 13 per cent protein diet was comparable to the higher protein levels for egg production and feed efficiency. The 11 per cent diet was insufficient under all conditions when the dietary energy level was high. When the dietary energy level was reduced, this protein level was comparable to the three higher energy levels for egg production, feed efficiency and hatchability.

Carlson and Stangeland (1960) studied the effect of protein levels and furazolidone treatments under both cage and floor pens on egg production. Single comb White Leghorn hens were placed in floor pens as well as in individual and colony cages. Dietary treatments included protein levels of 12, 13.4 and 16 per cent on all-mash corn-soybean fat type diets of constant energy content with and without supplements of furazolidone at 25 gram/tonne. Through 6 months of treatment, the hens in the floor pens laid at a superior rate compared to those in cages but were not influenced by protein level or furazolidone treatment. It was evident that hens in floor pens required less protein then hens in cages.

The protein requirement for egg production was studied under various conditions by Thornton and Whittet (1960). The factors included the type of management (floor or cage) dietary energy level and the genetic background. Four different protein levels viz., 17, 15, 13 and 11 per cent were employed at two different energy levels of approximately 700 and 900 Calories productive energy per pound of ration. Under floor management condition, tho three higher protein groups were merely identical in the rate of egg production and superior to the 11 per cent protein levels for hen fed the high energy ration. Feed efficiency was higher for those three groups compared to the group given 11 per cent protein.

The effect of three energy levels viz., 2650, 2750 and 3050 Kcal ME/Kg with two dietary protein levels viz., 15 and 18 per cent on the performance of laying hens in floor pens and in cages in the tropics was studied by Sugandi et al. (1975). With continuous high temperature and almost no variation in day length annual egg production was 73 per cent for the better diets in floor pens. The most efficient and profitable diet contained 17.5 per cent protein and 2850 Kcal ME/kg. Egg production and feed conversion were significantly better in floor pens with higher protein levels.

Rama Rao et al. (1983) took up studies to determine the influence of housing systems, stocking density and protein level during different stages of growth and production on performance of commercial egg type chicken. The per cent hen-day egg production and feed efficiency were found highest in litter floor birds than cage and slat floor birds. In laying phase the birds with

1.6 sq.ft/bird on litter performed better than the birds with 2.0 sq.ft/bird. The birds with 18 per cent protein performed better than the birds fed with 15 per cent protein irrespective of housing systems.

Prasad et al. (1984) studied the production and biochemical responses of White Leghorn pullets as affected by varying housing systems and stocking densities and dietary protein levels. Results showed that in each housing system lower space allowance gave better performance than the higher allowance. Higher dietary protein (18%) supported significantly higher production than 15 per cent dietary protein. Litter reared birds had higher levels of serum protein, uric acid, calcium, phosphorus and alkaline phosphatase activity than birds on slats or in cages.

Materials and Methods

MATERIALS AND METHODS

An experiment was designed and conducted at the All India Co-ordinated Research Project on Poultry Nutrition, Centre for Advanced Studies in Poultry Science, Kerala Agricultural University, Mannuthy, to find out the influence of housing systems on energy and protein requirements of White Leghorn strain cross birds from one day old to 72 weeks of age under the prevailing agroclimatic conditions of Kerala.

Two systems of housing namely deep litter and cage were taken up for study. Seven hundred and twenty, one-day old female chicks of ILM-90 were procured from All India Co-ordinated Research Project on Poultry for Eggs, Mannuthy Centre. The chicks were wing banded and weighed individually. They were randomly divided into two groups of 360 chicks each, one for experimentation in deep litter and other for cage experiment. Each group was further divided randomly into 36 units containing 10 chicks each. The birds were assigned to 12 dietary combinations of protein and energy. Four levels of protein viz., 14, 16, 18 and 20 per cent and three levels of metabolizable energy, viz., 2300, 2500 and 2700 Kcal ME/Kg were employed in all possible combinations. Thus, in all, there were 12 treatments and each treatment was replicated thrice and each replicate had ten chicks under both systems of rearing.

The three hundred and sixty chicks meant for cage study were housed in electrically operated battery brooders with raised wire netting floor. The remaining 360 chicks were brooded on deep litter. The chicks in the two systems were fed different experimental diets. The composition of the experimental diets is given in Table 1. The ingredients required for the formulation of the diet were procured and were analysed for proximate composition. The proximate composition of ingredients as well as the rations was estimated according to the procedure outlined in A.O.A.C. (1970). The level of the fish meal, being the sole animal protein source, was kept constant in all the diets. Marginal adjustments were made in 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 value of the ingredients and rations was calculated using the prediction equation suggested by Carpenter and Clegg (1956). The available carbohydrate was estimated by the application of method suggested by Carpenter and Clegg (1956).

Feed and water were provided _ad libitum_. The routine managemental practices were uniformly followed throughout the experimental period in both the groups. The chicks were vaccinated against Marek's disease (first day), Ranikhet disease (at 5 days, sixth and eighteenth weeks of age), Infectious bursal disease (at 21 days of age) and Fowl Pox (at 14th day and 8th week of age). Daily minimum and maximum temperature and relative humidity were recorded during the period of experimentation.

The observations during starter phase was made from 0-8 weeks of age and subsequently during grower and layer phases the data were collected at intervals of four weeks.

The observations recorded during the starter phase and grower phase were feed intake, body weight, feed conversion efficiency and mortality.

Because of sexing error and mortality, only two replicates were used during the grower and layer phases.

During the layer phase (20-72 weeks of age) individual body weights were recorded at 20, 40, 60 and 72 weeks of age.

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 28-day period.

Feed intake was recorded replicate-wise at the end of each 28-day period and from this data feed intake per bird per day was calculated for the various treatment groups. Feed conversion efficiency (feed per dozen eggs) was calculated utilizing the data on hen-day egg production and feed intake.

During the last three consecutive days of each 28-day period, egg collected from all the treatments were weighed individually and one egg from each replicate was saved at random every day for egg quality studies. They were marked 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).

At the end of the experimental period, one bird from each replicate was selected at random for measuring abdominal fat and estimation of liver lipids. The birds were fasted and killed. The fat detached from the viscera of each bird was weighed for the assessment of abdominal fat. One piece of liver from each bird was saved, marked and sealed in polyethylene bag and was stored in deep freezer for estimation of liver lipids. The liver samples were thawed, dried and finely ground before analysis. Estimation of ether extractives of liver samples was made employing the procedure described in A.O.A.C. (1970).

Cost of feeding was calculated for different phases based on the actual feed intake per bird during each phase and the prevailing cost of feed ingredients.

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

Table 1 Percentage composition of experimental diets

Ingredients / Protein (%)	14			16			18			20		
Energy (Kcal/Kg)	2300	2500	2700	2300	2500	2700	2300	2500	2700	2300	2500	2700
Yellow maize	43.50	52.00	60.00	36.00	46.00	60.00	35.00	45.00	54.00	35.00	45.00	54.00
Ground nut cake	-	-	-	3.00	4.00	4.00	4.00	5.00	10.00	6.00	7.00	8.00
Gingelly oil cake	3.00	1.00	1.00	3.00	4.00	4.00	10.00	10.00	5.00	15.00	15.00	15.00
Wheat bran	12.00	14.00	4.00	21.00	12.00	4.00	21.00	12.00	-	22.00	12.00	3.00
Rice polish	20.00	16.50	18.50	20.50	17.50	11.50	14.00	12.00	14.50	6.00	5.00	4.00
Fishmeal	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Mineral mixture	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Shell meal*	4.50	4.50	4.50	4.50	4.50	4.50	4.00	4.00	4.50	4.00	4.00	4.00
Saw Dust	5.00	-	-	-	-	-	-	-	-	-	-	-
Salt (g)	250.0	250.0	250.0	250.0	250.0	250.0	250.0	250.0	250.0	250.0	250.0	250.0
Merivite (g)	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Liv-52 (g)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Amprosol	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
Calculated value												
Protein (%)	14.26	14.37	14.09	16.10	16.38	16.08	18.23	18.26	18.17	20.12	20.13	20.17
Energy (Kcal ME/Kg)	2328	2513	2661	2318	2490	2692	2331	2502	2693	2344	2521	2691
Calcium (%)	3.25	3.22	3.23	3.27	3.29	3.29	3.24	3.24	3.32	3.34	3.34	3.35
Phosphorus (%)	0.99	0.97	0.91	1.10	1.01	0.87	1.10	0.99	0.91	1.04	0.95	0.87
Lysine	0.68	0.67	0.64	0.75	0.73	0.69	0.81	0.79	0.76	0.86	0.84	0.82
Methionine	0.35	0.29	0.29	0.33	0.34	0.34	0.41	0.41	0.38	0.46	0.47	0.47

*Shell meal was not incorporated in chick starter and grower rations. The level was adjusted with appropriate addition of saw-dust

Results

RESULTS

The results of research carried out to examine the influence of housing systems on the dietary protein and energy requirements of White Leghorn Strain Cross (ILM-90) from one day old to seventy two weeks of age is presented in this chapter.

Temperature and Relative humidity

The mean maximum and minimum temperature as well as relative humidity (monthwise) from April 1989 to August 1990 (period of experiment) recorded inside the poultry houses where the experiments were undertaken are given in Table 2.

During starter phase (0-8 weeks), the range of maximum temperature inside cage and deep litter houses was 28.7 to 34.2°C and 29.4 to 34.4°C, minimum temperature was 24.9 to 26.3°C and 24.5 to 26.2°C and relative humidity was 69 to 83 and 66 to 81 per cent respectively. During grower phase (9-20 weeks) the corresponding values were 27.6 to 29.9°C and 27.6 to 31°C, 23.1 to 24.6°C and 24.0 to 24.5°C and 82 to 84 and 79 to 82 per cent respectively. Likewise, while the birds were in lay (21-72 weeks) the values were 27.3 to 36.1°C and 28.0 to 36.5°C, 23.0 to 26.2°C and 22.7 to 26.7°C and 67 to 86 and 64 to 84 per cent respectively.

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

Period	Cage house			Deep litter house		
	Temperature (°C)		Relative humidity (%)	Temperature (°C)		Relative humidity (%)
	Maximum	Minimum		Maximum	Minimum	
April 1989	34.2	26.3	70	34.4	26.2	66
May	33.0	25.8	69	33.3	26.0	67
June	28.7	24.0	83	29.4	24.5	81
July	27.6	24.0	84	27.6	24.0	80
August	29.6	24.6	82	31.1	24.5	79
September	29.9	23.1	82	30.0	24.0	82
October	31.0	23.0	80	31.0	24.6	78
November	32.5	22.7	73	31.0	25.1	70
December	30.6	24.8	68	32.0	24.0	65
January 1990	33.1	23.4	72	33.5	22.4	72
February	34.8	23.8	67	35.4	22.7	64
March	36.1	26.1	65	36.5	26.1	64
April	35.8	26.0	70	36.2	26.7	72
May	30.5	26.2	80	32.7	24.8	79
June	28.4	25.0	86	30.3	24.8	84
July	27.3	24.3	85	28.0	24.4	83
August	28.5	25.1	83	29.4	24.6	81

In cage house the highest maximum temperature was recorded during March 1990 and lowest maximum temperature during July 1990. While in deep litter house the highest and lowest maximum temperatures were recorded during March 1990 and July 1989 respectively. Meanwhile, the highest minimum temperature in cage and deep litter houses was recorded during April 1989 and April 1990 and lowest minimum during November 1989 and January 1990, respectively.

Likewise, the highest relative humidity was recorded during June 1990 and lowest during March 1990 in both the houses.

Starter Phase (0-8 weeks)

The mean value of eighth week body weight (g), feed intake per bird during zero to eight weeks (g), weight gain (g) and feed conversion efficiency of different housing systems and varying protein and energy levels are given in Table 3.

Eighth week body weight

Mean body weight of birds at eight weeks of age (Table 3) revealed that those reared in cages were heavier (340.10 g) than that on floor (265.86 g). Body weight showed a numerical increase as the level of protein

Table 3 Effect of housing systems, dietary protein and energy levels on the performance of starter chicks (0-8 weeks)

Character		Figth week body weight (g)	Feed intake per bird (g)	Weight gain (g)	Feed conversion efficiency
Housing systems	Cage	340.10[b]	1440.31	307.73[b]	4.73[a]
	Litter	265.86[a]	1441.42	233.42[a]	6.34[b]
Protein (% CP)	14	274.69[a]	1466.27[ab]	242.61[a]	6.25[c]
	16	289.18[a]	1414.81[ab]	256.54[a]	5.65[b]
	18	313.45[b]	1501.67[b]	280.89[b]	5.52[b]
	20	334.61[b]	1380.71[a]	302.26[b]	4.72[a]
Energy (Kcal ME/Kg)	2300	295.46	1460.91	262.90	5.73[b]
	2500	301.78	1448.66	269.72	5.62[b]
	2700	311.71	1413.02	279.10	5.27[a]
CD	Housing	16.957 ($P < 0.01$)	--	17.207 ($P < 0.01$)	0.373 ($P < 0.01$)
	Protein	23.980 ($P < 0.01$)	91.051 ($P < 0.01$)	24.335 ($P < 0.01$)	0.527 ($P < 0.01$)
	Housing x protein	--	--	--	--
	Energy	--	--	--	0.342 ($P < 0.05$)
	Housing x energy	--	--	--	--
	Protein x energy	31.101 ($P < 0.05$)	--	31.561 ($P < 0.01$)	0.913 ($P < 0.01$)
	Housing x protein x energy	--	--	--	--

Letters bearing the same superscript do not differ significantly between each character

in the ration increased. The mean body weights of birds fed with 14, 16, 18 and 20 per cent protein diets were 274.69, 289.18, 313.45 and 334.61 g respectively at eight weeks of age. Eight weeks body weights among the three energy groups, 2300, 2500 and 2700 Kcal ME/Kg were 295.46, 301.78 and 311.71 g respectively.

The analysis of data on eighth week body weight (Table 4) showed that both housing systems and protein levels in the ration influenced this trait but not

Table 4 Analysis of variance of eighth week body weight of birds fed varying levels of protein and energy under both systems of housing

Source	Df	SS	MSS	F
Block	2	1312.500	656.250	0.915
Housing	1	99211.502	99211.502	138.402**
Protein	3	37817.497	12605.832	17.585**
Housing x Protein	3	2888.000	962.667	1.343 NS
Energy	2	3218.500	1609.250	2.245 NS
Housing x Energy	2	336.500	168.250	0.235 NS
Protein x Energy	6	13391.500	2231.917	3.114*
Housing x Protein x Energy	6	6450.000	1075.000	1.500 NS
Error	46	32974.500	716.837	

* Significant at 5% level

** Significant at 1% level

NS Non significant

energy levels. Birds reared in cages showed significantly heavier ($P < 0.01$) body weight than those on floor. Significantly higher body weight ($P < 0.01$) was observed with 20 per cent protein diet and significantly lower with 14 per cent protein diet. However, statistically the difference between 14 and 16 per cent protein was not significant. Likewise, the difference between 18 and 20 per cent was also not significant. Energy levels in the diet did not show any significant influence on body weight at eight weeks. The interaction effect between protein and energy levels in the diet was found to be significant ($P < 0.01$). Significantly higher body weight was observed with protein energy combinations of 18 : 2700, 20 : 2500 and 20 : 2700. However, the interaction effect between housing and protein, housing and energy and housing - protein and energy was nonsignificant.

Feed intake

Mean feed intake per bird during zero to eight weeks of age as influenced by housing systems, dietary protein and energy levels are presented in Table 3. Irrespective of the housing systems and varying levels of protein and energy in the diets, the range of mean feed intake per bird during zero to eight weeks of age varied from 1380.71 to 1501.67 g. Feed intake was more or less similar for birds reared in both housing systems, 1440.31 g per bird for cage reared birds and 1441.42 g for litter reared birds. Birds fed with 18 per cent protein consumed more feed (1501.67 g) and lowest feed intake was reported with 20 per cent protein diet (1380.71 g) during starter phase. It was medium with 14 and 16 per cent protein diets. Feed intake for the birds fed with energy levels of 2300, 2500 and 2700 Kcal ME/Kg were 1460.91, 1448.66 and 1413.02 g respectively.

Analysis of feed intake data during starter phase (Table 5) revealed that cumulative feed intake per bird was influenced significantly ($P < 0.01$) by protein levels only. Testing the means, it was observed that birds consumed significantly (P 0.01) more quantity of feed with 18 per cent protein (1501.67 g) than 14, 16 and 20 per cent, the difference among them being statistically non-significant. Feed intake during zero to eight weeks of age was not influenced by housing systems and energy levels in the diet. Interaction effect of feed intake between housing and protein, housing and energy, protein and energy and housing - protein and energy were also not significant.

Table 5 Analysis of variance of feed intake per bird (g) fed varying levels of protein and energy during 0-8 weeks of age under both systems of housing

Source	Df	MSS	F
Block	2	15607.999	1.510
Housing	1	0.000	0.000 NS
Protein	3	51834.669	5.016**
Housing x Protein	3	9312.001	0.901 NS
Energy	2	14848.001	1.437 NS
Housing x Energy	2	2096.000	0.203 NS
Protein x Energy	6	1232.000	0.119 NS
Housing x Protein x Energy	6	10914.667	1.056 NS
Error	46	10334.261	
Total	71		

** Significant at 5% level

NS Non significant

Weight gain

The weight gain data (Table 3) reflected the same trend as the body weight. Birds housed in cages showed higher weight gain (307.73 g) than those reared on litter (233.42 g). Body weight gain was superior with respect to

20 per cent protein diet (302.26 g) and poorest with 14 per cent protein diet (242.61 g) and the values for 16 and 18 per cent protein diet were intermediary.

As the level of protein in the diet increases, weight gain also showed a numerical increase. Energy levels in the diet also showed the same trend with respect to weight gain. The value was higher (279.10 g) with 2700 Kcal/ME/Kg diet and lower (262.90 g) with 2300 Kcal ME/Kg diet and medium with 2500 Kcal ME/Kg diet.

Analysis of variance of weight gain data is presented in Table 6. Significantly superior ($P < 0.01$) body weight gain was observed with chicks reared in cages than those on litter. With regard to protein levels in the diet, birds on higher protein levels, that is 18 and 20 per cent had higher weight gain than 14 and 16 per cent protein levels. The difference between 18 and 20 per cent and that between 14 and 16 per cent were statistically non-significant. It also revealed that energy levels in the diet did not have any influence upon weight gain during zero to eight weeks of age. Protein x energy interaction on weight gain was also significant ($P < 0.05$). Protein-energy combinations of 18 : 2700, 20 : 2500 and 20 : 2700 showed significantly ($P < 0.05$) higher body weight gain than others. The interaction effects between housing and protein, housing and energy and housing - protein and energy were not statistically significant.

Table 6 Analysis of variance of weight gain of birds fed varying levels of protein and energy during 0-8 weeks of age under both systems of housing

Source	DF	MSS	F
Block	2	793.500	1.075
Housing	1	99384.994	134.634**
Protein	3	12534.499	16.980**
Housing x Protein	3	939.000	1.272 NS
Energy	2	1588.750	2.152 NS
Housing x Energy	2	160.250	0.217 NS
Protein x Energy	6	2251.500	3.050*
Housing x Protein x Energy	6	1164.083	1.577 NS
Error	46	738.185	
Total	71		

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

Feed conversion efficiency

The mean feed conversion efficiency as influenced by housing systems, dietary protein and energy levels are presented in Table 3 and the analysis of variance in Table 7. Birds reared in cages showed superior feed

Table 7 Analysis of variance of feed conversion efficiency of starter chicks (0-8 weeks) fed varying levels of protein and energy under both systems of housing

Source	DF	MSS	F
Block	2	1.036	2.992
Housing	1	46.288	133.633**
Protein	3	7.128	20.579**
Housing x Protein	3	0.854	2.467 NS
Energy	2	1.393	4.022*
Housing x Energy	2	0.106	0.307 NS
Protein x Energy	6	1.256	3.626**
Housing x Protein x Energy	6	0.518	1.494 NS
Total	71		

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

efficiency (4.73) than those maintained on floor (6.34). The feed efficiency was best with 20 per cent protein diet (4.72) and least with 14 per cent protein diet. The values for 16 and 18 per cent protein diets were intermediate. The mean feed coversion efficiency for the groups fed with 2300, 2500 and 2700 Kcal ME diets were 5.73, 5.62 and 5.27 respectively.

Feed efficiency was significantly ($P < 0.01$) influenced by systems of housing. It was significantly ($P < 0.01$) better in cages than in deep litter. Feed efficiency was also influenced significantly ($P < 0.01$) by levels of protein in the diet. A dietary protein level of 20 per cent resulted in significantly ($P < 0.01$) superior feed efficiency. The feed efficiency observed with 16 and 18 per cent protein levels was medium and that obtained with 14 per cent was poorest. Energy levels in the diet also influenced feed efficiency significantly($P < 0.05$). The feed efficiency with a dietary energy level of 2700 Kcal ME/Kg was statistically superior than that of 2300 or 2500 Kcal ME/Kg. The feed efficiency of 2300 and 2500 Kcal ME/Kg diet was statistically similar. Protein x energy interaction on feed efficiency was also significant ($P < 0.01$). Statistically better feed efficiency was observed with protein - energy combinations of 18 : 2700, 20 : 2500 and 20 : 2700 and these three groups are equally effective. However, the interaction effects between housing and protein, housing and energy and housing - protein and energy were not significant.

Cost of feeding

Influence of housing systems, dietary protein and energy levels on cost of feeding during starter phase is shown in Table 8 and statistical analysis of data in Table 9. The cost of feeding during starter phase for the birds reared under both housing systems viz., cage and litter was Rs.5.64 per bird. The feeding cost for the groups fed 14, 16, 18 and 20 per cent protein levels were 5.56, 5.44, 5.93 and 5.63 rupees per bird

Table 8 Influence of housing systems, dietary protein and energy levels on cost of feeding per bird (Starter phase)

Character		Feeding cost during 0-8 weeks of age (Rs.)
Housing systems	Cage	5.64
	Litter	5.64
Protein (% CP)	14	5.56[a]
	16	5.44[a]
	18	5.93[b]
	20	5.63[ab]
Energy (Kcal ME/Kg)	2300	5.49
	2500	5.70
	2700	5.73
CD Housing		-
Protein		0.36 ($P < 0.01$)
Housing x protein		-
Energy		-
Housing x energy		-
Protein x energy		-
Housing x protein x energy		-

Letters bearing the same superscript do not differ significantly between each character

Table 9 Analysis of variance of cost of feeding of starter chicks (0-8 weeks) fed varying levels of protein and energy under both systems of housing

Source	DF	MSS	F
Block	2	0.249	1.527
Housing	1	0.001	0.006 NS
Protein	3	0.762	4.677**
Housing x protein	3	0.141	0.863 NS
Energy	2	0.402	2.469 NS
Housing x energy	2	0.026	0.157 NS
Protein x energy	6	0.025	0.151 NS
Housing x protein x energy	6	0.156	0.960 NS
Error	46	0.163	
Total	71		

** Significant at 1% level

NS Non-significant

respectively. The corresponding values were 5.49, 5.70 and 5.73 rupees per bird for the three energy groups 2300, 2500 and 2700 Kcal ME/Kg respectively. The analysed data revealed that during the starter phase protein levels in the diet significantly influenced feeding cost, whereas housing systems and energy content in the diet did not have any significant influence. Among protein levels significantly lowest ($P \angle 0.01$) feeding cost was observed with 16 per cent protein diet (Rs. 5.44/bird). Feeding cost values were statistically comparable with 14, 16 and 20 per cent protein diets.

Significantly higher ($P \angle 0.01$) feeding cost was obtained with 18 per cent protein diet (Rs. 5.93/bird) and was statistically similar with 20 per cent protein diet. Analysis of the data also revealed that interaction effects on feeding costs were non-significant.

Grower Phase (9-20 weeks)

The mean values of observations monitored at 28 day periods such as four weekly body weight, cumulative feed intake per bird for each period, weight gain and feed conversion efficiency during nine to 20 weeks of age are shown in Appendix I to III. The mean values with respect to 20th week body weight, cumulative feed intake per bird, body weight gain and feed conversion efficiency for the grower phase as influenced by housing systems, dietary protein and energy levels are given in Table 10.

Twentieth week body weight

Irrespective of the housing systems, dietary protein and energy levels employed in this trial, body weight at

Table 10 Effect of housing systems, dietary protein and energy levels on the performance of growers (9-20 weeks)

Character		Twentieth week body weight (g)	Feed intake per bird (g)	Weight gain (g)	Feed conversion efficiency
Housing systems	Cage	1274.21^{b}	5003.37^{a}	930.89	5.39^{a}
	Litter	1209.52^{a}	5672.34^{b}	940.88	6.07^{b}
Protein (% CP)	14	1242.48^{ab}	5241.07	940.12^{ab}	5.59
	16	1243.20^{ab}	5465.95	974.37^{b}	5.61
	18	1206.02^{a}	5358.43	922.92^{ab}	5.83
	20	1275.76^{b}	5285.98	906.13^{a}	5.88
Energy (Kcal ME/Kg)	2300	1230.92	5605.89	932.72	6.03^{b}
	2500	1243.21	5264.24	939.65	5.65^{ab}
	2700	1251.47	5143.44	935.28	5.50^{a}
CD					
Housing		38.588 ($P \angle 0.01$)	422.083 ($P \angle 0.01$)	--	0.447 ($P \angle 0.01$)
Protein		40.224 ($P \angle 0.05$)	--	36.900 ($P \angle 0.01$)	--
Housing x protein		--	--	--	--
Energy		--	--	--	0.403 ($P \angle 0.05$)
Housing x energy		66.837 ($P \angle 0.01$)	--	47.109 ($P \angle 0.05$)	--
Protein x energy		--	1033.88 ($P \angle 0.01$)	--	1.094 ($P \angle 0.05$)
Housing x protein x energy		--	1462.139 ($P \angle 0.01$)	127.826 ($P \angle 0.01$)	1.548 ($P \angle 0.01$)

Letters bearing the same superscript do not differ significantly between each character

20th week was optimal. However, birds reared in cages put on more weight at 20 weeks of age (1274.21 g) than floor reared birds (1209.52 g). Twentieth week weight was higher with groups fed a 20 per cent protein diet (1275.76 g) and lower with groups offered a diet having 18 per cent protein diet. Body weight of other two groups were intermediary. A numerical increase in body weight was observed as the level of energy in the ration increased.

Table 11 Analysis of variance of 20th week body weight of birds fed varying levels of protein and energy under both systems of housing

Source	DF	MSS	F
Block	1	1816.000	0.801
Housing	1	50232.000	22.150**
Protein	3	9746.667	4.298*
Housing x protein	3	3661.334	1.614 NS
Energy	2	1716.000	0.757 NS
Housing x energy	2	13331.998	5.879*
Protein x energy	6	5414 667	2.388 NS
Housing x protein x energy	6	4658.667	2.054 NS
Error	23		
Total	47		

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

The body weight of birds at 20th week of age was significantly ($P < 0.01$) superior in cages than in deep litter (Table 11). Twenty week body weight was also influenced significantly by levels of protein in the diet. Significantly higher body weight ($P < 0.05$) was observed with a protein level of 20 per cent (1275.76 g) and was statistically in par with 14 and 16 per cent protein levels. Likewise, there was no significant difference between 14, 16 and 18 per cent protein levels with respect to 20th week body weight. Energy levels did not have any significant influence upon 20th week body weight. It was significantly ($P < 0.01$) influenced by housing x energy interaction. However, the other interaction effects viz., housing x protein, protein x energy and housing x protein x energy were non-significant. Analysis of housing x energy interaction revealed that birds attained maximum body weight with 2700 Kcal ME/Kg in cage house and was statistically similar with 2500 Kcal ME/Kg in the same house.

Feed intake

Mean cumulative feed intake per bird during nine to 20 weeks of age is presented in Table 10 and the statistical analysis thereto in Table 12. Birds reared under deep litter system consumed more feed (5672.34 g)

Table 12 Analysis of variance of feed intake per bird fed varying levels of protein and energy during 9 to 20 weeks of the age under both systems of housing

Source	DF	MSS	F
Block	1	2270720.005	8.369
Housing	1	5370368.003	19.793**
Protein	3	115626.668	0.426 NS
Housing x protein	3	278741.335	1.027 NS
Energy	2	920576.000	3.393 NS
Housing x energy	2	236608.004	0.872 NS
Protein x energy	6	1252223.968	4.615**
Housing x protein x energy	6	1020778.656	3.762**
Error	23	271326.613	
Total	47		

** Significant at 1% level

NS Non-significant

than those reared in cages (5003.37 g) during nine to 20 weeks of age. The cumulative feed intake per bird during the grower phase for the groups fed with 14, 16, 18 and 20 per cent protein diets were 5241.07, 5465.75, 5358.43 and 5285.98 g respectively. The feed intake values for the energy groups, 2300, 2500 and 2700 Kcal ME/Kg were

5605.89, 5264.24 and 5143.44 g respectively. Feed intake was significantly ($P < 0.01$) lower for cage reared birds (5003.37 g). Litter reared birds consumed significantly ($P < 0.01$) more feed during grower stage. Feed consumption was not statistically influenced either by dietary protein or energy levels during grower phase. However, there was significant ($P < 0.01$) protein x energy interaction effect on feed intake. Significantly less feed was consumed with a protein : energy combination of 18 : 2700 and was statistically in par with 14 : 2500, 14 : 2700, 16 : 2300, 16 : 2500, 20 : 2300, 20 : 2500 and 20 : 2700 combinations. Housing x protein x energy interaction was also statistically significant ($P < 0.01$). In cage system high feed intake values were observed with protein-energy combinations of 14 : 2300, 14 : 2500, 16 : 2700, 18 : 2300 and 18 : 2500, while in deep litter except with a protein-energy combination of 14 : 2500 diet all other diets resulted in more feed intake.

Body weight gain

The mean body weight gain during nine to 20 weeks of age influenced by housing systems, dietary protein and energy is presented in Table 10 and statistical analysis in Table 13. Mean body weight gain observed during the grower phase for the birds reared in cages and floor were 930.89 and 940.88 g respectively. Corresponding values for the 14, 16, 18 and 20 per cent protein fed groups and

Table 13 Analysis of variance of weight gain of birds fed varying levels of protein and energy during 9 to 20 weeks of age under both systems of housing

Source	DF	MSS	F
Block	1	872.000	0.420
Housing	1	1200.000	0.579 NS
Protein	3	10210.667	4.924**
Housing x protein	3	6016.000	2.901 NS
Energy	2	198.000	0.095 NS
Housing x energy	2	10712.001	5.166 *
Protein x energy	6	1965.333	0.948 NS
Housing x protein x energy	6	10761.998	5.190**
Error	23	2073.739	
Total	47		

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

2300, 2500 and 2700 Kcal ME/Kg fed groups were 940.12, 974.37, 922.92 and 906.13 and 932.72, 939.65 and 935.28 g respectively.

It could be seen from the analysis of variance table that body weight gain between nine and 20 weeks of age was not statistically influenced by systems of housing and energy levels in the feed. But variation in dietary protein resulted a significant influence upon weight gain.

Significantly ($P < 0.01$) more weight gain was obtained with a protein level of 16 per cent (974.37 g) and this was not statistically different from 14 and 18 per cent protein levels. Body weight gain was significantly ($P < 0.01$) less with 20 per cent protein (906.13 g) and was statistically in par with 14 and 18 per cent protein levels. Housing x protein and protein x energy interactions were not statistically influenced whereas housing x energy interaction ($P < 0.05$) and housing x protein x energy interaction ($P < 0.01$) were statistically significant. In cage system more weight gain was obtained with all protein energy combinations except 18 : 2300, 18 : 2700, 20 : 2300 and 20 : 2700, while in deep litter more weight gain was noted with 14 : 2500, 16 : 2300, 16 : 2500, 16 : 2700, 18 : 2300 and 20 : 2700 combinations.

Feed conversion efficiency

Mean feed conversion efficiency during nine to 20 weeks of age is given in Table 10. Statistical analysis of the data on feed conversion efficiency presented in Table 14 revealed that the amount of feed consumed per unit gain in body weight between nine and 20 weeks of age was statistically influenced by housing systems and energy

Table 14 Analysis of variance of feed efficiency of birds fed varying levels of protein and energy under both systems of housing during 9 to 20 weeks of age

Source	DF	MSS	F
Block	1	2.113	6.951
Housing	1	5.489	18.052**
Protein	3	0.275	0.903 NS
Housing x protein	3	0.490	1.610 NS
Energy	2	1.208	3.974 *
Housing x energy	2	0.993	3.267
Protein x energy	6	1.634	5.373 **
Housing x protein x energy	6	1.946	6.399 *
Error	23	0.304	
Total	47		

* Significant at 5% level

** Significant at 1% level

NS Non-significant

levels but not by protein levels. Feed efficiency was significantly superior ($P < 0.01$) for birds reared in

With respect to energy levels, feed efficiency was significantly better ($P \angle 0.05$) for birds fed with diets having an energy level of 2700 Kcal ME (5.50) and was statistically comparable with 2500 Kcal ME (5.65). Significantly poor ($P \angle 0.05$) feed efficiency was noted with 2300 Kcal ME (6.03). There was no significant difference between 2300 and 2500 Kcal ME. Protein x energy interaction and housing x protein x energy interactions on feed efficiency was statistically significant ($P \angle 0.01$). Among protein-energy combinations highest feed conversion efficiency was observed with 16 : 2500 diet, while the lowest with 18 : 2300 diet. In cage system superior feed efficiency value were obtained with protein energy combinations of 14 : 2500, 14 : 2700, 16 : 2300, 16 : 2500, 18 : 2700, 20 : 2500 and 20 : 2700, while in deep litter protein-energy combinations of 14 : 2500 and 16 : 2500 resulted in superior feed efficiency.

<u>Cost of feeding</u>

Influence of housing systems, dietary protein and energy levels on cost of feeding is presented in Table 15 and statistical analysis of the data in Table 16.

During grower stage lesser feeding cost was observed with birds reared in cages (Rs.19.56 per bird)

Table 15 Influence of housing systems, dietary protein and energy levels on cost of feeding per bird during grower phase (9-20 weeks)

Character		Cost of feeding during 9 to 20 weeks of age (Rs.)
Housing systems	Cage	19.56[a]
	Litter	22.21[b]
Protein (% CP)	14	19.76
	16	21.06
	18	21.12
	20	21.60
Energy (Kcal ME/Kg)	2300	21.07
	2500	20.72
	2700	20.86

CD	
Housing	1.68 ($P < 0.01$)
Protein	--
Housing x protein	--
Energy	--
Housing x energy	--
Protein x energy	4.12 ($P < 0.01$)
Housing x protein x energy	4.29 ($P < 0.01$)

than those maintained on floor (Rs.22.21 per bird). With respect to protein levels, the feeding costs were 19.76, 21.06, 21.12 and 21.60 rupees per bird for the groups fed with 14, 16, 18 and 20 per cent protein diets. The corresponding figures for the energy groups 2300, 2500 and 2700 Kcal ME/Kg were 21.07, 20.72 and 20.86 rupees per bird, respectively. It could be seen

Table 16 Analysis of variance of cost of feeding of growers (9-20 weeks) fed varying levels of protein and energy under both systems of housing

Source	DF	MSS	F
Block	1	32.535	7.557
Housing	1	84.641	19.660**
Protein	3	7.471	1.735
Housing x protein	3	3.367	0.782
Energy	2	0.504	0.117
Housing x energy	2	4.252	0.988
Protein x energy	6	20.659	4.799**
Housing x protein	6	15.398	3.577 *
Error	23	4.305	
Total	71		

* Significant at 5% level

** Significant at 1% level

from the analysis table that during grower phase housing systems significantly influenced feeding cost. It was significantly ($P \angle 0.01$) lower with cage reared birds. Protein and energy levels in the diet did not significantly influence feeding cost during grower phase. Interaction effects on feeding costs between protein and energy ($P \angle 0.01$) and housing - protein - energy were significant. Feeding cost was higher with protein-energy combinations of 16 : 2500, 18 : 2500 and 20 : 2500 and lesser with 14 : 2500, 16 : 2500 and 18 : 2500.

In cage system maximum cost of feeding was obtained with protein-energy combination of 16 : 2700 and in deep litter system with 20 : 2500 combination. Cost of feeding was less with protein-energy combinations of 14 : 2700, 16 : 2300, 16 : 2500, 18 : 2700 and 20 : 2700 in cage system and with 14 : 2700 in deep litter system.

Layer Phase (21-72 weeks)

Influence of dietary protein and energy on layers housed in different systems on age at first egg and body weight gain during the layer phase is depicted in Table 17 and its statistical analysis in Table 18.

Table 17 Influence of housing systems, dietary protein and energy levels on age at first egg and body weight gain during the period 21-72 weeks

Character		Age at 1st egg (days)	Body weight gain (g)
Housing systems	Cage	130.50[a]	146.87[a]
	Litter	135.25[b]	246.69[b]
Protein (% CP)	14	134.17	183.88
	16	133.42	211.68
	18	133.50	207.02
	20	130.42	184.53
Energy (Kcal ME/Kg)	2300	134.63	183.41
	2500	133.06	215.77
	2700	130.94	191.16
CD			
Housing		4.189 ($P < 0.01$)	57.123 ($P < 0.01$)
Protein		--	--
Housing x protein		--	--
Energy		--	--
Housing x energy		--	--
Protein x energy		--	--
Housing x protein x energy		--	--

Table 18 Analysis of variance of age at 1st egg of birds fed varying levels of protein and energy under both systems of housing

Source	DF	MSS	F
Block	1	33.313	1.246
Housing	1	270.756	10.131 **
Protein	3	33.583	1.257
Housing x protein	3	9.021	0.338
Energy	2	54.812	2.051
Housing x energy	2	11.813	0.442
Protein x energy	6	9.479	0.355
Housing x protein x energy	6	12.427	0.465
Error	23	26.726	
Total	47		

** Significant at 1% level

Age at first egg

The birds housed in cages laid their first egg earlier (130.5 days) that the birds housed in deep litter system (135.25 days). The mean age in days on which first egg laid by the birds fed with protein levels of 14, 16, 18 and 20 per cent were 134.17, 133.42, 133.50 and 130.42 days respectively. Age at first egg for the birds fed with energy levels of 2300, 2500 and 2700 Kcal ME/Kg were 134.63, 133.06 and 130.94 days, respectively.

The analysed data revealed that the parameter was influenced only by housing systems. Birds housed in cages laid significantly ($P < 0.01$) earlier than their counter part on the litter. Dietary protein, energy or any of the interactions did not significantly influence this character.

Body weight gain (21-72 weeks of age)

Mean body weight gain obtained during 21 to 72 weeks of age, presented in Table 17 showed that housing of birds under deep litter system resulted in higher gain in weight (246.69 g) than the birds housed in cages (146.87 g). The gain in weight observed for the groups fed with 14, 16, 18 and 20 per cent protein were 183.88, 211.68, 207.02 and 184.53 g respectively. With regard to energy levels studied, birds fed with a diet having 2500 Kcal ME/Kg gained more weight (215.77 g) and those fed with 2300 Kcal ME/Kg gained less weight (183.41 g). The weight gain for the groups offered with 2700 Kcal ME/Kg was medium.

Statistical analysis of the weight gain data (Table 19) revealed that it was influenced significantly

(P ∠ 0.01) by housing systems only. Birds housed in deep litter showed significantly higher body weight gain (246.69 g) than caged birds (146.87 g). The dietary protein or energy levels as well as their interactions did not have any influence on weight gain.

Table 19 Analysis of variance of weight gain of layers fed varying levels of protein and energy under both systems of housing during 21 to 72 weeks of age

Source	DF	MSS	F
Block	1	3123.375	0.628
Housing	1	119577.503	24.062**
Protein	3	2574.625	0.518 NS
Housing x protein	3	4105.291	0.826 NS
Energy	2	4566.937	0.919 NS
Housing x energy	2	1529.875	0.308 NS
Protein x energy	6	7786.312	1.567 NS
Housing x protein x energy	6	1357.937	0.273 NS
Error	23	4969.625	
Total	47		

** Significant at 1% level

NS Non-significant

Influence of housing systems, dietary protein and energy levels on production traits such as per cent hen-day egg production, daily feed intake per bird, feed conversion efficiency and egg weight recorded at 28 days periods, from 21 to 72 weeks of age (layer phase) is presented in Appendix IV to XVI.

Mean values of the production traits as influenced by housing systems, dietary protein and energy levels for the whole laying period from 21 to 72 weeks of age is given in Table 20.

Hen-day egg production

Egg production of the experimental birds during the whole laying phase (21-72 weeks of age) calculated as per cent hen-day egg production is presented in Table 20. The highest egg production of 60.34 per cent was observed among the birds reared in cages and the lowest of 47.98 per cent among the birds maintained on floor. If protein levels alone is considered, the lowest egg production of 52.56 per cent was observed among birds fed a diet containing 14 per cent protein and the highest of 57.36 per cent for the diet containing 20 per cent protein. Likewise, when energy levels alone is considered, the lowest rate of 53.12 per cent production was observed in those birds fed 2300 Kcal ME/Kg, while the highest value of 55.16 per cent was observed in the groups fed 2500 Kcal ME/Kg diet.

Table 20 Effect of housing systems, dietary protein and energy levels on age at first egg and production traits of layers during 21 to 72 weeks of age

Characters		Hen day egg production (%)	Daily feed intake per bird (g)	Feed per dozen eggs (Kg)	Egg weight (g)
Housing systems	Cage	60.34^{b}	110.91	2.21^{a}	48.58^{a}
	Floor	47.98^{a}	108.64	2.75^{b}	49.38^{b}
Protein (% CP)	14	52.56	113.32	2.64^{b}	48.07^{a}
	16	53.41	109.41	2.50^{b}	49.28^{b}
	18	53.31	114.71	2.63^{b}	49.43^{b}
	20	57.36	101.65	2.15^{a}	49.12^{b}
Energy (Kcal ME/Kg)	2300	53.12	114.26	2.61^{b}	48.60
	2500	55.16	107.95	2.41^{a}	49.20
	2700	54.20	107.10	2.41^{a}	49.13
CD					
Housing		4.02 (P∠ 0.01)	--	0.19 (P∠ 0.01)	0.67 (P∠ 0.05)
Protein		--	--	0.27 (P∠ 0.01)	0.95 (P∠ 0.05)
Housing x protein		--	--	--	--
Energy		--	--	0.17 (P∠ 0.05)	--
Housing x energy		--	--	--	--
Protein x energy		--	--	--	--
Housing x protein x energy		--	--	--	--

Letters bearing the same superscript do not differ significantly between each character

Analysis of the hen-day egg production given in Table 21 revealed that except with housing systems dietary variables such as protein or energy levels or any of the interactions did not significantly influence this trait. Of the housing systems studied birds reared in cages produced significantly ($P < 0.01$) more number of eggs

Table 21 Analysis of variance of hen-day egg production of birds fed varying levels of protein and energy under both systems of housing during 21-72 weeks of age

Source	DF	MSS	F
Block	1	23.484	0.954
Housing	1	1831.875	74.444 **
Protein	3	56.214	2.284 NS
Housing x protein	3	41.292	1.678 NS
Energy	2	16.734	0.680 NS
Housing x energy	2	58.898	2.394 NS
Protein x energy	6	32.609	1.325 NS
Housing x protein x energy	6	30.302	1.231 NS
Error	23	24.607	
Total	47		

** Significant at 1% level

NS Non-significant

(60.34%) than those in deep litter system. Neither protein nor energy levels in the diet significantly influenced hen-day egg production thereby indicating that a protein-energy combination of 14 : 2300 is sufficient for optimum egg production.

Feed intake

Data on mean daily feed intake of birds fed varying levels of protein and energy and maintained in different housing systems are shown in Table 20. The range of mean daily feed intake varied from 101.65 g to 114.71 g. Among the housing systems, highest daily feed intake of 110.90 g was recorded with birds housed in cages and a lowest value of 108.64 g with floor reared birds. Daily feed intake was maximum with groups fed on 18 per cent protein diet (114.71 g) and minimum with 20 per cent protein fed group (101.65 g). Among the energy levels tested, birds fed with diets having 2300 Kcal ME/Kg consumed more feed (114.26 g) and those fed with 2700 Kcal ME/Kg recorded the least (107.10 g).

When the data were subjected to statistical analysis the magnitude of differences in daily feed intake per bird among the different treatment groups was not found to be different (Table 22). Similarly, any of the interactions studied did not significantly influence daily feed intake.

Table 22 Analysis of variance of daily feed intake per bird fed varying levels of protein and energy under both systems of housing during 21-72 weeks of age

Source	DF	MSS	F
Block	1	-0.063	-0.000
Housing	1	61.875	0.368 NS
Protein	3	412.229	2.449 NS
Housing x protein	3	76.500	0.455 NS
Energy	2	244.656	1.454 NS
Housing x energy	2	22.094	0.131 NS
Protein x energy	6	170.240	1.012 NS
Housing x protein x energy	6	262.146	1.558 NS
Error	23	168.299	
Total	47		

NS Non-significant

Feed per dozen eggs

Feed conversion efficiency as affected by variation in housing systems as well as dietary protein and energy levels is shown in Table 23. A superior feed efficiency of 2.21 was noted with birds reared in cage system. Feed required to produce one dozen of eggs for the birds reared

Table 23 Analysis of variance of feed per dozen eggs of layers fed varying levels of protein and energy under both systems of housing during 21 to 72 weeks of age

Source	DF	MSS	F
Block	1	0.023	0.411
Housing	1	3.435	62.533**
Protein	3	0.620	11.296**
Housing x protein	3	0.065	1.192 NS
Energy	2	0.214	3.901 *
Housing x energy	2	0.042	0.762 NS
Protein x energy	6	0.097	1.763 NS
Housing x protein x energy	6	0.108	1.969 NS
Error	23	0.055	
Total	47		

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

under deep litter system was 2.75. Unlike feed intake, feed per dozen eggs was significantly influenced by housing systems, dietary protein and energy levels. Cage reared birds showed significantly ($P < 0.01$) superior feed efficiency than birds maintained on floor.

Regarding protein levels studied, the lowest ratio of 2.15 was obtained with 20 per cent protein diet while the highest ratio of 2.64 was obtained with 14 per cent protein diet. Statistical analysis of the data presented in Table 23 revealed that birds fed with 20 per cent protein had significantly ($P < 0.01$) better feed efficiency than other levels. There was no significant difference in feed efficiency between 14, 16 and 18 per cent protein levels. Among the three energy levels tested, the groups offered with 2500 and 2700 Kcal ME/Kg had significantly ($P < 0.05$) better feed efficiency than other. Feed efficiency was significantly ($P < 0.05$) inferior with 2300 Kcal ME diet (2.61). Interaction effects of housing - protein, housing - energy, protein - energy and housing - protein - energy were found to be non-significant.

Egg weight

Mean egg weight data pooled for the whole laying period as affected by dietary protein, energy and housing systems are presented in Table 20. Birds reared under deep litter system laid heavier egg (49.38 g) than those reared in cage system. Eggs laid by birds fed with 14 per cent protein diet was lighter (48.07 g) compared to other levels. Mean egg weight values for the birds fed with diets containing protein levels of 14, 16, 18 and

20 per cent were 48.07, 49.29, 49.43 and 49.12 g respectively. Corresponding egg weight values for the three energy groups viz., 2300, 2500 and 2700 Kcal/Kg diets were 48.60, 49.20 and 49.13 g, respectively. Statistical analysis of the egg weight values (Table 24) showed that it was influenced significantly by housing

Table 24 Analysis of variance of egg weight of layers fed varying protein and energy levels under both systems of housing during 21-72 weeks of age

Source	DF	MSS	F
Block	1	0.547	0.435
Housing	1	7.703	6.121 *
Protein	3	4.536	3.605 *
Housing x protein	3	3.307	2.628 NS
Energy	2	1.684	1.338 NS
Housing x energy	2	1.406	1.117 NS
Protein x energy	6	0.759	0.603 NS
Housing x protein x energy	6	2.892	2.298 NS
Total	47		

* Significant at 5% level

NS Non-significant

systems and dietary protein levels but not by dietary energy levels. Among the housing systems, litter reared birds produced significantly ($P \angle 0.01$) heavier eggs than caged birds. Regarding protein levels, except with 14 per cent diet, all other protein levels produced significantly ($P \angle 0.05$) layger sized eggs. Mean egg weight values were not significantly influenced by any of the interaction studied.

Cost of feeding

Mean value of the feeding cost calculated for the whole laying phase (20-72 weeks) is shown in Table 25 and its statistical analysis in Table 26. The range of mean values for cost of feeding varied from Rs. 149.42 to Rs. 163.38 during 21 to 72 weeks of age.

Feeding cost of birds reared under floor during the layer phase was comparatively less (Rs.153.21) than those in cages (Rs.156.39). Among different protein levels tested, cost of feeding was more (Rs.163.38) with birds fed diets containing 18 per cent protein and was less with 20 per cent protein groups (Rs.149.42). It was medium with 14 and 16 per cent protein fed birds (Rs.154.06 and 152.32 respectively). If the energy level alone is considered, cost of feeding was more with group fed diet containing 2700 Kcal ME (Rs.156.95) and

Table 25 Influence of housing systems, dietry protein and energy levels on cost of feeding during layer phase (20-72 weeks of age)

Character		Cost of feeding (Rs.)
Housing systems	Cage	156.39
	Litter	153.21
Protein (% CP)	14	154.06
	16	152.32
	18	163.38
	20	149.42
Energy (Kcal ME/Kg)	2300	155.02
	2500	152.42
	2700	156.95

CD	
Housing	--
Protein	--
Housing x protein	--
Energy	--
Housing x energy	--
Protein x energy	--
Housing x protein x energy	--

Table 26 Analysis of variance of cost of feeding of birds fed varying levels of protein and energy under both systems of housing during 21-72 weeks period

Source	DF	MSS	F
Block	1	1.250	0.004
Housing	1	121.625	0.360
Protein	3	437.000	1.292
Housing x protein	3	147.625	0.436
Energy	2	82.688	0.244
Housing x energy	2	39.188	0.166
Protein x energy	6	346.271	1.024
Housing x protein x energy	6	513.792	1.519
Error	23	338.315	
Total	47		

less with 2500 Kcal ME/Kg group (Rs.152.42), and it was medium with 2300 Kcal ME group (Rs.155.02). The statistical analysis of the data on cost of feeding revealed that it was not significantly influenced by either housing systems, dietary protein or energy levels or its interactions investigated.

Egg quality parameters

Mean values of the egg quality parameters for the whole period (21-72 weeks) studied are shown in Table 27.

Shell thickness

The data on shell thickness of the eggs produced by the birds housed in different systems and fed different dietary regimes are presented in Table 27 and the analysis of variance in Table 28. Mean shell thickness was similar (0.34 mm) for the birds housed in both housing systems. 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 dietary protein levels of 18 and 20 per cent had comparatively more shell thickness value (0.35 mm), than those fed 14 and 16 per cent protein diets (0.34 mm). When the energy levels were observed the eggs obtained from all the three energy groups tested had similar shell thickness values (0.34 mm). Statistical analysis revealed that the differences in shell thickness observed among various treatments studied in this trial were not significant. Except with protein x energy interaction, where it was significant at 5 per cent level, all other interactions on shell thickness were

Table 27 Influence of housing systems, dietary protein and energy levels on egg quality parameters during 21-72 weeks of age

Character		Albumen index	Yolk index	Haugh unit	Shell thickness (mm)
Housing systems	Cage	0.09	0.42^{a}	81.04	0.34
	Litter	0.09	0.44^{b}	81.54	0.34
Protein (% CP)	14	0.09	0.43	80.67^{a}	0.34
	16	0.09	0.44	83.00^{b}	0.34
	18	0.09	0.43	82.17^{b}	0.35
	20	0.09	0.43	79.33^{a}	0.35
Energy (Kcal ME/Kg)	2300	0.09	0.43	82.00	0.34
	2500	0.09	0.43	80.69	0.34
	2700	0.09	0.43	81.19	0.34
CD	Housing	-	0.011 ($P < 0.05$)	-	-
	Protein	-	-	1.906 ($P < 0.05$)	-
	Housing x protein	-	-	-	-
	Energy	-	-	-	-
	Housing x energy	-	-	-	-
	Protein x energy	-	-	-	0.015 ($P < 0.05$)
	Housing x protein x energy	-	-	-	-

Letters bearing the same superscript do not differ significantly between each character

Table 28 Analysis of variance of shell thickness of eggs from birds fed varying levels of protein and energy under both systems of housing during 21-72 weeks of age

Source	DF	MSS	F
Block	1	0.000	0.070
Housing	1	0.000	2.758
Protein	3	0.000	1.971
Housing x protein	3	1.000	1.386
Energy	2	0.000	0.532
Housing x energy	2	0.000	0.697
Protein x energy	6	0.000	3.051 *
Housing x protein x energy	6	0.000	1.305
Error	23		
Total	47		

* Significant at 5% level

statistically non-significant. Eggs with highest shell thickness was obtained with a diet having protein-energy combination of 20 : 2500 and lowest with protein-energy combinations of 14 : 2500 and 14 : 2700.

Albumen index

The albumen index of the eggs received from layers housed in cage and floor and fed varying levels of protein and energy is presented in Table 27 and the statistical analysis in Table 29. Albumen index score of all treatments tested in this study was same (0.09).

Table 29 Analysis of variance of albumen index of eggs from birds fed varying levels of protein and energy under both systems of housing during 21 to 72 weeks of age

Source	DF	MSS	F
Block	1	0.000	0.002
Housing	1	0.000	3.157
Protein	3	0.000	1.598
Housing x protein	3	0.000	2.052
Energy	2	0.000	0.350
Housing x energy	2	0.000	3.264
Protein x energy	6	0.000	1.321
Housing x protein x energy	6	0.000	0.862
Error	23	0.000	
Total	47		

Yolk index

Mean yolk index values of eggs collected from layers housed in different systems and fed varying levels of energy and protein are presented in Table 27 and its statistical analysis in Table 30. The yolk index values obtained with birds housed in litter was higher (0.44) than those obtained with cage reared

Table 30 Analysis of variance yolk index of eggs from birds fed varying levels of protein and energy under both systems of housing during 21 to 72 weeks of age

Source	DF	MSS	F
Block	1	0.000	0.680
Housing	1	0.002	5.793 *
Protein	3	0.000	0.814
Housing x protein	3	0.001	2.534
Energy	2	0.000	0.373
Housing x energy	2	0.000	0.416
Protein x energy	6	0.000	1.444
Housing x protein x energy	6	0.000	1.204
Error	23	0.000	
Total	47		

* Significant at 5% level

birds (0.42). The yolk index values did not show any specific trend with different levels of protein studied. The values for the dietary protein levels viz., 14, 16, 18 and 20 per cent were 0.43, 0.44, 0.43 and 0.43, respectively. Among the various energy levels tested yolk index value was same (0.43) for the three groups. Statistical analysis revealed that the yolk index was influenced only by housing systems and not by protein or energy levels in the diet or any of the interactions. It was significantly higher ($P < 0.05$) with eggs obtained from birds reared on floor.

Haugh Unit

The data on the Haugh unit score of the eggs received from layers housed in cage and deep litter and fed varying levels of protein and energy are set out in Table 27 and the related statistical analysis in Table 31. The Haugh unit score of eggs obtained from layers housed in cage and floor were 81.04 and 81.54 respectively. When the influence of protein on Haugh unit score was analysed, it was observed that eggs obtained from birds fed a diet containing 16 per cent protein had a score of 83.00 which was the highest and that obtained from hens fed 20 per cent protein was 79.33 which was the lowest. The Haugh unit score for

Table 31 Analysis of variance of Haugh unit of eggs from birds fed varying levels of protein and energy under both systems of housing during 21 to 72 weeks of age

Source	DF	MSS	F
Block	1	0.750	0.074
Housing	1	3.000	0.295
Protein	3	31.635	3.106 *
Housing x protein	3	22.552	2.214
Energy	2	7.016	0.689
Housing x energy	2	27.562	2.706
Protein x energy	6	4.245	0.415
Housing x protein x energy	6	9.120	0.895
Error	23	10.185	0.895
Total	47		

* Significant at 5% level

eggs obtained from hens fed an energy level of 2300 Kcal ME/Kg had the highest score (82.00) while that for 2500 Kcal ME/Kg was 80.69 which was lowest.

Statistical analysis of the data on Haugh unit score revealed that it was influenced significantly only by the levels of protein in the diet while housing systems or energy levels of diet did not have any influence. Among the protein levels, birds fed with a diet of 16 per cent protein had significantly higher ($P < 0.05$) score and was statistically comparable with values obtained with 18 per cent protein diet. Statistically, lower Haugh unit score was observed with a protein level of 20 per cent. The difference in values obtained between 14 and 20 per cent protein was non-significant. Interactions of housing x protein, housing x energy, protein x energy and housing x protein x energy on Haugh Unit score were also non-significant.

Abdominal fat

Mean values of the abdominal fat as influenced by housing systems, dietary protein and energy levels are given in Table 32. Range of mean values for abdominal fat varied from 14.75 to 35.75 g. Litter reared birds had less abdominal fat (18.38 g) than caged birds (30.04 g). When the protein level alone is considered, less abdominal fat (14.75 g) was observed with a diet containing 16 per cent protein, while it was highest with 20 per cent protein diet (35.75 g). Among the energy levels, lowest value of 20.44 g was observed with a diet containing 2300 Kcal ME/Kg and the highest value of 28.00 g

Table 32 Effect of housing systems, dietary protein and energy levels on abdominal fat (g) and liver lipid (%) of layers

Character		Abdominal fat (g)	Liver lipid (%)
Housing systems	Cage	30.04	39.98[b]
	Litter	18.83	37.67[a]
Protein	14	25.83	37.55[b]
	16	14.75	41.89[c]
	18	21.42	32.81[a]
	20	35.75	43.05[d]
Energy (Kcal ME/Kg)	2300	20.44	34.26[a]
	2500	24.87	37.88[b]
	2700	28.00	44.35[c]

CD

Housing	--	0.647 ($P \angle 0.01$)
Protein	--	0.916 ($P \angle 0.01$)
Housing x protein	--	1.295 ($P \angle 0.01$)
Energy	--	0.793 ($P \angle 0.01$)
Housing x energy	--	1.121 ($P \angle 0.01$)
Protein x energy	--	1.586 ($P \angle 0.01$)
Housing x protein x energy	--	2.243 ($P \angle 0.01$)

was noted with diet containing 2700 Kcal ME/Kg. Statistical analysis of the data on abdominal fat (Table 33) revealed that it was not significantly influenced by housing systems, dietary protein and energy levels or its interactions studied.

Table 33 Analysis of variance of abdominal fat (g) of layers fed varying levels of protein and energy under both systems of housing

Source	DF	MSS	F
Block	1	50.021	0.118
Housing	1	1507.522	3.565 NS
Protein	3	931.576	2.203 NS
Housing x protein	3	171.688	0.406 NS
Energy	2	231.063	0.546 NS
Housing x energy	2	1035.395	2.546 NS
Protein x energy	6	162.451	0.384 NS
Housing x protein x energy	6	412.562	0.976 NS
Error	23	422.847	
Total	47		

NS Non-significant

Liver lipid

The liver lipid values of random birds housed in cages and deep litter and fed different levels of protein and energy are shown in Table 32 and its analysis of variance in Table 34. Total liver lipid value was higher among the birds housed in cages (39.98%) than those reared on floor (37.67%).

Table 34 Analysis of variance of liver lipid (%) of layers fed varying levels of protein and energy under both systems of housing

Source	DF	MSS	F
Block	1	0.211	0.330
Housing	1	63.914	100.140**
Protein	3	260.130	407.570**
Housing x protein	3	90.391	141.623**
Energy	2	418.102	655.078**
Housing x energy	2	39.402	61.735**
Protein x energy	6	43.936	68.839**
Housing x protein x energy	6	17.048	26.711**
Error	23	0.638	
Total	47		

** Significant at 1% level

Analysis of variance of liver lipid revealed that it was influenced by the systems of housing. Caged birds had significantly ($P < 0.01$) higher liver lipid per cent than litter reared birds.

The mean liver lipid per cent pooled based on protein level alone were 37.55, 41.89, 32.81 and 43.05 per cent for diets containing 14, 16, 18 and 20 per cent protein respectively. The magnitude of difference in the liver lipid values among various protein levels was statistically significant. Significantly ($P < 0.01$) higher values obtained with diet having 20 per cent protein level (43.05%) and lowest with 18 per cent protein level (32.81%) and all the four levels are significantly different from each other. There was no specific trend in liver fat per cent with levels of protein in the diet.

On perusal of the liver lipid values it was observed that as the energy levels increased the liver lipid content also showed an increasing trend. The highest liver lipid value of 44.35 per cent was observed with diet containing 2700 Kcal ME/Kg and the lowest value of 34.26 per cent was observed with 2300 Kcal ME/Kg diet. The differences in liver lipid per cent when subjected to statistical analysis it was revealed that significant differences existed between each level of energy in a direct order.

The statistical analysis further revealed the existence of a significant difference in interaction between housing and protein, housing and energy, protein and energy and also housing - protein and energy. Interaction effects between protein and energy level indicated that the protein energy combinations of 14 : 2700 and 20 : 2700 resulted in highest liver lipid per cent while the combination of 18 : 2300 resulted in lowest liver lipid per cent. Housing x energy interaction indicated that litter reared birds fed a diet containing energy level of 2700 Kcal MF/Kg resulted highest liver lipid per cent. In cage system, highest liver lipid value was obtained with protein-energy combination of 20 : 2700 (44.19%) and lowest with 18 : 2300 (21.01%). In deep litter system, highest value obtained with 20 : 2700 (50.30%) combination and lowest with 14 : 2300 combination (25.41%).

Mortality

Mortality observed among different treatment groups in both housing systems during three phases viz., starter, grower and layer are shown in Table 35, 36 and 37 respectively. During starter phase overall per cent mortality was 15.55 in cage house and 28.05 in deep litter house. The causes accounted for mortality during the starter phase were coccidiosis, omphalitis, air sacculitis, ententis and hepatitis, of which coccidiosis was the major cause of death among chicks in deep litter system, while amphalitis and airsacculitis constituted the major causes of death on wire floor. During grower phase, the corresponding figures were 3.2 and 7.3 per cent respectively. During layer phase the per cent mortality was 23.05 in cage house and 16.15 in deep litter house. Both figures were slightly above the standard limit.

At 40 weeks of age birds reared in cages were infested with Pasteurellosis. Though, mortality due to infection was accounted only six to eight per cent, the morbidity was very high (75-80%). The postmortem data revealed that the causes of mortality was not either due to dietary regimen or due to housing systems.

Table 35 Mortality particulars of birds subjected to various dietary combinations during 0-8 weeks of age

Protein : energy	Cage	Litter
14 : 2300	4	10
14 : 2500	9	16
14 : 2700	6	11
16 : 2300	2	6
16 : 2500	5	10
16 : 2700	1	2
18 : 2300	9	14
18 : 2500	7	16
18 : 2700	5	3
20 : 2300	5	9
20 : 2500	1	3
20 : 2700	2	1
Total number	56	101
Mortality %	15.55	28.05

Table 36 Mortality particulars of birds subjected to various diatery combinations during grower phase (9-20 weeks of age)

Protein : energy	Cage	Litter
14 : 2300	2	1
14 : 2500	-	3
14 : 2700	1	1
16 : 2300	-	-
16 : 2500	-	3
16 : 2700	1	2
18 : 2300	2	1
18 : 2500	-	-
18 : 2700	1	-
20 : 2300	1	1
20 : 2500	1	-
20 : 2700	1	2
Total number	10	14
Mortality %	3.2	7.3

Table 37 Mortality particulars of birds subjected various dietary combinations during layer phase (21-72 weeks of age)

Protein : energy	Litter	Cage
14 : 2300	3	7
14 : 2500	2	4
14 : 2700	2	5
16 : 2300	1	4
16 : 2500	2	1
16 : 2700	4	10
18 : 2300	4	6
18 : 2500	2	3
18 : 2700	6	2
20 : 2300	2	7
20 : 2500	2	5
20 : 2700	1	5
Total number	31	59
Mortality %	16.15	23.05

DISCUSSION

Starter Phase (0-8 weeks)

Eighth week body weight and body weight gain

The body weight at eighth week of age for the experimental birds averaged 340.10 and 265.86 g for cage and floor reared chicks, respectively, which is well within normal limits for egg type strain cross pullet chicks. Similarly, eighth week body weight ranged from 274.69 to 334.61 g for the four dietary protein levels and from 295.46 to 311.71 g for the three energy groups which can be considered as standard weights. Statistical analysis of the data revealed that housing systems and protein levels in the diet influenced this trait but energy levels had no effect. Weight gain of chicks is a direct indication of its growth rate. In as much as uniform sized chicks were used for the experiment, the trend in weight gain was very similar with that of eighth week body weight. It was significantly better among cage reared birds. With respect to dietary protein levels, significantly superior gain was noted with increased levels of dietary protein. Minimum gain in weight of 242.61 g was observed with 14 per cent protein as against 302.26 g for 20 per cent protein which was maximum. Screening the weight gain data as influenced by energy levels, presented in Table 3, indicated that it showed an increasing trend with increased levels of energy. However the differences observed among the values were statistically non-significant.

Jin and Craig (1988) reported superior body weight for chicks reared in cages than on the floor. Significantly lesser body weight at eighth week and consequent reduction in weight gain observed with floor rearing of chicks during the starter phase could also be due to infection of the stock with coccidiosis. Reddy et al. (1977) conducted experiments to estimate the protein and energy requirements of starter chicks and opined that the chicks receiving 20 per cent protein diets with energy levels of either 2250, 2340 or 2430 Kcal ME/Kg performed significantly better at the end of eight weeks than 18 per cent protein diets having similar energy levels. In another trial, they could observe significantly better weight gain at eight weeks of age ($P \angle 0.05$) with 20 per cent protein diet having energy levels of 2340 and 2250 Kcal ME/Kg. However they could observe no significant difference in weight gain among the different groups of chicks fed either 2320 or 2430 Kcal ME/Kg. In the present study, the dietary protein levels significantly affected body weight gain and with the increase in level of dietary protein, an improvement was observed in growth rate. Nagabhushanam *et al.* (1979) recommended higher protein levels (24%) during summer and lower protein levels (22%) during winter. Haque and Agarwala (1975) obtained the best weight gain at 23 per cent protein level with a calorie-protein ratio of 128 : 1. The results in the present study are in close agreement with these observations. Absence of any significant influence on body weight by the various energy levels tested in this trial is in agreement with the findings of Nagabhushanam *et al.* (1979). Weight gain was statistically similar for the groups fed 18 and 20 per cent protein levels. This might be due to availability of more or less constant essential amino acids in these rations, since fishmeal, the sole source of animal protein, was kept constant in all rations. Under the conditions of this experiment protein-energy combinations of 18 : 2700, 20 : 2500 and 20 : 2700 showed better performance in terms of weight gain.

Feed intake

Feed intake per bird during zero-eight weeks of age was found to be significantly influenced by protein levels in the diet alone. Housing systems and dietary energy levels did not have any effect upon feed intake. Among protein levels, significantly higher feed intake was observed with 18 per cent protein level and significantly lower intake with 20 per cent protein level.

Satyanarayana Reddy *et al*. (1989) evaluating the effect of varying protein levels during starter and grower stages in subsequent production performance of layers using five protein diets viz., 22, 19.8, 17.6, 15.4 and 13.2 per cent and reported that feed intake values on protein content of 22.0, 17.6, 15.4 and 13.2 per cent during starter phase were not significantly different from each other. Significantly lower feed consumption observed in the present study with 20 per cent protein fed groups may be due to better utilisation of nutrients. The energy levels in the diet did not contribute to any variation as feed intake, which may possibly because the variation in the energy levels employed were too narrow to exhibit any difference.

Feed conversion efficiency

Housing systems and protein and energy concentrations of the diet influenced feed conversion efficiency during the starter phase. The inferior feed conversion efficiency reported with floor system of housing could be attributed to significantly inferior growth rate as expressed by low weight gain.

Feed conversion efficiency showed significant improvement with increased levels of dietary protein. Significantly superior feed conversion efficiency was recorded with 20 per cent protein and significantly poor efficiency was observed with 14 per cent protein. Groups fed diets containing 16 and 18 per cent protein were intermediate and was significantly different from the other two levels. The superior feed conversion efficiency observed with increasing levels of protein in this trial is in agreement with the findings of Reddy _et al_. (1977) and Satyanarayana Reddy _et al_. (1989). The better feed conversion efficiency on higher protein levels was more due to improved growth rate at these levels than due to actual feed consumption. The diets containing higher energy (2700 Kcal ME/Kg) level supported better feed efficiency over lower energy (2300 and 2500 Kcal ME/Kg) levels of the diet. These results are in agreement with the reports of Rajashekara Reddy _et al_. (1977) and Nagabhushanam _et al_. (1989). The better feed conversion efficiency with higher energy level might be due to better utilization of nutrients in those feeds and increased body weight gain. Presence of significant protein x energy interaction on feed conversion efficiency was suggestive of protein energy combinations of 18 : 2700, 20 : 2500 and 20 : 2700 during starter phase.

Cost of feeding

Data on feeding cost during starter phase revealed that it was influenced significantly by protein levels in the diet, whereas housing systems, and energy content of the diet did not have significant influence. The feeding cost was significantly highest with birds fed diets containing 18 per cent protein and significantly lowest with diets containing 14 per cent protein. However, the differences observed between the feeding cost values of diets containing 14, 16 and 20 per cent protein were statistically comparable. Similarly the difference between 18 and 20 per cent protein levels was also not statistically different. The profits over feeding cost appears to favour lower levels of protein in the starter diets but this may be viewed with caution as weight gain was less. Since energy levels were not statistically different on feeding cost, other factors should be taken into account while deciding on the optimum energy level for the starter phase. Therefore, considering various aspects, viz., growth rate, feed intake, feed conversion efficiency and cost of feeding, it appears that a dietary protein level of 20 per cent with an energy level or 2300 Kcal ME/kg diet appears to be optimum during starter phase (0-8 weeks) for commercial egg type pullets reared in cages as well as on litter floor system.

Grower Phase (9-20 weeks)

Twentieth week body weight and body weight gain

The mean body weight at twentieth week for cage reared birds was 1274.21 g, while for the floor reared birds the value was 1209.52 g. For dietary protein and energy levels the values ranged from 1206.02 to 1275.76 g with slight variation between different groups. The statistical analysis of the data revealed significant differences among housing systems and dietary protein levels, but not among energy levels. But in case of weight gain data this trend was not observed as in the case of starter phase. During grower phase, weight gain was found to be significantly influenced by protein levels only. Housing systems and dietary energy levels had no effect. Eventhough, body weight at 20th week was significantly higher ($P \angle 0.01$) for cage reared birds body weight gain was not significantly affected by systems of housing. Maximum weight gain during grower phase was observed with 16 per cent protein diet which was statistically similar with 14 and 18 per cent protein diets, but with respect to body weight 20 per cent protein diet resulted in maximum body weight which was not statistically different from 14 and 16 per cent protein diets.

Higher body weight obtained for caged birds at 20th week agrees with the finding of Jin and Craig (1988). Satyanarayana Reddy et al. (1989) reported that weight gain was not significantly influenced by dietary protein content of 16 or 18 per cent from 9 to 21 weeks of age. This finding is in agreement with the present trial in which statistically similar body weight gain during grower phase was recorded with 14, 16 and 18 per cent protein diets. The absence of any significant effect due to different energy levels also confirms the findings of the same authors. Thakur and Saxena (1985) suggested a 16 per cent dietary protein for grower replacement pullets from nine to 18 weeks of age in summer months. In the present study also the results obtained for body weight and weight gain favour a 16 per cent dietary protein, but it is better to suggest a 14 per cent dietary protein since the values were not statistically different at these two levels. The interaction effect existed between housing and energy in terms of body weight and weight gain favours an energy level of either 2500 or 2700 Kcal ME/Kg in cage system during this phase.

Feed intake

Feed intake per bird during nine to 20 weeks of age was found to be significantly influenced by housing systems alone, whereas protein and energy levels in the diet did not have any influence. Among housing systems, significantly higher feed intake was observed with floor reared birds. Satyanarayana Reddy et al. (1989) reported that different feeding regimen during growing period had no significant influence on feed intake. Although no significant differences were recorded for feed intake per bird, highest feed intake was recorded for the pullets on 16 per cent protein diet and lowest on 14 per cent protein diet.

Among energy levels, highest feed intake was noted with 2300 Kcal ME/Kg diet and lowest with 2700 Kcal ME/Kg diet. The effect due to either protein or energy level was non-significant. This is in agreement with findings of Thakur and Saxena (1985).

Feed conversion efficiency

Housing systems and energy concentration of the diet influenced feed conversion efficiency during grower phase. The inferior feed conversion efficiency reported with floor system of housing could be attributed to significantly increased feed intake during this phase. Eventhough, feed conversion efficiency was not significantly influenced by different protein levels, superior feed efficiency was observed with 14 per cent protein diet and poor feed efficiency with 20 and 18 per cent protein diets. Absence of any significant effect of feeding different protein levels on feed conversion efficiency during grower phase found in this trial is in agreement with findings of Satyanarayana Reddy et al. (1989) and Thakur and Saxena (1985). With respect to energy levels, the diets containing higher energy level (2700 Kcal ME/Kg) resulted in better feed efficiency than lower energy level (2300 Kcal ME/Kg). This might be due to better utilisation of nutrients in those diets. But this result is in contrast to the findings of Thakur and Saxena (1985) who found no significant effect on feed conversion efficiency by applying different energy levels viz., 2800, 2900 and 3000 Kcal ME/Kg. Presence of significant housing - protein - energy interaction on feed conversion efficiency is suggestive of Protein-energy combinations of 14 : 2500, 14 : 2700, 16 : 2300, 16 : 2500, 18 : 2700, 20 : 2500 and 20 : 2700 in cage system and 16 : 2500 in deep litter system during grower phase.

Cost of feeding

Cost of feeding per bird during grower phase was influenced significantly by the systems of housing, but not by dietary protein or energy levels. The feeding cost was significantly higher with floor reared birds compared to cage reared birds. This finding could be attributed to the significantly higher feed intake by the floor reared birds during this period. However, the feeding cost appears almost similar for different protein and energy levels ranging from Rs. 1976 to 21.60 per bird. Presence of housing - protein - energy interaction on feeding cost is suggestive of protein energy combinations of 14 : 2700, 16 : 2300, 16 : 2500, 18 : 2700 and 20 : 2700 in cage system and 14 : 2700 in deep litter system. From this study it may be concluded that a dietary crude protein level of 14 per cent with an energy level of 2300 Kcal ME/Kg was found to be optimum for egg type pullets during grower phase, irrespective of the housing systems.

Layer Phase

Age at first egg

Data on age at first egg revealed that it was influenced by housing systems alone, not by protein and energy levels in the diet. Birds housed in cages laid their first egg significantly earlier ($P \leq 0.01$) than those maintained on floor. This result is quite in line with those reported by Sharma (1974) and Jin and Craig (1988). This might presumably be attributed to the social order which may be predominant among birds on floor pens, thereby affecting socially recessives and ultimately the average sexual maturity. Protein or energy levels did not have any significant influence on this trait. This finding agrees with that of Summers and Leeson (1983).

Body weight gain (20-72 weeks of age)

Body weight gain during layer phase was significantly influenced by housing systems only. Dietary protein or energy levels did not significantly influence this trait. Birds maintained on floor attained significantly superior weight gain ($P \angle 0.01$) than birds in cages . This significant reduction in body weight gain observed among caged birds compared to other group might be due to the loss of weight resulted from pasteurellosis infection during laying phase. Absence of any significant effect on body weight gain due to dietary protein and energy levels confirms the findings of Thatte et al. (1981a) and Jalaludeen and Ramakrishnan (1989a).

Hen-day egg production

Percent hen-day egg production among the birds reared in cages appears to be optimum, whereas that reported for the litter reared birds could not be considered as ideal for strain cross egg type pullets. Birds housed in cages produced significantly more eggs (60.34%)

than those on floor (47.98%). The wide difference observed in egg production among the birds housed in two systems cannot be solely attributed to housing systems alone.

At 36 weeks of age, layers in cages had a mild attack of Pasteurellosis. Though, the mortality was negligible, morbidity was very high. As a consequence, further egg production was persistently lower for the remaining laying cycle. This could be observed from egg production data presented phasewise, viz., 20-40 weeks, 40-60 weeks and 61-72 weeks (Appendix XVII to XIX). Hen-day egg production was 70.33 per cent for cage reared birds as against 50.71 per cent for litter reared birds during 20 to 40 weeks of age. The values for 40 to 60 weeks of age and 61 to 72 weeks of age were 51.42 and 46.57 and 54.52 and 45.44 per cent for caged birds and floor birds, respectively. Thus it is evident that the egg production of the experimental birds reared in cages was far below than the potential of ILM 90 which could be attributed to infection with pasteurellosis.

Perusal of the mortality data, presented in Table 35 indicated that death rate was very high among the chicks reared on floor than the standards prescribed. The chicks were infected with intestinal coccidiosis during starter phase. Though, the disease could be controlled with proper managemental procedures including therapeutic use of anticoccidial medicines, the morbidity was very high. Therefore, the very low egg production per cent observed among the litter reared birds in this experiment could be attributed to Coccidiosis infection of the stock during starter phase. Absence of any significant interaction effect between housing and nutrients was suggestive of advocating any level of energy or protein studied to any housing systems. In egg production, there was not much variation among the protein level tested in the experiment. Statistical analysis also confirms this trend. It indicates that birds will be able to deliver satisfactory egg production with a diet containing 14 per cent CP. The present results confirm the observations of speers and Balloun (1967a), Reid (1976), Mather et al. (1976) Mohan et al. (1977) and Jalaludeen and Ramakrishnan (1989b) who reported satisfactory egg production in caged layers with 14 per cent dietary protein. The present finding also agrees with Thornton and Whittet (1959) who observed that even a protein level of 13 per cent in the diet was comparable to the higher protein levels for egg production among birds reared under cage and floor management. Sadagopan et al. (1971) suggested that the protein requirement of caged layers lies between 14 and 16 per cent.

Hen-day egg production was not affected when energy level alone was considered. Varying energy levels studied did not have any significant influence upon hen-day egg production. After studying the effect of dietary energy level on the performance of caged layers, Hulett *et al*. (1960) reported that altering the energy level in the diet did not significantly affect over all production. Bragg and Hodgson (1969) conducted a study employing three levels of metabolizable energy viz., 2794, 2570 and 2354 Kcal ME/Kg in isonitrogenous laying rations and observed no difference in egg production between the three energy levels. Peterson (1957), Pepper (1959), Lillie *et al*. (1976), Summers and Leeson (1978), Jalaludeen and Ramakrishnan (1989a, 1989b), also reported that lowering the energy level did not influence egg production. Infact, Lillie *et al*. (1976) could observe significantly higher egg production at an energy level of 2220 than at 3080 Kcal ME/Kg in the diet. Considering the above, it can be reasonably concluded that a diet containing 14 per cent protein and 2300 Kcal ME/Kg is sufficient for satisfactory egg production among layers. Though egg production for the cage reared birds were markedly higher than floor raised birds, the general production data pertaining to varying protein and energy levels employed could not be regarded as optimum. Egg production estimated for a particular level of nutrient taken together for both housing systems could be a reason for this lowered egg production. Since the effect of particular level of nutrients on egg production taken together for both the housing conditions, any influence in the performance of birds in both systems of management had contributed to the overall performance of birds.

Feed intake

Feed consumption per bird per day was not influenced significantly by either housing systems or variations in protein or energy concentrations in the diet. By scanning the literature on feed intake it could be seen that daily feed intake of layers as influenced by dietary protein and energy levels were contradictory. Bragg and Hdgson (1969), Ahmad et al. (1974), Carew et al. (1980) and Olomu and Offiong (1983) noted significant reduction in feed intake with higher dietary energy level. There was significant inverse relationship between dietary energy level and feed intake (Lillie et al., 1976 and Mather et al. 1976). 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. Prasad et al. (1984) also reported that protein had no effect on feed intake. Wilson et al. (1973) studied the influence of temperature on energy intake and stated that layers did not adjust their caloric intake to the energy level of feed. Absence of any significant influence on feed intake due to protein and energy levels studied in the experiment also agree with Jalaludeen and Ramakrishnan (1989a, 1989b). Smaller differences in energy levels used in this trial might have contributed to the non influence on feed intake.

Feed per dozen eggs

The feed required to produce one dozen eggs was found to be 2.21 kg for caged birds against 2.75 for floor reared birds and the difference was highly significant. Sugandi *et al*. (1975) and Rama Rao *et al*. (1983) studied the influence of housing systems on protein requirements and opined that feed efficiency was superior among birds housed in cages than those on floor. Comparatively poor feed efficiency noted in this work with floor system of management can be attributed to the low egg production recorded in that system.

The mean values for feed conversion efficiency expressed as feed per dozen eggs ranged from 2.15 for the 20 per cent crude protein diet to 2.64 for the 14 per cent crude protein diet and the values can be considered as acceptable for high producing egg type commercial birds. The feed per dozen eggs was significantly superior among 20 per cent protein fed birds than other levels employed. Sadagopan *et al.* (1971) after studying for levels of protein viz., 12, 15, 18 and 20 per cent stated that feed required to produce one dozen eggs was progressively decreased as the protein content in the diet increased. Reddy *et al.* (1980) also reported improved feed efficiency at increased level of protein. Among the three protein levels viz., 12, 15 and 18 per cent crude protein, tested, maximum feed efficiency was with 18 per cent protein (Ameenuddin *et al.*, 1976). However, Thornton and Whittet (1959) and Miller and Smith (1975) could not observe any significant change in feed efficiency due to variation in the dietary protein level. Mohan *et al.* (1977) reported better feed efficiency at high protein levels. Similar results have also been reported by Hochreich *et al.* (1958), and Quisenberry *et al.* (1964).

The feed per dozen eggs showed a numerical improvement with increasing the energy levels in the diet. Statistical analysis of the data confirmed this trend. Feed conversion efficiency was significantly superior with 2500 and 2700 Kcal ME/Kg diet than with 2300 Kcal ME/Kg diet. The results of the present study is in close agreement with Sadagopan *et al.* (1971), Reid and Maicrino (1980), Doran *et al.* (1980) and Thatte *et al.* (1981b) who reported that increased energy content in the diet reduced the feed required to produce one dozen eggs. However, Mohan et al. (1977), Summers and Leeson (1978), Olomu and Offiong (1983) and Jalaludeen and Ramakrishnan (1989a, 1989b) reported that energy levels in the diet did not have any effect on feed conversion efficiency. The improved feed efficiency with increasing level of energy in the diet in this experiment might be due to better utilisation of nutrients in that diet. Therefore, the present trial tends to suggest that a protein level of 20 per cent crude protein and energy level of 2500 or 2700 Kcal ME/Kg are ideal in as far as feed per dozen eggs is considered.

Egg weight

The egg weight was significantly influenced by both housing systems and protein level but not by energy content of the diet. Birds reared on floor produced significantly heavier eggs than caged birds. The large sized eggs produced by litter reared birds could be attributed to lower hen-day egg production recorded by the birds in that system. Among the protein levels tested, birds fed with crude protein contents of 16, 18 and 20 per cent produced eggs with significantly highest egg weight. Feeding 14 per cent protein diet resulted in significantly lower egg weight. Quisenberry et al. (1964), reported that when the protein was 15 per cent or less egg size was depressed. On the other hand, Fernandez et al. (1973), Miller and Smith (1975) and Thatte et al. (1981a, 1981b) stated that protein content of the diet had no effect on egg weight. However, Mac Intyre and Aitken (1957) noted that higher levels of protein were necessary for maximum egg weight. Similar results were reported by Gleaves et al. (1977), Mohan et al. (1977), Reddy et al. (1980), Doran et al. (1980) and Olomu and Offiong (1983). This is in agreement with the present finding that increasing the level of protein in the diet resulted in higher egg weight.

The egg weight was not significantly influenced by energy levels of the ration. Absence of any significant impact on egg weight by varying energy levels in the diet, noted in this study confirms the findings of Hulett (1960), Summers and Leeson (1978), Thatte et al. (1981a, 1981b) and Olomu and Offiong (1983). On the contrary, Lillie et al. (1970) and Reddy et al. (1980) opined that high energy diet significantly lowered egg weight. Lowered egg weight with increasing level of energy observed in the above reports may be due to lowered feed intake and consequent inadequate protein which resulted in lowered egg size. Considering the results, it can be concluded that for balancing optimum egg size a dietary protein-energy combination of 16 : 2300 was found to be ideal for egg type commercial layers.

Cost of feeding

Feeding cost during the layer phase as influenced by systems of housing, dietary protein and energy levels is shown in Table 25. Statistical analysis of the data revealed that it was not influenced by housing systems, dietary protein or energy levels. Thus, it is evident that among the 12 diets used in this experiment with varying protein and energy levels, any one could be considered, provided, it satisfies the other requirements such as production traits, egg quality traits etc.

Egg quality traits

The results of egg quality parameters such as shell thickness, albumen index, yolk index and Haugh unit obtained in the experiment revealed that the values recorded are within the normal range. This indicates that the dietary concentration of protein or energy tested had not adversely affected egg quality traits, resulting in the production of sound eggs, Mean shell thickness (0.34 mm) was same for the birds maintained in both housing systems and fed different energy levels. Similarly not much variation could be observed between birds of different groups fed different protein levels. Statistical analysis of the mean shell thickness revealed that none of the characters had any influence on this trait. 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 (Stadelman, 1977). Judging by this criteria the mean shell thickness obtained in this study can be clearly adjudged as optimal. The mean albumen index of 0.09 for all the dietary combinations and housing systems indicate that irrespective of treatments all eggs examined have good albumen quality. However, an increase in albumen quality with decrease in dietary protein has been reported by Mohan *et al*. (1977). Significantly similar hen-day egg production observed in the present experiment might be due to similar albumen index values.

Mean Haugh unit score, shown in Table 27, indicated that it was significantly influenced only by dietary protein levels and not by either housing systems or dietary energy levels. Significantly better Haugh unit score was noted with a dietary protein level of 16 per cent and significantly lower Haugh unit score observed 20 per cent crude protein level. However, the difference observed between 14 and 20 and 16 and 18 per cent protein levels were statistically similar. This erratic difference in Haugh Unit observed among the protein levels tested in this experiment could not be explained. Energy levels studied did not have any significant influence on Haugh unit score. This result is in agreement with Lillie *et al*. (1976), Mather *et al*. (1976) and Olomu and Offiong (1983).

The yolk index value in the present trial ranged from 0.42 to 0.44. Average values for fresh egg falls between 0.42 and 0.44. The yolk index values were significantly influenced by housing systems. Significantly superior values were recorded with floor reared birds. Though, eggs produced by cage reared birds were of significantly lower yolk index values, in general, it can be considered satisfactory. Yolk index values were statistically unaffected by dietary protein and energy levels and were within the normal range.

Abdominal fat

On perusal of the mean abdominal fat data (Table 32) it was observed that caged layers had more abdominal fat than litter reared birds, but the differences observed were not found to be significant. With respect to protein levels tested highest values were recorded with 20 per cent protein and lowest with 16 per cent protein. However, the differences in values among various protein levels were not found to be significant. Apparently, increase in abdominal fat values were noted with increase in energy content of the diet. But the energy content did not have any significant influence on abdominal fat.

Liver lipid

The trend in liver lipid per cent was more or less similar to that of abdominal fat. But significant differences were noted in this trait due to housing systems, dietary protein and energy levels. Per cent liver lipid estimated was significantly more with caged layers than floor birds. With respect to varying protein levels significantly highest values were noted with birds offered with 20 per cent protein and less values with those fed with 18 per cent protein diet. Significant difference could be observed between each regimen of protein used. Absence of any specific trend in liver lipid due to variation in protein level of the diet might be due to less number of samples tested for estimation of this trait. The liver lipid content of layers fed diet containing an energy level of 2700 Kcal ME/Kg was significantly more. It was significantly less with those fed with 2300 Kcal ME/Kg. The groups maintained on 2500 Kcal ME/Kg had intermediate liver lipid values. There were significant differences between each regimen of energy levels employed. The possible influence of different energy levels on fat deposition in the liver of laying hens was investigated by Ivy and Nesheim (1971) and reported that higher energy in the diet resulted in increase in liver fat content. This is in agreement with the present trial. Considering the different production traits as well as egg quality traits it can be concluded that a crude protein content of 16 per cent with an energy level of 2300 Kcal ME/Kg was found to be optimal for commercial egg type strain cross layers.

SUMMARY

An experiment was designed to study the influence of housing systems on protein and energy requirements of strain cross White Leghorn chicken from day old to seventy two weeks of age under the prevailing agro-climatic conditions of Kerala.

Seven hundred and twenty, one-day old female chicks of ILM-90 (IWN x IWP) of the Mannuthy Centre of All India Co-ordinated Research Project on Poultry for eggs, were used for the experiment. Two housing systems, namely, cage and deep litter were taken up for the study. The chicks were randomly divided into two groups of 360 chicks each, one group meant for floor and the other for cage experiment. They were randomly alloted to 12 dietary protein-energy combination groups with each treatment having three replicates and each replicate having ten chicks each in both housing systems. The observations were recorded from one day of age to seventy two weeks of age. Feed and water were provided *ad libitum*. The Scientific managemental practices were followed throughout the experimental period. The observations during starter phase were made from zero to eight weeks of age and during grower and layer phases at intervals of four weeks. The observations monitored during the starter

phase and grower phase were body weight, feed intake, feed conversion efficiency and mortality. During the layer phase (20-72 weeks of age) individual body weights were recorded at 20, 40, 60 and 72 weeks of age. 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 conversion efficiency was calculated based on Kilogram feed per dozen eggs. Data on egg quality traits such as egg weight, shell thickness, albumen index, yolk index and Haugh unit were recorded period-wise. Abdominal fat and liver lipids were also estimated at the end of the experiment.

Economics on cost of feeding per bird was calculated for different phases separately.

The following observations were made from this investigation.

Starter phase (0-8 weeks of age)

1. Eighth week body weight and body weight gain was influenced by housing systems and dietary protein levels, but not by energy levels. Birds reared in cages showed significantly higher ($P < 0.01$) body weight gain.

Body weight gain was superior with 20 per cent protein diet and poorest with 14 per cent protein diet and the values for 16 and 18 per cent protein diets were intermediary. Protein-energy combinations of 18 : 2700, 20 : 2500 and 20 : 2700 showed significantly higher ($P < 0.05$) body weight gain than others.

2. Feed intake per bird was significantly ($P < 0.01$) influenced by dietary protein levels only. Birds consumed significantly ($P < 0.01$) more quantity of feed with 18 per cent protein than 14, 16 and 20 per cent, the difference among them being statistically non-significant. Housing systems and energy levels studied did not have any influence on feed intake.

3. Feed conversion efficiency was significantly influenced by housing systems, dietary protein and energy levels. It was significantly ($P < 0.01$) better in cages than in deep litter. A dietary protein level of 20 per cent resulted in significantly ($P < 0.01$) superior feed efficiency and 14 per cent resulted in poorest feed efficiency. The feed efficiency with a dietary energy level of 2700 Kcal ME/Kg was statistically superior than that of 2300 or 2500 Kcal ME/Kg. Statistically better feed conversion efficiency was observed with protein-energy combination of 18 : 2700, 20 : 2500 and 20 : 2700.

4. During the Starter phase protein levels in the diet significantly influenced feeding cost whereas housing systems and energy contents in the diet did not have any significant influence. Among protein levels, significantly ($P < 0.01$) lowest feeding cost was observed with 16 per cent protein diet. Significantly ($P < 0.01$) higher feeding cost was observed with 18 per cent protein diet.

Considering the overall performance, it appeared that a dietary protein level of 20 per cent with an energy level of 2300 Kcal ME/Kg was found to be optimum during starter phase for commercial egg type pullets reared in cages as well as on litter floor system.

Grower phase (9-20 weeks of age)

1. Body weight of birds at 20th week of age was significantly influenced by housing systems and dietary protein levels, nut not by energy levels. Body weight of birds was significantly ($P < 0.01$) more in cages than in deep litter. Significantly ($P < 0.05$) higher body weight was observed with a protein level of 20 per cent and was statistically at par with 14 and 16 per cent protein levels. Significant effect ($P < 0.01$) of housing x energy interaction on body weight indicated that birds attained maximum body weight with 2700 and 2500 Kcal ME/Kg

in cage system of housing. Body weight gain during grower phase was significantly influenced by dietary protein levels only. Significantly ($P < 0.01$) more weight gain was observed that the diet containing a protein level of 16 per cent and less with a protein level of 20 per cent.

2. Feed intake per bird during grower phase was significantly ($P < 0.01$) influenced only by housing systems. Birds reared under deep litter consumed more feed than those reared in cages. Significantly ($P < 0.01$) less feed was consumed with a protein energy combination of 18 : 2700.

3. Feed conversion efficiency was significantly influenced by housing systems and dietary energy levels and not by protein levels. Feed efficiency was significantly ($P < 0.01$) superior for birds reared in cages. Significantly ($P < 0.05$) better feed efficiency was observed with 2700 Kcal ME/Kg diet and less with 2300 Kcal ME/Kg diet. Significantly superior feed conversion efficiency was observed with a diet containing protein-energy combination of 16 : 2500 and lowest with 18 : 2300.

4. Cost of feeding per bird during grower phase was influenced only by housing systems. Significantly

($P < 0.01$) lower feeding cost was observed among cage reared birds. In cage system feeding cost was found less with protein-energy combinations of 14 : 2700, 16 : 2300, 16 : 2500, 18 : 2700 and 20 : 2700 while that in deep litter was with 14 : 2700 combination only. Considering various aspects, it was seen that a dietary crude protein level of 14 per cent and energy level of 2300 Kcal ME/Kg was found to be optimum for egg type pullets during grower phase irrespective of the housing systems.

Layer phase (20-72 weeks of age)

1. Age at first egg was influenced by housing systems only. Birds housed in cages laid first egg significantly ($P < 0.01$) earlier than those maintained on floor.

2. Birds maintained on floor attained significantly ($P < 0.01$) superior weight gain than those in cages.

3. Hen-day egg production was significantly influenced only by the type of housing. Birds reared in cages produced significantly ($P < 0.01$) more numbers

of eggs than those on deep litter system. Hen-day egg production was not significantly influenced by varying levels of protein and energy employed.

4. Daily feed intake per bird was not influenced by either housing systems or dietary protein and energy levels studied.

5. Feed conversion efficiency was influenced by housing systems as well as dietary protein and energy levels. Significantly ($P < 0.01$) superior feed conversion efficiency was observed with cage reared birds. Among protein levels, birds offered with 20 per cent protein diet showed significantly superior ($P < 0.01$) feed conversion efficiency. Dietary energy levels of 2500 and 2700 Kcal ME/Kg showed significantly ($P < 0.05$) better feed efficiency than the other level.

6. Egg weight was significantly influenced by housing systems and dietary protein levels and not by energy levels. Litter reared birds produced significantly ($P < 0.05$) heavier eggs than caged birds. Except with 14 per cent protein, all other protein levels produced significantly ($P < 0.05$) larger sized eggs.

7. Cost of feeding per bird during layer phase was not significantly influenced by housing systems, dietary protein and energy levels employed.

8. Values for egg quality parameters, in general, were found well within the normal range. Shell thickness and albumen index were not significantly influenced by housing systems, dietary protein and energy levels. Yolk index was significantly ($P < 0.05$) higher with eggs obtained from birds reared on floor. Birds fed with a diet containing 16 per cent protein had significantly ($P < 0.05$) higher Haugh unit score and lower score was observed with a protein level of 20 per cent.

9. Abdominal fat content was not significantly influenced by housing systems, dietary protein and energy levels or its interaction studied.

10. Liver lipid values were significantly influenced by systems of housing as well as by dietary protein and energy levels employed. Caged birds had significantly ($P < 0.01$) higher liver lipid per cent than litter reared birds. Significantly ($P < 0.01$) higher liver lipid values obtained with diets having 20 per cent protein level and lowest with 18 per cent protein level. Highest liver lipid ($P < 0.01$) value was observed with a diet containing 2700 Kcal ME/Kg and lowest with 2300 Kcal ME/Kg diet.

In both housing systems, highest liver lipid value observed with protein energy combination of 20 : 2700 while lowest with 18 : 2300 in cage system and 14 : 2300 in deep litter system. Considering the different traits during layer phase, it could reasonably surmised that a dietary crude protein content of 16 per cent with an energy level of 2300 Kcal ME/Kg was found to be optimum for commercial egg type strain cross layers.

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Appendix

Appendix I

Effect of housing systems, dietary protein and energy levels on the performance of grower chicks during 9-12 weeks of age

Character		12th week body weight (g)	Feed intake per bird (g)	Weight gain (g)	Feed conversion efficiency
Housing systems	Cage	666.43[b]	1188.21	326.33[a]	3.69
	Litter	619.82[a]	1158.07	354.03[b]	3.38
Protein (% CP)	14	610.54[a]	1116.44	335.84[ab]	3.42
	16	598.51[a]	1177.11	309.32[a]	3.89
	18	669.23[b]	1149.06	355.79[b]	3.30
	20	694.23[b]	1249.97	359.77[b]	3.53
Energy	2300	637.42	1158.62	341.95	3.53
(Kcal ME/Kg)	2500	654.57	1186.53	352.78	3.43
	2700	637.39	1174.28	325.80	3.65
CD					
Housing		37.719 ($P < 0.01$)	--	24.335 ($P < 0.05$)	--
Protein		53.343 ($P < 0.01$)	--	34.414 ($P < 0.05$)	--
Housing x protein		--	--	--	--
Energy		--	--	--	--
Housing x energy		--	189.726 ($P < 0.01$)	--	--
Protein x energy		--	--	--	--
Housing x protein x energy		--	--	--	--

Letters bearing the same superscript do not differ significantly between each character

Appendix II

Effect of housing systems, dietary protein and energy levels on the performance of grower chicks during 13-16 weeks of age

Character		16th week body weight (g)	Feed intake per bird (g)	Weight gain (g)	Feed eff
Housing systems	Cage	1034.14^{b}	1582.64^{a}	358.13^{b}	
	Litter	934.09^{a}	2260.09^{b}	260.66^{a}	
Protein (% CP)	14	957.97^{a}	1904.79	306.62	
	16	977.97^{ab}	1989.15	329.54	
	18	992.19^{bc}	1929.01	298.26	
	20	1008.33^{c}	1862.53	303.16	
Energy	2300	970.89^{a}	1896.84	301.57^{a}	
(Kcal ME/Kg)	2500	975.01^{a}	1936.80	295.57^{a}	
	2700	1006.45^{b}	1930.46	331.05^{b}	
CD					
Housing		27.87 ($P < 0.01$)	107.38 ($P < 0.01$)	29.79 ($P < 0.01$)	0.82
Protein		29.05 ($P < 0.05$)	--	--	
Housing x protein		--	214.76 ($P < 0.01$)	--	
Energy		25.16 ($P < 0.05$)	--	26.89 ($P < 0.05$)	0.74
Housing x energy		--	--	--	
Protein x energy		--	263.03 ($P < 0.01$)	--	
Housing x protein x energy		--	--	--	

Letters bearing the same superscript do not differ significantly between each ch

Appendix III

Effect of housing systems, dietary protein and energy levels on the performance of grower chicks during 17-20 weeks of age

Character		20th week body weight (g)	Feed intake per bird (g)	Weight gain (g)	Feed conversion efficiency
Housing systems	Cage	1274.21^{b}	2221.37	240.07^{a}	10.21^{b}
	Litter	1209.52^{a}	2235.31	275.43^{b}	8.46^{a}
Protein (% CP)	14	1242.48^{ab}	2258.80	284.51^{b}	8.20^{a}
	16	1243.20^{ab}	2202.32	265.23^{b}	8.64^{a}
	18	1206.02^{a}	2314.12	213.83^{a}	12.34^{b}
	20	1275.76^{b}	2138.14	267.43^{b}	8.16^{a}
Energy (Kcal ME/Kg)	2300	1230.92	2512.96	260.03	11.11^{b}
	2500	1243.21	2141.79	268.20	8.15^{a}
	2700	1251.47	2030.28	245.02	8.75^{a}
CD					
Housing		38.59 ($P < 0.01$)	--	29.94 ($P < 0.01$)	1.35 ($P < 0.05$)
Protein		40.22 ($P < 0.05$)	--	42.34 ($P < 0.01$)	2.59 ($P < 0.01$)
Housing x protein		--	--	--	--
Energy		--	--	--	2.24 ($P < 0.01$)
Housing x energy		66.84 ($P < 0.01$)	--	51.86 ($P < 0.01$)	3.16 ($P < 0.01$)
Protein x energy		--	--	--	4.48 ($P < 0.01$)
Housing x protein x energy		--	--	76.44 ($P < 0.05$)	6.33 ($P < 0.01$)

Letters bearing the same superscript do not differ significantly between each character

Appendix IV

Effect of housing systems, dietary protein and energy levels on age at first egg and production traits of pullets during 21-24 weeks of age

Character		Age at first egg (days)	Hen-day egg production (%)	Daily feed intake per bird (g)	Feed per dozen eggs (kg)	Egg weight (g)
Housing systems	Cage	130.50[a]	63.99[b]	107.98	2.13[a]	42.84[b]
	Litter	135.25[b]	27.88[a]	102.70	5.16[b]	41.41[a]
Protein (% CP)	14	134.17	43.48[a]	107.21	4.42[b]	41.06
	16	133.42	46.10[ab]	108.67	3.60[b]	42.50
	18	133.50	40.23[a]	101.84	4.11[b]	42.82
	20	130.42	53.94[b]	103.63	2.15[a]	42.12
Energy (Kcal ME/Kg)	2300	134.63	44.17[a]	111.92	3.74	41.83
	2500	133.06	43.75[a]	103.61	3.95	42.43
	2700	130.94	49.90[b]	100.48	3.25	42.11
CD						
Housing		4.189 ($P < 0.01$)	5.93 ($P < 0.01$)	--	0.955 ($P < 0.01$)	1.42 ($P < 0.01$)
Protein		--	8.38 ($P < 0.01$)	--	0.996 ($P < 0.05$)	--
Housing x protein		--	--	--	1.408 ($P < 0.05$)	--
Energy		--	5.35 ($P < 0.05$)	--	--	--
Housing x energy		--	7.56 ($P < 0.05$)	--	--	--
Protein x energy		--	--	--	--	--
Housing x protein x energy		--	--	--	--	--

Letters bearing the same superscript do not differ significantly between each character

Appendix V

Effect of housing systems, dietary protein and energy levels on production traits of pullets during 25-28 weeks of age

Character		Hen-day egg production (%)	Daily feed intake per bird (g)	Feed per dozen eggs (kg)	Egg weight (g)
Housing systems	Cage	76.72^{b}	119.66^{b}	1.91^{a}	45.60
	Litter	47.40^{a}	95.73^{a}	2.58^{b}	45.70
Protein (% CP)	14	65.35	118.34^{b}	2.38	45.58
	16	59.90	104.90^{ab}	2.39	45.48
	18	57.22	109.78^{ab}	2.30	45.33
	20	65.77	97.85^{a}	1.91	46.21
Energy (Kcal ME/Kg)	2300	62.69^{ab}	119.65^{b}	2.34^{b}	45.32
	2500	57.63^{a}	101.75^{a}	2.46^{b}	45.73
	2700	65.86^{b}	101.76^{a}	1.93^{a}	45.90
CD					
Housing		6.92 ($P < 0.01$)	10.67 ($P < 0.01$)	0.38 ($P < 0.01$)	--
Protein		--	15.09 ($P < 0.01$)	--	--
Housing x protein		--	--	--	--
Energy		6.25 ($P < 0.05$)	13.06 ($P < 0.01$)	0.34 ($P < 0.05$)	--
Housing x energy		--	13.62 ($P < 0.05$)	0.66 ($P < 0.05$)	--
Protein x energy		--	19.26 ($P < 0.05$)	--	--
Housing x protein x energy		17.65 ($P < 0.05$)	27.24 ($P < 0.05$)	--	--

Letters bearing the same superscript do not differ significantly between each character

Appendix VI

Effect of housing systems, dietary protein and energy levels on traits of pullets during 29-32 weeks of age

Character		Hen-day egg production (%)	Daily feed intake per bird (g)	Feed per dozen eggs (kg)	Egg weight (g)
Housing systems	Cage	80.30^{b}	112.39	1.71^{a}	47.73
	Litter	58.24^{a}	99.06	2.10^{b}	47.82
Protein (% CP)	14	63.98	107.66	2.10	47.54
	16	69.54	111.80	2.03	47.75
	18	71.69	105.91	1.77	47.98
	20	71.86	97.52	1.72	47.83
Energy (Kcal ME/Kg)	2300	68.55	108.30	2.01	47.64
	2500	66.12	105.91	2.00	47.98
	2700	73.14	102.95	1.70	47.70
CD					
Housing		8.82 ($P < 0.01$)	--	0.365 ($P < 0.01$)	--
Protein		--	--	--	--
Housing x protein		--	--	--	--
Energy		--	--	--	--
Housing x energy		--	--	--	--
Protein x energy		--	--	--	--
Housing x protein x energy		--	--	--	--

Letters bearing the same superscript do not differ significantly between each character

					50.04
Protein (% CP)	14	72.89	108.82	1.79	48.41
	16	71.42	108.67	1.85	49.57
	18	71.08	110.24	1.81	48.89
	20	74.50	99.22	1.64	49.12
Energy (Kcal ME/Kg)	2300	73.15	108.62	1.78	48.05[a]
	2500	70.13	101.97	1.78	49.96[b]
	2700	74.13	109.62	1.75	48.98[a]
CD					
Housing		--	--	--	1.22 ($P <$
Protein		--	--	--	--
Housing x protein		--	21.95 ($P < 0.05$)	--	--
Energy		--	--	--	1.49 ($P <$ 0
Housing x energy		--	--	--	--
Protein x energy		--	--	--	--
Housing x protein x energy		--	--	--	--

Letters bearing the same superscript do not differ significantly between each character

Appendix VIII

Effect of housing systems, dietary protein and energy levels on production traits of pullets during 37-40 weeks of age

Character		Hen-day egg production (%)	Daily feed intake per bird (g)	Feed per dozen eggs (kg)	Egg weight (g)
Housing systems	Cage	53.96	116.96	2.64	51.10
	Litter	49.78	113.96	3.00	51.06
Protein (% CP)	14	50.92	120.18	2.94[b]	50.62
	16	52.90	114.52	2.65[ab]	51.25
	18	48.99	129.74	3.53[c]	51.01
	20	54.67	97.40	2.17	51.43
Energy	2300	53.17	115.87	2.78	50.44
(Kcal ME/Kg)	2500	54.99	106.63	2.37[a]	51.52
	2700	47.45	128.87	3.31[b]	51.27
CD					
Housing		--	--	--	--
Protein		--	--	0.67 ($P < 0.05$)	--
Housing x protein		--	--	--	--
Energy		--	--	0.58 ($P < 0.05$)	--
Housing x energy		--	--	--	--
Protein x energy		--	--	1.15 ($P < 0.05$)	--
Housing x protein x energy		--	--	--	--

Letters bearing the same superscript do not differ significantly between each character

Appendix IX

Influence of housing systems, dietary protein and energy levels on production traits of layers during 41-44 weeks of age

Character		Hen-day egg production (%)	Daily feed intake per bird (g)	Feed per dozen eggs (kg)	Egg weight (g)
Housing systems	Cage	62.16^{b}	112.23	2.24^{a}	50.89
	Litter	53.79^{a}	116.87	2.66^{b}	47.93
Protein (% CP)	14	56.98	120.70	2.64	45.86
	16	58.39	110.44	2.37	50.74
	18	57.21	120.06	2.55	50.37
	20	59.30	107.01	2.23	50.68
Energy (Kcal ME/Kg)	2300	57.42	117.06	2.51	50.37
	2500	60.19	114.14	2.37	50.05
	2700	56.30	112.46	2.46	47.81
CD					
Housing		6.95 ($P < 0.01$)	--	0.39 ($P < 0.01$)	--
Protein		--	--	--	--
Housing x protein		--	--	--	--
Energy		--	--	--	--
Housing x energy		8.87 ($P < 0.05$)	--	0.50 ($P < 0.05$)	--
Protein x energy		--	--	--	--
Housing x protein x energy		--	--	--	--

Letters bearing the same superscript do not differ significantly between each character

Appendix X

Influence of housing systems, dietary protein and energy levels on production traits of layers during 45-48 weeks of age

Character		Hen-day egg production (%)	Daily feed intake per bird (g)	Feed per dozen eggs (kg)	Egg weight (g)
Housing systems	Cage	52.56	111.10	2.64	49.16
	Litter	49.20	109.82	2.71	48.63
Protein (% CP)	14	52.71	115.43	2.70^{ab}	49.21
	16	50.05	110.92	2.73^{ab}	50.03
	18	48.91	116.64	2.92^{b}	46.30
	20	51.87	98.87	2.36^{a}	50.03
Energy (Kcal ME/Kg)	2300	49.10	111.71	2.79	50.02
	2500	52.64	110.41	2.60	49.60
	2700	50.91	109.27	2.63	47.05
CD					
Housing		--	--	--	--
Protein		--	--	0.39 ($P < 0.05$)	--
Housing x protein		--	--	--	--
Energy		--	--	--	--
Housing x energy		9.11 ($P < 0.05$)	--	--	--
Protein x energy		--	--	--	--
Housing x protein x energy		--	--	1.28 ($P < 0.01$)	--

Letters bearing the same superscript do not differ significantly between each character

Appendix XI

Influence of housing systems, dietary protein and energy levels on production traits of layers during 49-52 weeks of age

Character		Hen-day egg production (%)	Daily feed intake per bird (g)	Feed per dozen eggs (kg)	Egg weight (g)
Housing systems	Cage	49.49	107.74	2.66	49.42
	Litter	50.52	113.81	2.81	50.42
Protein (% CP)	14	52.40[bc]	111.83	2.72[ab]	49.44
	16	47.94[ab]	102.64	2.59[a]	49.58
	18	42.50[a]	117.99	3.31[b]	49.65
	20	57.16[c]	110.62	2.31[a]	50.99
Energy	2300	50.18	125.09[b]	3.02[b]	50.01
(Kcal ME/Kg)	2500	51.57	104.67[a]	2.59[a]	49.09
	2700	48.26	102.56[a]	2.59[a]	50.65
CD					
Housing		--	--	--	--
Protein		8.09 ($P < 0.01$)	--	0.59 ($P < 0.01$)	--
Housing x protein		8.43 ($P < 0.05$)	--	--	2.41 ($P < 0.05$)
Energy		--	14.20 ($P < 0.01$)	0.37 ($P < 0.05$)	--
Housing x energy		--	--	--	--
Protein x energy		--	--	--	--
Housing x protein x energy		--	--	--	--

Letters bearing the same superscript do not differ significantly between each character

Appendix XII

Influence of housing systems, dietary protein and energy levels on production traits of layers during 53-56 weeks of age

Character		Hen-day egg production (%)	Daily feed intake per bird (g)	Feed per dozen eggs (kg)	Egg weight (g)
Housing systems	Cage	42.90	106.70	3.08	49.29
	Litter	42.84	110.04	3.13	50.88
Protein (% CP)	14	38.74[a]	103.57	3.26	52.25
	16	43.12[ab]	107.65	3.07	47.08
	18	40.83[a]	113.68	3.41	53.33
	20	48.79[b]	108.59	2.70	47.67
Energy	2300	40.50[a]	115.46[b]	3.54[b]	52.56
(Kcal ME/Kg)	2500	47.25[b]	109.11[ab]	2.75[a]	52.19
	2700	40.85[a]	100.55[a]	3.03[ab]	45.50
CD					
Housing		--	--	--	--
Protein		6.45 ($P < 0.05$)	--	--	--
Housing x protein		--	--	--	--
Energy		5.59 ($P < 0.05$)	11.13 ($P < 0.05$)	0.62 ($P < 0.01$)	--
Housing x energy		--	--	--	--
Protein x energy		--	--	0.91 ($P < 0.05$)	--
Housing x protein x energy		--	--	--	--

Letters bearing the same superscript do not differ significantly between each character

Appendix XIII

Influence of housing systems, dietary protein and energy levels on production traits of layers during 57-60 weeks of age

Character		Hen-day egg production (%)	Daily feed intake per bird (g)	Feed per dozen eggs (kg)	Egg weight (g)
Housing system	Cage	49.25^{b}	113.67	2.80^{a}	52.66^{b}
	Litter	38.29^{a}	107.72	3.50^{b}	44.97^{a}
Protein (% CP)	14	43.16	112.03	3.15	47.90
	16	43.06	112.69	3.15	51.13
	18	43.95	115.61	3.48	43.50
	20	44.91	102.44	2.82	52.72
Energy	2300	40.20^{a}	118.78^{b}	3.68^{b}	49.44
(Kcal ME/Kg)	2500	47.71^{b}	107.47^{a}	2.82^{a}	51.42
	2700	43.40^{ab}	105.83^{a}	2.94^{a}	45.58
CD					
Housing		6.11 ($P < 0.01$)	--	0.48 ($P < 0.01$)	7.37 ($P < 0.05$)
Protein		--	--	--	--
Housing x protein		9.00 ($P < 0.05$)	--	0.71 ($P < 0.05$)	--
Energy		5.51 ($P < 0.05$)	10.67 ($P < 0.05$)	0.59 ($P < 0.01$)	--
Housing x energy		--	--	--	--
Protein x energy		--	21.34 ($P < 0.05$)	0.86 ($P < 0.05$)	--
Housing x protein x energy		--	--	1.22 ($P < 0.05$)	--

Letters bearing the same superscript do not differ significantly between each character

Appendix XIV

Influence of housing systems, dietary protein and energy levels on production traits of layers during 61-64 weeks of age

Character		Hen-day egg production (%)	Daily feed intake per bird (g)	Feed per dozen eggs (kg)	Egg weight (g)
Housing systems	Cage	56.55^{b}	104.45	2.24^{a}	48.00
	Litter	48.24^{a}	103.89	2.59^{b}	49.96
Protein (% CP)	14	48.53^{a}	107.46	2.69^{b}	48.72
	16	51.62^{ab}	104.56	2.45^{ab}	52.43
	18	56.65^{c}	105.05	2.26^{a}	47.16
	20	52.79^{b}	99.62	2.26^{a}	47.61
Energy	2300	50.43^{a}	113.10^{b}	2.71^{b}	48.79
(Kcal ME/Kg)	2500	55.12^{b}	99.50^{a}	2.20^{a}	51.60
	2700	51.64^{a}	99.92^{a}	2.34^{a}	46.55
CD					
Housing		2.24 ($P < 0.01$)	--	0.23 ($P < 0.01$)	--
Protein		3.17 ($P < 0.01$)	--	0.33 ($P < 0.01$)	--
Housing x protein		4.49 ($P < 0.01$)	--	--	--
Energy		2.75 ($P < 0.01$)	10.41 ($P < 0.01$)	0.28 ($P < 0.01$)	--
Housing x energy		--	--	--	--
Protein x energy		4.05 ($P < 0.05$)	--	--	--
Housing x protein x energy		7.77 ($P < 0.01$)	--	--	--

Letters bearing the same superscript do not differ significantly between each character

Appendix XV

Influence of housing systems, diotary protein and energy levels on production traits of layers during 65-68 weeks of age

Character		Hen-day egg production (%)	Daily feed intake per bird (g)	Feed per dozen eggs (kg)	Egg weight (g)
Housing systems	Cage	54.94^{b}	106.16	2.35^{a}	52.49
	Litter	44.55^{a}	107.76	3.07^{b}	51.50
Protein (% CP)	14	47.35^{a}	113.99	2.95^{b}	50.63
	16	49.19^{ab}	108.30	2.72^{ab}	53.21
	18	52.94^{b}	109.74	2.62^{a}	51.59
	20	49.48^{ab}	95.81	2.55^{a}	52.74
Energy (Kcal ME/Kg)	2300	47.25^{a}	111.46	2.89^{b}	50.91
	2500	52.37^{b}	106.60	2.53^{a}	51.75
	2700	49.61^{ab}	102.81	2.71^{ab}	54.55
CD					
Housing		3.00 ($P < 0.01$)	--	0.28 ($P < 0.01$)	--
Protein		4.25 ($P < 0.01$)	--	0.29 ($P < 0.05$)	--
Housing x protein		--	--	--	--
Energy		3.68 ($P < 0.01$)	--	0.25 ($P < 0.05$)	--
Housing x energy		3.83 ($P < 0.05$)	--	--	--
Procein x energy		7.35 ($P < 0.01$)	--	--	--
Housing x protein x energy		--	--	--	--

Letters bearing the same superscript do not differ significantly between each character

Appendix XVI

Influence of housing systems, dietary protein and energy levels on production traits of layers during 69-72 weeks of age

Character		Hen-day egg production (%)	Daily feed intake per bird (g)	Feed per dozen eggs (kg)	Egg weight (g)
Housing systems	Cage	48.78^{b}	112.14^{a}	2.85^{a}	54.21
	Litter	43.38^{a}	120.43^{b}	3.38^{b}	53.91
Protein (% CP)	14	45.07	126.81^{c}	3.45^{c}	52.92
	16	46.57	114.05^{ab}	3.03^{ab}	54.69
	18	47.56	122.25^{bc}	3.22^{bc}	53.90
	20	45.13	102.02^{a}	2.75^{a}	54.71
Energy (Kcal ME/Kg)	2300	44.68	124.71^{b}	3.40^{b}	54.83
	2500	48.71	113.39^{a}	2.89^{a}	54.58
	2700	44.85	110.75^{a}	3.05^{ab}	53.50
CD					
Housing		4.29 ($P < 0.05$)	6.29 ($P < 0.05$)	0.39 ($P < 0.01$)	--
Protein		--	12.06 ($P < 0.01$)	0.41 ($P < 0.05$)	--
Housing x protein		--	12.57 ($P < 0.05$)	0.58 ($P < 0.05$)	--
Energy		--	10.45 ($P < 0.01$)	0.36 ($P < 0.05$)	--
Housing x energy		--	--	--	--
Protein x energy		--	--	--	--
Housing x protein x energy		--	--	--	--

Letters bearing the same superscript do not differ significantly between each character

Appendix XVII

Influence of housing systems, dietary protein and energy levels on production traits of layers during 20-40 week period

Character		Hen-day egg production (%)	Daily feed intake per bird (g)	Feed per dozen eggs (kg)
Housing systems	Cage	70.33^{b}	110.51^{b}	1.97^{a}
	Litter	50.71^{a}	101.68^{a}	2.52^{b}
Protein (% CP)	14	58.58	110.58	2.43^{b}
	16	59.86	105.80	2.28^{ab}
	18	59.49	110.61	2.40^{b}
	20	64.15	97.40	1.86^{a}
Energy	2300	60.40	112.47	2.32
(Kcal ME/Kg)	2500	58.87	102.94	2.23
	2700	62.30	102.89	2.17
CD				
Housing		6.584 ($P < 0.01$)	8.016 ($P < 0.05$)	0.32 ($P < 0.01$)
Protein		--	--	0.453 ($P < 0.01$)
Housing x protein		--	--	--
Energy		--	--	--
Housing x energy		--	--	--
Protein x energy		--	--	--
Housing x protein x energy		--	--	--

Letters bearing the same superscript do not differ significantly between each character

Appendix XVIII

Influence of housing systems, dietary protein and energy levels on production traits of layers during 40-60 week period

Character		Hen-day egg production (%)	Daily feed intake per bird (g)	Feed per dozen eggs (kg)
Housing systems	Cage	51.42[b]	107.72	2.63[a]
	Litter	46.57[a]	112.13	2.91[b]
Protein (% CP)	14	48.88	110.61	2.85[b]
	16	47.81	107.69	2.78[ab]
	18	46.46	116.48	3.02[b]
	20	52.84	104.93	2.42[a]
Energy	2300	47.86	115.33[b]	2.96
(Kcal ME/Kg)	2500	51.79	109.70[a]	2.62
	2700	47.34	104.75[a]	2.73
CD				
Housing		4.881 ($P < 0.01$)	--	0.252 ($P < 0.05$)
Protein		--	--	0.356 ($P < 0.05$)
Housing x protein		--	--	--
Energy		--	7.907 ($P < 0.05$)	--
Housing x energy		--	--	--
Protein x energy		--	--	0.616 ($P < 0.05$)
Housing x protein x energy		--	22.365 ($P < 0.05$)	--

Letters bearing the same superscript do not differ significantly between each character

Appendix XIX

Influence of housing systems, dietary protein and energy levels on production traits of layers during 61-72 week period

Character		Hen-day egg production (%)	Daily feed intake per bird (g)	Feed per dozen eggs (kg)
Housing systems	Cage	54.52[b]	109.84	2.46[a]
	Litter	45.44[a]	112.04	2.97[b]
Protein (% CP)	14	46.24[a]	115.90	3.04[b]
	16	49.69[a]	109.18	2.69[a]
	18	52.74[b]	113.12	2.65[a]
	20	51.26[b]	105.55	2.49[a]
Energy (Kcal ME/Kg)	2300	47.06[a]	116.23[b]	2.99[b]
	2500	53.49[b]	110.37[a]	2.52[a]
	2700	49.40[a]	106.21[a]	2.64[a]
CD				
Housing		3.317 ($P < 0.01$)	--	0.203 ($P < 0.01$)
Protein		4.691 ($P < 0.01$)	--	0.287 ($P < 0.01$)
Housing x protein		--	--	--
Energy		4.062 ($P < 0.01$)	6.830 ($P < 0.05$)	0.248 ($P < 0.01$)
Housing x energy		4.235 ($P < 0.05$)	--	--
Protein x energy		--	--	--
Housing x protein x energy		--	--	--

Letters bearing the same superscript do not differ significantly between each character

EFFECT OF HOUSING SYSTEM ON PROTEIN AND ENERGY REQUIREMENTS OF WHITE LEGHORN

By

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ABSTRACT OF A THESIS

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requirement for the degree

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ABSTRACT

An experiment was designed to study the influence of housing systems on protein and energy requirements of strain cross White Leghorn chicken (ILM-90) from one day old to seventy two weeks of age.

Seven hundred and twenty, one-day old female chicks of ILM-90 (IWN x IWP) of the Mannuthy Centre of All India Co-ordinated Research Project on Poultry for eggs, were randomly divided into two groups of 360 chicks each, one group for floor and other for cage experiment. They were randomly alloted to 12 dietary protein-energy combination groups with each treatment having three replicates and each replicate having ten chicks in both housing systems.

The observations monitored during the starter and grower phases were weight gain, feed intake, feed conversion efficiency and mortality. During layer phase individual body weights were recorded at 20, 40, 60 and 72 weeks of age. Hen-day egg production, daily feed intake per bird, feed per dozen eggs, egg quality traits such as egg weight, shell thickness, albumen index, yolk index and Haugh unit were recorded for each 28-day period. Cost of feeding per bird was also calculated. Abdominal fat and liver lipid were also estimated at the end of the experiment. Results

showed that eighth week body weight and weight gain were influenced by housing systems and protein levels but not by energy levels. Birds reared in cages and also those fed with 20 per cent protein diet showed significantly higher ($P \angle 0.05$) body weight gain. Feed intake per bird and cost of feeding were influenced only by dietary protein levels. Significantly higher ($P \angle 0.01$) feed intake was observed with diet containing 18 per cent protein. Considering the over all performance, a dietary protein level of 20 per cent with an energy level of 2300 Kcal ME/Kg was found to be optimum during starter phase for commercial egg type pullet chicks reared in cages as well as on deep litter system.

Body weight at 20th week of age was significantly influenced by housing systems and dietary protein levels, whereas body weight gain was influenced by protein levels only. Feed intake per bird and cost of feeding were influenced only by housing systems. Feed conversion efficiency was significantly influenced by housing systems and dietary energy levels. Birds reared in cages and those fed with 2700 Kcal ME/Kg diet showed better feed efficiency. A dietary protein level of 14 per cent and energy level of 2300 Kcal ME/Kg was found to be optimum for egg type pullets during grower phase, irrespective of the housing systems.

Age at first egg was significantly influenced by housing systems only. Caged birds laid first egg significantly earlier ($P < 0.01$). Birds reared in cages produced significantly ($P < 0.01$) more number of eggs than those on floor. Daily feed intake per bird and cost of feeding were not influenced by either housing systems or dietary protein and energy levels. Feed conversion efficiency was influenced by housing systems as well as dietary protein and energy levels. Significantly ($P < 0.01$) superior feed conversion efficiency was observed with cage system of housing, 20 per cent dietary protein level and dietary energy levels of 2500 and 2700 Kcal ME/Kg. Egg weight was influenced by housing systems and dietary protein levels and not by energy levels. Liver lipid values were significantly influenced by housing systems as well as dietary protein and energy levels employed whereas, abdominal fat content was not influenced by any of these. Considering the different traits monitored during layer phase, it was seen that a dietary crude protein content of 16 per cent with an energy level of 2300 Kcal ME/Kg diet was found to be optimum for commercial egg type strain cross layers.