EFFECT OF DIETARY SUPPLEMENTATION OF LYSINE AND METHIONINE ON PRODUCTION PERFORMANCE OF JAPANESE QUAIL (*Coturnix coturnix japonica*)

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Thesis submitted in partial fulfillment of the requirement for the degree of

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DECLARATION

I hereby declare that this thesis, entitled **"EFFECT OF DIETARY SUPPLEMENTATION OF LYSINE AND METHIONINE ON PRODUCTION PERFORMANCE OF JAPANESE QUAIL (*Coturnix coturnix japonica*)"** 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 DIETARY SUPPLEMENTATION OF LYSINE AND METHIONINE ON PRODUCTION PERFORMANCE OF JAPANESE QUAIL (*Coturnix coturnix japonica*)"** is a record of research work done independently by **Preethymol Joseph**, under my guidance and supervision and it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Introduction

1. INTRODUCTION

Poultry production conferred with high efficiency of land use and diverse potential for value addition of egg and meat aspires to be the most emerging agricultural sub sector in India in terms of nutritional support, income generation and employment creation. Poultry meat and egg are considered as the best and most preferred form of animal protein source in the country owing to its high biological value and lack of social taboos.

At present, per capita annual availability of chicken meat in India is 1.5 kg per person per year while the recommendation by National Institute of Nutrition is 9.5 kg. In case of eggs, the per capita availability is only 47 eggs while recommendation by ICMR is half an egg per person per day. Thus, poultry meat and egg output does not meet the recommended per capita requirements of the nation. The wide gap existing between supply and demand of poultry products offers vast scope for development of other avian species like quails.

The multi fold advantages of quail rearing over other domesticated poultry include small body size, relative ease of maintaining, less unit space and feed requirements, early sexual maturity, high rate of egg production, ability to produce more generations in a year and better disease resistance. But quail farmers in Kerala often complain about wide variations in egg production. Among the various factors affecting egg production, feed is of prime importance. Availability of quality layer feed is the major problem of quail rearing in the State. Considering the shortage of feedstuffs in India, effective manipulation of protein sources for lowering the cost of production is a need of the day, especially for a species like quail having high protein requirement.

Scientific protein nutrition of poultry is not only based upon crude protein content of the feed, but also upon the dietary level and biological availability of each essential and non-essential amino acid. Based on 'ideal protein concept', a protein that can supply amino acids in exactly the amounts and proportions required by the animal can completely be utilised under appropriate circumstances. Conversely, if one or two amino acids are deficient, other amino acids present in excess will be wasted as nitrogen excretion. To avoid this and to overcome deficiencies, the most limiting ones can be added to the diets. Methionine and lysine are considered to be limiting amino acids in poultry rations and are available commercially in crystalline form. Crystalline DL-methionine and L-lysine are 100 per cent digestible by poultry compared to the 70 to 93 per cent digestibility of methionine and lysine from feedstuffs and the use of crystalline amino acids in rations optimises production to a great extent.

In general, information on amino acid requirements of layer quails raised in tropical climate is not adequate and the Bureau of Indian Standards (BIS) has not specified standards for feeding quails. Under these circumstances, more studies are warranted in the field of ideal protein concept and biological availability of limiting amino acids from natural and synthetic sources so that layer quails can express their maximum genetic potential. Therefore, the present investigation was conceived with an objective to study the influence of supplementation of lysine and methionine in quail layer rations on egg production and egg quality and to examine the economics.

Review of Literature

2. REVIEW OF LITERATURE

2.1 METEOROLOGICAL OBSERVATIONS

Somanathan (1980) reported a maximum temperature ranging from 31.14 to 35.14°C, minimum temperature ranging from 21.15 to 25.80°C and average relative humidity (R.H.) ranging from 58.49 to 84.39 per cent during the period from January to June in the years 1974 to 1978 at the Meteorological observatory unit, Mannuthy. The measurements were taken at latitude of 10° 32" N, longitude of 76° 16" E and altitude of 22.25 m above MSL for 5 years and average values were reported.

Narayanankutty (1987) reported a maximum temperature of 32.2°C, minimum temperature of 28.9°C and R.H. of 56 to 68 per cent inside the experimental house at Mannuthy during January to February 1987.

Padmakumar (1993) reported maximum temperature of 33.4, 36.18 and 32.74°C inside the experimental house during the periods of Dec-Jan, Apr-May and May-Jun respectively at Mannuthy. The minimum temperature was 20.90, 24.64 and 24.42 °C in the respective periods. The R.H. in the F.N. was 74.8, 81.2 and 87.8 per cent and in the A.N. was 35.6, 48.2 and 65.2 per cent in the respective periods when an experiment was carried out in Japanese quails.

Sheena (2005) reported a maximum temperature of 34.2°C, minimum temperature of 23.3°C, R.H. of 78.1 per cent at 8 a.m. and 43.5 per cent at 2 p.m. inside the experimental house at Mannuthy during Dec 2004 to May 2005, when an experiment was carried out in Japanese quails.

2.2 REQUIREMENT OF LYSINE AND METHIONINE

Allen and Young (1980) estimated the lysine and methionine requirements of laying Japanese quail for egg production, which were 0.86 and 0.37 per cent of the diet, respectively.

Schutte *et al.* (1983) found that the sulphur amino acid (SAA) requirement of hens for maximum egg production was approximately 0.55 and 0.6 per cent in diets containing 11.5 and 12.35 MJ ME per kg respectively for a laying period of 52 weeks. Maximum efficiency of food utilisation was achieved with SAA concentrations of 0.6 and 0.65 per cent at the respective energy levels.

Shrivastav *et al.* (1984) suggested 1.3 per cent lysine at 27 per cent protein and 2800 kcal ME per kg for optimum performance during the growing period of zero to 5 weeks of age in Japanese quails.

Shim and Vohra (1984) reviewed that the lysine and methionine requirements of growing quail was determined as 1.15 and 0.43 per cent of the diet respectively and suggested 0.45 per cent methionine, 0.9 per cent lysine, 20 per cent protein and 2800 kcal ME per kg for layer Japanese quails.

Gazo *et al.* (1987) studied the effect of dietary lysine excess and deficiency on metabolism in Japanese quail and demonstrated the existence of a regulating mechanism that does not allow elevation of lysine concentrations in the blood plasma of Japanese quails.

Panda and Mohapatra (1989) suggested 22 per cent CP, 2650 kcal per kg ME, 0.73 per cent lysine, 0.33 per cent methionine and 0.62 per cent methionine plus cystine for breeding Japanese quails.

NRC (1994) recommended 20 per cent CP, 2900 kcal per kg ME, 1 per cent lysine, 0.45 per cent methionine and 0.7 per cent methionine plus cystine for breeding quails after 6 weeks of age.

Harms and Russell (1995) concluded that the protein level of the broiler breeder hen diet could be lowered considerably below the NRC (1994) recommendation of 19.5 g per hen per day provided that methionine and lysine are supplemented to meet the requirement for these amino acids.

Ravikiran and Devegowda (1998) concluded that for a tropical layer diet, the methionine level has to be maintained to obtain a methionine intake of 380-420mg per hen per day. The SAA requirement was found to be higher for maximum efficiency of feed utilization than for maximum egg yield.

Vidhyadharan (1998) concluded that addition of methionine at 0.3 per cent level to vegetable protein diet is effective in formulation of layer ration when scarcity of fish occurs.

Shrivastav and Panda (1999) suggested 0.8 per cent lysine, 0.33 per cent methionine, 19 per cent protein and 11.3 MJ ME per kg for quail layers above 6 weeks of age.

Pinto *et al.* (2003a) estimated the digestible methionine plus cystine requirement of laying Japanese quail as 0.727 per cent with an intake of the same at the rate of 164 mg daily. A ratio of 0.8 between digestible methionine plus cystine and digestible lysine was considered the best.

Pinto *et al.* (2003b) reported the requirement of digestible lysine for laying Japanese quail as 1.117 per cent of the diet, corresponding to a daily intake of 254 mg.

Garcia *et al.* (2005) revealed that Japanese quails of 5 to 24 weeks of age did not require dietary lysine levels higher than 1.1 per cent and daily intake higher than 275 mg per quail per day. Dietary methionine plus cystine levels higher than 0.7 per cent and daily intake higher than 174 mg per quail per day were not recommended.

Liu *et al.* (2005) concluded that a methionine plus cystine to lysine ratio of 0.75 was adequate for laying hens and the quality of a low protein diet with 14.3 or 13.6 per cent CP can be improved by adding lysine, when methionine plus cystine to lysine ratio is maintained at 0.75.

Solarte *et al.* (2005) determined the total sulphur amino acid (TSAA) requirement in laying hens for maximum egg production, egg weight, egg mass, body weight gain and FCR as 0.658, 0.681, 0.664, 0.683 and 0.665 per cent respectively. The mean of TSAA requirements for all the above traits was 0.67 per cent.

Esquerra and Leeson (2006) opined that whether the requirements for specific amino acids change during heat stress is controversial and that the temperature effect on lysine requirements for broilers was sex-dependent, remaining unchanged for male broilers but increasing for females.

2.3 BODY WEIGHT

Damron and Harms (1973) found that each increment of SAA up to 0.47 per cent in the diet of Dekalb pullets supported a significant increase in body weight (from 1374 to 1767 g) in 10 months experiment and increasing SAA above 0.47 per cent level provided no significant effect.

Latshaw (1976) observed that the final body weight of hens fed a basal diet with 0.46 per cent lysine and 0.56 per cent SAA supplemented with 0.05 per cent lysine for 26 weeks period was improved significantly from 1.82 to 1.92 kg. The body weight of laying hens increased significantly from 1.815 to 1.925 kg when a diet with 0.45 per cent lysine was supplemented with 0.08 per cent lysine and then reduced slightly to 1.875 kg with 0.12 per cent lysine supplementation.

Arscott and Goeger (1981) found that the body weight of Japanese quails at the end of 40 weeks laying period varied from 137 to 140 g when they were fed a ration with 21 per cent protein, 1.13 per cent lysine and 0.31 per cent methionine and it varied from 131 to 135 g with a negative control ration having 15 per cent protein, 0.71 per cent lysine and 0.26 per cent methionine. When the negative control ration was supplemented with 0.05, 0.1 and 0.15 per cent methionine or 0.05 per cent lysine, the final body weight was 123-132, 132, 128 and 129 g, respectively. But none of the values varied significantly.

Sachdev and Ahuja (1986) reported that egg line Japanese quails having a body weight of 181 to 200 g at 6 weeks of age produced 206 eggs, while those with 161-180 g body weight produced only 172 eggs up to 50 weeks of age.

Mishra *et al.* (1993) observed that diet containing 24 per cent crude protein supplemented with 0.1 per cent each of methionine and lysine appeared to be as efficient as the diet containing 27 per cent crude protein to maximise the growth performance traits in Japanese quail broilers up to 5 weeks of age.

Shrivastav *et al.* (1993) reported a body weight gain of 18.8 g in female breeder Japanese quails in 100 days of production fed a ration having 22 per cent CP, 2750 kcal ME per kg, 1 per cent lysine and 0.7 per cent methionine plus cystine.

Harms and Russell (1995) found a reduced body weight gain in Arbor acres broiler breeder hens as the lysine and protein content of the diet was reduced. The addition of lysine to diets containing less than 0.479 per cent lysine and 10.32 per cent protein resulted in increase in weight gain.

Shafer *et al.* (1998) observed that final body weights of commercial layers were not significantly affected by feeding methionine at 0.38, 0.46 and 0.53 per cent levels for a period of 27 weeks from 29 weeks of age.

Vidhyadharan (1998) reported that the 1.688 kg body weight of 48-week-old layers fed a diet with 18 per cent CP, 0.83 per cent lysine and 0.31 per cent methionine from 20 weeks of age was comparable with the 1.595 kg body weight of birds fed an all vegetable protein diet with 18 per cent CP, 0.75 per cent lysine and 0.24 per cent methionine supplemented with 0.3 per cent DL-methionine.

Pinto *et al.* (2003a) reported that the body weight of female Japanese quails at 23 weeks of age (145 to 148 g) was not affected by feeding varying digestible methionine plus cystine levels ranging from 0.550 to 0.774 per cent from 45 days of age.

Pinto *et al.* (2003b) observed that the body weight of female Japanese quails at 23 weeks of age (148 to 153 g) was not affected by feeding different levels of total lysine from 0.89 to 1.40 per cent with corresponding digestible lysine levels from 0.8 to 1.3 per cent in a basal ration having 19.556 per cent CP.

According to Novak *et al.* (2004) body weight gain in laying hens was affected by lysine intake during 20-63 weeks of age and by TSAA intake during 20-43 weeks of age. Hens consumed 422 mg methionine per hen per day (689 mg TSAA) during 20-43 weeks age gained the maximum weight compared to lower and higher levels. During 44 to 63 weeks of age, the hens lost body weight, but hens consumed 816 mg lysine per hen per day lost less, compared with those consumed the lower level. Overall weight gain was greatest for hens consuming the higher lysine diets.

Ozbey *et al.* (2004a) reported that broiler Japanese quails reared under a constant temperature of 35^0C had a body weight of 167.78 g at 6 weeks of age, while those reared under 18-24^0C had 177.61 g body weight.

Lekshmi (2005) obseved body weight of 160.05 g in Japanese quails at 6 weeks of age and 204.77 g at 26 weeks of age with a gain of 44.73 g in body weight on feeding a ration having 22 per cent CP and 2650 kcal per kg ME.

Sheena (2005) reported body weight of 172.24 g in Japanese quails at 6 weeks of age and 205.16 g at 26 weeks of age with a gain of 32.92 g in body weight, when a ration having 22 per cent CP, 2650 kcal per kg ME, 1.03 per cent lysine and 0.37 per cent methionine was fed from 6 weeks of age.

Solarte *et al.* (2005) noticed a quadratic effect of TSAA level on body weight gain and hens fed 0.484 per cent TSAA had the lowest and those fed 0.684 per cent had the highest body weight gain.

2.4 AGE AT SEXUAL MATURITY (ASM)

Sachdev and Ahuja (1986) observed that egg line Japanese quails having a body weight of 161 to 180 g at 6 weeks of age reached sexual maturity at 78 days of age while those with 181 to 200 g body weight reached sexual maturity at 66 days of age with an average age at sexual maturity of 73.18 days.

Padmakumar (1993) reported that the age at first egg was 55 days and age at 50 per cent production was 72 days for Japanese quails reared on 250 cm^2 floor space in cage and fed a ration with 22.9 per cent CP supplemented with 0.02 per cent L-lysine and 0.03 per cent DL-methionine.

Sreenivasaiah (1998) stated that Japanese quails start egg production by the end of sixth week and reach peak production of 90 per cent by 15 weeks of age.

Vidhyadharan (1998) could not find any significant difference in age at first egg and at 50 per cent production between layers fed a control diet with 0.83 per cent lysine and 0.31 per cent methionine and those fed a diet with same protein content, 0.75 per cent lysine and 0.24 per cent methionine supplemented with 0.3 per cent DL-methionine.

Lekshmi (2005) reported that the average age at first egg was 45.25 days and mean age at 50 per cent production was 62.5 days in Japanese quails fed a ration having 22 per cent CP and 2650 kcal per kg ME from 6 weeks of age.

Sheena (2005) observed that the average age at sexual maturity was 47 days and average age at 50 per cent production was 58 days in Japanese quails fed a ration having 22 per cent CP, 1.03 per cent lysine and 0.37 per cent methionine from 6 weeks of age.

2.5 EGG PRODUCTION

Hummel *et al.* (1965) reported improved egg production in 307 days laying period in White Leghorn (WL) pullets fed 16 per cent protein diet supplemented with 0.075 per cent methionine from 21 weeks of age. Non significant response was observed at higher levels of 0.15, 0.225 and 0.30 per cent methionine. Supplemental lysine at 0.1 per cent level did not influence egg production.

A diet containing 0.528 per cent TSAA, 0.308 per cent methionine and 14.3 per cent CP supported significantly higher rate of egg production (66.7 per cent HD) than a diet with 0.412 per cent TSAA, 0.228 per cent methionine and 11.84 per cent protein (61.1 per cent HD) in an experiment for 10 months in Dekalb pullets (Damron and Harms, 1973).

Latshaw (1976) compared a diet with 0.46 per cent lysine and 0.56 per cent SAA and another diet with 0.57 per cent lysine and 0.62 per cent SAA, with these diets supplemented with varying levels of L-lysine ranging from zero to 0.15 per cent in laying hens from 32 to 60 weeks age. Egg production was lowest (73.7 per cent) in hens fed ration having 0.46 per cent lysine but was comparable to all other groups.

Waldroup *et al.* (1976) observed that the supplementation of 200 mg per hen per day of lysine and methionine had no significant effect on hen day egg production when daily protein intake was 14.5 g per hen per day (HD production reduced from 47.8 to 45.9 per cent) or 16 g per hen per day (HD production increased from 49.5 to 51.9 per cent) in broiler breeder hens.

Johri and Vohra (1977) reported that female Japanese quail breeders fed purified diet with 20.3 per cent CP, 2690 kcal per kg ME and 0.36 per cent DL- methionine for a period of 44 days starting from 50 per cent production had a HD production of 62.6 per cent. A ration having 24 per cent CP, 2700 kcal ME per kg and 0.43 per cent DL-methionine fed quails gave 60 per cent HD production.

Yamane *et al.* (1979) observed that Japanese quails fed a diet with 19.2 per cent CP and 13.21 MJ ME per kg containing 1.06 per cent lysine and 0.55 per cent methionine plus cystine from 90 to 135 days of age had a bird day production of 83.6 per cent and it increased to 88.8 per cent when the CP of the diet was 23.2 per cent containing 1.44 per cent lysine and 0.69 per cent methionine plus cystine.

Arscott and Goeger (1981) reported that the average egg production of Japanese quails fed a positive control diet with 21 per cent protein, 1.13 per cent lysine and 0.31 per cent methionine was 66.5 per cent and it was reduced to 51.13 per cent in quails fed a negative control ration with 15, 0.71 and 0.26 per cent protein, lysine and methionine respectively. Addition of 0.05 per cent DL-methionine to the negative control ration increased egg production to 62.1 per cent, which was comparable to that of positive control group. Addition of 0.05 per cent lysine to the negative control ration could not increase egg production instead, gave a numerical reduction to 48.1 per cent. In another trial, the positive and negative control rations gave 61.5 and 46.8

per cent production respectively. Addition of 0.1 and 0.15 per cent DL-methionine to the negative control ration significantly increased egg production to 57.1 and 52.0 respectively, compared to the negative control ration. Egg production of quails fed 0.15 per cent DL-methionine was significantly below that of the quails fed 0.1 per cent DL-methionine.

Ichhponani *et al.* (1983) conducted an experiment for 254 days in WL hens by feeding all vegetable protein maize-GNC based diet having 15.5 per cent CP supplemented with 0.1 per cent each of lysine and methionine and resulted in 67.4 per cent egg production, which was significantly higher than that of the basal diet without supplementation and equivalent to the 67.7 per cent production in hens fed a diet containing 5 per cent fish meal having 16.9 per cent CP. There was a numerical reduction in egg production to 64.8 per cent when the supplemental level of lysine and methionine was at 0.2 per cent each.

Schutte *et al.* (1983) found that in a basal diet with 14 per cent CP and 0.7 per cent lysine, increasing the SAA content from 0.55 to 0.6 per cent had no significant effect on egg production up to 52 weeks of lay. The trend towards an increased egg production from zero to 36 weeks of lay was virtually offset by slightly lower egg production from 37 to 52 weeks of lay.

Penz and Jensen (1991) could not find any significant difference in rate of egg production in WL pullets of 28 weeks of age fed a 16 per cent CP ration having 0.82 per cent lysine and 0.57 per cent methionine plus cystine, a second group fed 13 per cent CP ration having 0.61 per cent lysine and 0.57 per cent methionine plus cystine and a third group of birds fed this 13 per cent CP ration supplemented with 0.04 or 0.17 per cent of L-lysine or 0.09 per cent DL-methionine in an 18 week experiment.

Shrivastav *et al.* (1993) found that breeding Japanese quails had a HDP of 78.4 per cent for 100 days of production when fed a diet containing 22 per cent CP, 2750 kcal ME per kg, 1 per cent lysine and 0.7 per cent methionine plus cystine.

Shukla *et al.* (1993) found a HDP of 80.6 per cent from 7 to 19 weeks of age in Japanese quails fed a diet having 21 per cent CP, 2728 kcal per kg ME supplemented with 0.11 per cent each of L-lysine and DL-methionine to give total levels of 1.1 per cent lysine and 0.5 per cent methionine.

Schutte *et al.* (1994) reported that the egg production per hen-day from 25 to 77 weeks of age was not significantly different in WL layers fed different levels of methionine ranging from 0.1 to 0.25 per cent.

Ravikiran and Devegowda (1998) observed that egg production was significantly improved to 90.8 and 92.6 per cent in 28-week-old layers fed basal diet supplemented with 0.04 and 0.08 per cent methionine respectively, in comparison with the 87.7 per cent production of the control group received basal diet with 18 per cent CP, 0.88 per cent lysine and 0.32 per cent methionine for 6 weeks during summer stress (32-39^{0}C). But the difference between the two supplemented groups was non significant.

Shafer *et al.* (1998) observed that egg production was significantly higher in 29-week-old commercial layers fed 0.46 per cent methionine for 27 weeks period compared to 0.53 per cent methionine intake. Egg production of hens fed 0.38 per cent methionine was not significantly different from both the above groups.

Vidhyadharan (1998) reported that the 61.1 per cent HDP and 59.4 HHP egg production upto 48 weeks of age in layers fed diet with 0.83 per cent lysine and 0.31 per cent methionine from 20 weeks of age was comparable with the 60.9 HDP and 58.9 HHP production of layers fed all vegetable protein diet with same protein level, 0.75 per cent lysine and 0.24 per cent methionine supplemented with 0.3 per cent DL-methionine.

Shrivastav and Panda (1999) reported that a dietary lysine concentration of 0.8 per cent and SAA content of 0.6 per cent was adequate for optimum production performance of Japanese quails and the requirements of these amino acids were not directly related to dietary protein concentrations between 16 to 22 per cent.

Pinto *et al.* (2003a) formulated a basal ration with 19.29 per cent CP, 2900 kcal ME per kg, 1 per cent total lysine and 0.55 per cent digestible methionine plus cystine for Japanese quails from 45 to 161 days of age. In quails fed supplementary DL-methionine to get digestible methionine plus cystine levels of 0.550, 0.683, 0.728 and 0.774 per cent, the egg production per cent was 79.6, 89.2, 89.2 and 89.5 respectively.

Pinto *et al.* (2003b) observed egg production per cent of 82.0, 85.3, 83.2 and 79.3 per cent showing a quadratic effect, for Japanese quails fed diets having 0.998, 1.2, 1.3 and 1.4 per cent respectively of total lysine when the methionine plus cystine to lysine ratio was kept constant at 0.8 by supplementing varying levels of DL-methionine. The experiment was from 49 to 161 days of age by feeding a basal ration with 19.556 per cent CP, 2900 kcal per kg ME and 0.89 per cent total lysine.

Soares *et al.* (2003) reported that Japanese quail layers fed a diet having 22 per cent CP, 1.203 per cent lysine and 0.679 per cent methionine plus cystine from 7 to 14 weeks of age had 76.7 per cent egg production.

There was no significant effect on egg production in 21-week-old Hy-Line W36 hens upon increasing dietary lysine levels from 0.79 to 0.97 per cent without adding synthetic lysine, maintaining a constant methionine plus cystine to lysine ratio of 0.83 for a period of 16 weeks (Sohail *et al.*, 2003).

Amaefule *et al.* (2004) observed that the HD egg production in the control group, 0.1 per cent lysine supplemented group, 0.1 per cent methionine supplemented group, and the combination group were 48.4, 44.8, 51.7 and 48.3 per cent respectively in

Noven Nera layers that had been in lay for 10 months and fed a basal diet with 16 per cent CP. But none of the values differed significantly.

Novak *et al.* (2004) revealed that overall egg production was not significantly affected by lysine at 800 or 900 mg per hen per day or methionine at 349, 422, 521 or 591 mg per hen per day in Dekalb delta laying hens from 20 to 43 weeks of age.

In an experiment conducted by Garcia *et al.* (2005) egg production in Japanese quails was not improved by methionine plus cystine levels higher than 0.7 per cent, although production increased from 74.5 to 74.6 and then to 75.5 per cent by increasing the methionine plus cystine from 0.7 to 0.875 and to 1.05 per cent in a 24 weeks experiment from 5weeks of age. Increasing the lysine level from 1.1 to 1.375 per cent significantly reduced the egg production from 75.9 to 73.7 per cent.

Lekshmi (2005) reported 90.3 HHN and 93.5 HDN with corresponding percentages of 64.4 and 66.9 in Japanese quail layers from 6 to 26 weeks of age on feeding a ration having 22 per cent CP and 2650 kcal per kg ME.

Liu *et al.* (2005) observed that the methionine plus cysteine to lysine ratio ranging from 0.75 to 0.90 had no influence on egg production (average 83 per cent) in 37-week-old Hy-Line W-36 hens. The diets had 15.4 per cent CP, 0.825 per cent total lysine and varying levels of methionine plus cystine ranging from 0.619 to 0.743.

Martinez *et al.* (2005) found that diet with 15.7 per cent CP and 0.42 per cent digestible methionine with a range of digestible lysine levels from 0.47 to 0.87 per cent, increased the egg production up to 0.67 per cent digestible lysine (88.5 per cent production) in 24-week-old Isa Babcock WL hens for a period of 10 weeks.

Sheena (2005) reported a HHN of 83.7, HDN of 85.1 and corresponding percentages of 59.6 and 61.1 from 6 to 26 weeks of age in Japanese quail layers when fed a ration having 22 per cent CP, 1.03 per cent lysine and 0.37 per cent methionine.

Solarte *et al.* (2005) noted that Lohmann hens (white-egg laying) of 22 weeks of age fed total methionine levels ranging from 0.234 to 0.484 per cent for a period of 16 weeks, had shown increased egg production until the level of 0.434 per cent and increasing the level from 0.434 to 0.484 per cent did not improve egg production. They were fed all-vegetable basal ration containing 14.4 per cent CP, 0.71 per cent lysine, 0.234 per cent methionine and 0.484 per cent methionine plus cystine.

2.6 EGG WEIGHT

Hummel *et al.* (1965) reported that supplementation of 0.1 per cent lysine did not influence egg size in WL pullets fed 16 per cent protein diet for 307 days from 21 weeks of age.

Damron and Harms (1973) found that average egg weight in laying pullets was significantly improved (59.3 g) as the SAA level increased to 0.47 per cent (containing 0.268 per cent methionine) and further increase of SAA did not improve egg weight.

Latshaw (1976) observed that addition of 0.05 per cent lysine to a diet with 0.46 per cent lysine and 0.56 per cent SAA increased egg weight significantly from to 58.5 to 60.2 g and it was comparable to the egg weight supported by higher levels of lysine (0.10 or 0.15 per cent). Hens fed basal diet with 0.57 per cent lysine and 0.62 per cent SAA had 60.4 g egg weight and was not significantly improved by adding further lysine.

In a study for 44 days Johri and Vohra (1977) fed purified diet with 20.3 per cent CP, 2690 kcal per kg ME and 0.36 per cent DL-methionine to Japanese quail breeder hens at 50 per cent production and reported an average egg weight of 9.0 g. The egg weight was 8.9 g in quails fed a ration having 24 per cent CP, 2700 kcal ME per kg and 0.43 per cent DL-methionine.

Egg weight of Japanese quails fed a ration with 21 per cent protein, 1.13 per cent lysine and 0.31 per cent methionine ranged from 9.6 to 9.8 g and those fed a negative control ration with 15 per cent protein, 0.71 per cent lysine and 0.26 per cent methionine produced eggs weighing 8.9 to 9.2 g, which were statistically comparable. Addition of 0.05, 0.1 or 0.15 per cent DL-methionine or 0.05 per cent lysine to the negative control ration could not change the egg weight significantly. (Arscott and Goeger, 1981).

Ichhponani *et al.* (1983) concluded from two experiments in WL hens that lysine plus methionine had no effect on egg size of hens when fed all vegetable protein diet. In the first experiment 15.5 per cent CP diet was supplemented with 0.1 per cent each of lysine and methionine and in second experiment 16.7 per cent CP diet was supplemented with 0.05 or 0.1 per cent each of lysine and methionine.

Hiramoto *et al.* (1990) found significant reduction in egg weight from 55.7 to 51.9 g by the deficiency of methionine, while lysine deficiency did not cause significant reduction in egg weight when WL hens at 10 months of age were fed diets having 14.5 per cent CP and varying levels of lysine and methionine for a period of 14 days.

Koelkebeck *et al.* (1991) did not find significant difference in egg weight which ranged from 57 to 58.9 g in WL hens at peak production (31 weeks of age) fed a basal diet having 16 per cent CP and 0.55 per cent TSAA, supplemented with 1 per cent lysine or methionine for a period of 4 weeks, although 1 per cent methionine supplemented group showed a numerical increase in egg weight.

Padmakumar (1993) reported that the mean egg weight of Japanese quails were 10.0, 11.0, 10.6, 11.2 and 10.6 g based on the individual egg weights taken at the last three days of 28-day periods from sixth week onwards when reared on 250 cm^2 floor space in cages. They were fed a ration with 22.9 per cent CP supplemented with 0.02 per cent L-lysine and 0.03 per cent DL-methionine.

Shrivastav *et al.* (1993) found that breeding Japanese quails had a mean egg weight of 10.281 g in 100 days of production when fed a diet having 22 per cent CP, 2750 kcal ME per kg, 1 per cent lysine and 0.7 per cent methionine plus cystine.

Shukla *et al.* (1993) observed that the average egg weight from 7 to 19 weeks of age was 11.56g in Japanese quails fed a diet having 21 per cent CP and 2728 kcal per kg ME supplemented with 0.11 per cent each of L-lysine and DL-methionine to get 1.1 per cent lysine and 0.5 per cent methionine.

Schutte *et al.* (1994) reported that the egg weight (ranging from 53.8 to 55.4 g) was not significantly different in layers fed different levels of methionine ranging from 0.1 to 0.25 per cent.

Shafer *et al.* (1998) observed significantly higher egg weight in laying hens fed 0.46 and 0.53 per cent methionine compared to 0.38 per cent methionine in diets.

Sreenivasaiah (1998) stated that Japanese quails lay eggs weighing on an average 10 g ranging from 6.4 to 13.8 g.

Vidhyadharan (1998) reported that the mean egg weight of 52.4 g in layers fed diet with 0.83 per cent lysine and 0.31 per cent methionine was comparable with the 52.4 g egg weight of layers fed all vegetable protein diet with same CP, 0.75 per cent lysine and 0.24 per cent methionine supplemented with 0.3 per cent DL-methionine.

Pinto *et al.* (2003a) found that the egg weight of Japanese quails fed digestible methionine plus cystine levels of 0.550, 0.683, 0.728 and 0.774 per cent was 9.37, 10.57, 10.71 and 10.69 g respectively showing a quadratic effect.

Pinto *et al.* (2003b) observed egg weight of 9.89, 10.59, 10.50 and 10.47 g for Japanese quails fed diets having 0.998, 1.2, 1.3 and 1.4 per cent respectively of total lysine when the methionine plus cystine to lysine ratio was kept constant at 0.8.

Japanese quail layers fed diet having 22 per cent CP, 1.203 per cent lysine and 0.679 per cent methionine plus cystine from 7 to 14 weeks of age had an average egg weight of 9.32 g (Soares *et al.*, 2003).

Sohail *et al.* (2003) revealed that egg weight in 21-week-old Hy-Line hens increased linearly as the lysine level in the diet increased from 0.79 to 0.97 per cent without adding synthetic lysine and maintaining a constant methionine plus cystine to lysine ratio of 0.83. Adding synthetic lysine (0.097 per cent) to these diets had no influence on egg weight.

The average egg weight of Noven Nera layers in the control group, groups supplemented with 0.1 per cent methionine, 0.1 per cent lysine and the combination group were 66.1, 68.4, 66.2 and 66.8 g respectively, which did not differ significantly (Amaefule *et al.*, 2004).

Novak *et al.* (2004) found that the effects of lysine and TSAA on egg weight were not significant during 20-43 weeks of age whereas, 44-63 weeks old hens showed significant effect with heavier eggs in hens fed the high lysine diet. Increasing lysine intake from 860 to 959 mg per hen per day improved average egg weight from 59.0 to 60.2 g. The lysine requirement suggested to maximise egg weight was 959 mg per hen per day for early production and 816 mg per hen per day for late egg production.

Increasing methionine to 0.44 per cent in a 14 per cent CP diet by adding 0.18 per cent DL-methionine improved egg weight (54.8 g) same as that of the control group (54.9 g) fed 16 per cent CP diet with 0.38 per cent methionine (Bunchasak and Silapasorn, 2005).

Garcia *et al.* (2005) observed a significant interaction between protein and methionine plus cystine levels in the diet on egg weight of Japanese quails. Quails fed a ration having 18 per cent CP and 0.875 per cent methionine plus cystine had significantly higher egg weight (11.6 g) than those fed 0.7 per cent methionine plus cystine (11.4 g), while the quails fed 1.05 per cent methionine plus cystine showed intermediate egg weight (11.5 g). In 16 or 20 per cent CP diets, lysine at 1.1 or 1.375 per cent level and varying levels of methionine plus cystine did not affect egg weight significantly.

Lekshmi (2005) reported an average egg weight of 10.8 g from 6 to 26 weeks of age in Japanese quail layers when fed a ration having 22 per cent CP.

Liu *et al.* (2005) observed that the methionine plus cysteine to lysine ratio ranging from 0.75 to 0.90 had no influence on egg weight (average 60.6 g) in 37-week-old Hy-Line hens.

Sheena (2005) reported an average egg weight of 11.1 g from 6 to 26 weeks of age in Japanese quail layers when fed a ration having 22 per cent CP, 1.03 per cent lysine and 0.37 per cent methionine.

Solarte *et al.* (2005) noticed that increasing methionine level from 0.234 to 0.434 per cent increased egg weight in laying hens and further increase to 0.484 per cent did not produce any improvement.

2.7 EGG MASS

Koelkebeck *et al.* (1991) reported that WL hens at peak production (31 weeks of age) fed diet having 16 per cent CP and 0.55 per cent TSAA supplemented with 1 per cent of lysine or methionine for a period of 4 weeks did not show any significant difference in egg mass represented as grams of egg per hen per day compared to the birds fed unsupplemented diet.

Summers *et al.* (1991) observed that Leghorn hens at 16 weeks of age fed diet with 10 per cent CP supplemented with 0.32 per cent DL-methionine for 24 weeks period showed 10 per cent increase in egg mass and those supplemented with 0.32 per cent

DL-methionine and 0.26 per cent L-lysine had a 26 per cent improvement in egg mass compared to the non-supplemented diet.

Shukla *et al.* (1993) found that the total egg mass was 782.8 g per quail from 7 to 19 weeks of age in Japanese quails fed a diet having 21 per cent CP, 2728 kcal per kg ME, 1.1 per cent lysine and 0.5 per cent methionine.

Schutte *et al.* (1994) conducted experiments in WL layers from 25-77 weeks of age by feeding a basal diet containing 15.4 per cent CP, 0.78 per cent lysine and 0.24 per cent methionine supplemented with DL-methionine ranging from 0.1 to 0.25 per cent and noticed that the egg mass was not significantly different among the treatments and ranged from 53.8 to 55.4 g per hen per day.

Harms and Russell (1995) noticed that broiler breeder hens had reduced egg mass as the lysine and protein content of the basal diet reduced. Lysine supplementation of diets with lower protein levels could improve egg mass significantly though it was significantly lower than that of hens fed high protein feed.

Pinto *et al.* (2003a) reported that the egg mass of Japanese quails fed digestible methionine plus cystine levels of 0.550, 0.683, 0.728 and 0.774 per cent was 7.46, 9.43, 9.55 and 9.58 g per quail per day respectively. In another experiment Pinto *et al.* (2003b) observed egg mass of 8.11, 9.04, 8.74 and 8.31 g per quail per day showing a quadratic effect in Japanese quails fed diets having 0.998, 1.2, 1.3 and 1.4 per cent respectively of total lysine when the methionine plus cystine to lysine ratio was kept constant at 0.8.

Bunchasak and Silapasorn (2005) observed that egg mass of hens fed low CP (14 per cent) diet with various levels of methionine up to 0.44 per cent (40.98 g egg per hen per day) was significantly poorer than that of the control group (42.05 g egg per hen per day) fed a diet with 16 per cent CP and 0.38 per cent methionine at an average temperature of 31.6°C and R.H. of 66.7 per cent.

Garcia *et al.* (2005) revealed that Japanese quails fed 1.375 per cent lysine in the diet had a significantly lower egg mass per day (8.52 g) than those fed 1.1 per cent lysine. Methionine plus cystine levels ranging from 0.7 to 1.05 per cent did not affect egg mass significantly.

Liu *et al.* (2005) observed that the methionine plus cysteine to lysine ratio ranging from 0.75 to 0.90 had no influence on egg mass (average 50.2 g per hen per day) in 37-week-old hens.

Martinez *et al.* (2005) observed that egg mass per bird per day was improved in WL hens fed diets having digestible SAA levels ranging from 0.41 to 0.65 per cent until the level of 0.59 per cent, wherein a higher egg mass of 50.1 g per bird per day was recorded.

Solarte *et al.* (2005) noted that increasing methionine level from 0.234 to 0.434 per cent increased egg mass and further increase of methionine to 0.484 per cent had no improvement on egg mass in laying hens.

2.8 FEED CONSUMPTION

Latshaw (1976) carried out a study in laying hens of 32 weeks of age by feeding a basal diet either with 0.46 per cent lysine and 0.56 per cent SAA or with 0.57 per cent lysine and 0.62 per cent SAA. The feed consumption ranged from 116 to 119 gram per hen per day and was not affected by the supplementation of L-lysine ranging from zero to 0.15 per cent until 60 weeks of age.

Maurice and Jensen (1978) observed that Japanese quails fed a diet having 23.2 per cent CP, 11.32 MJ ME per kg, 0.75 per cent TSAA and 1.4 per cent lysine from 20 to 26 weeks of age had a feed consumption of 26.7 g per hen per day. When a similar ration with 12.17 MJ ME per kg was fed from 8 to 16 weeks of age, the feed consumption was 25.2 g.

Layer Japanese quails fed a casein-soyabean diet containing 16 per cent protein and 2969 kcal per kg ME showed feed consumption of about 22 g per quail per day (Allen and Young, 1980).

Arscott and Goeger (1981) reported that the average daily feed consumption varied from 21 to 22 g for Japanese quails fed a ration with 21 per cent CP, 1.13 per cent lysine and 0.31 methionine and 19 to 21 g for those fed a negative control ration with 15, 0.71 and 0.26 per cent protein, lysine and methionine respectively. Addition of 0.05 to 0.15 per cent DL-methionine or 0.05 per cent lysine to the negative control ration did not change the feed intake significantly.

Hiramoto *et al.* (1990) observed significant reduction in feed intake from 102.9 to 91 g and from 99.1 to 71.8 g per hen per day by the deficiency of methionine and lysine respectively when WL hens of 10 months of age were fed diets having 14.5 per cent CP and varying levels of lysine and methionine for a period of 14 days.

Koelkebeck *et al.* (1991) did not find significant difference in feed intake in WL hens at 31 weeks of age fed a diet having 16 per cent CP and 0.55 per cent TSAA, supplemented with 1 per cent of lysine or methionine for a period of 4 weeks.

Penz and Jensen (1991) found no significant difference in daily feed consumption among the WL pullets fed a non-supplemented diet with 16 or 13 per cent CP and the latter supplemented with lysine or methionine or both for a period of 6 weeks.

Padmakumar (1993) reported that the average daily feed consumption of Japanese quails was 20.3, 23.1, 22.4, 23.5 and 24.6 g per quail for the periods of 6 – 10, 11 – 15, 16 – 20, 21- 25 and 26 – 30 weeks of age respectively when fed a ration with 22.9 per cent CP and reared on 250 cm^2 floor space in cages.

Shukla *et al.* (1993) found that the feed consumption was 27.7 g per day in Japanese quails fed a diet having 1.1 per cent lysine and 0.5 per cent methionine from 7 to 19 weeks of age.

Schutte *et al.* (1994) reported that daily feed intake of laying hens increased significantly when DL-methionine supplementation was increased from zero to 0.05 per cent and there was no significant change in daily feed intake at higher levels of DL-methionine up to 0.165 per cent.

Ravikiran and Devegowda (1998) reported that daily feed consumption per hen was significantly reduced from 108.3 g to 104.8 and 104.3 g when a control diet with 18 per cent CP having 0.32 per cent methionine was supplemented with 0.04 and 0.08 per cent methionine respectively during summer stress (32-39^{0}C) in commercial layers.

Shafer *et al.* (1998) observed that 29-weeks-old commercial layers fed diet with 16.5 per cent CP for 27 weeks had significantly higher feed consumption per hen per day when the diet was having 0.53 per cent methionine compared with methionine levels of 0.38 and 0.46 per cent.

Sreenivasaiah (1998) stated that Japanese quails consumed 25 to 28 g feed per bird per day during production period.

Vidhyadharan (1998) reported that the average daily feed intake of 115.7 g in layers fed diet with 0.83 per cent lysine and 0.31 per cent methionine from 20 to 48 weeks of age was comparable with the 110.1 g feed intake of layers fed all vegetable protein diet with same CP, 0.75 per cent lysine and 0.24 per cent methionine supplemented with 0.3 per cent DL-methionine.

Pinto *et al.* (2003a) found that the daily feed intake of Japanese quails fed digestible methionine plus cystine levels of 0.550, 0.683, 0.728 and 0.774 per cent was 19.82, 20.95, 22.25 and 22.07 g respectively, from 45 to 161 days of age.

Pinto *et al.* (2003b) observed feed intake of 21.54, 23.14 and 22.70 g per day for Japanese quails from 49 to 161 days of age fed diets having 0.998, 1.2 and 1.3 per cent respectively of total lysine when the methionine plus cystine to lysine ratio was kept constant at 0.8.

The feed intake of Japanese quail layers was 23 g per bird per day when fed diet having 22 per cent CP, 1.203 per cent lysine and 0.679 per cent methionine plus cystine from 42 to 98 days of age (Soares *et al.*, 2003).

Sohail *et al.* (2003) reported that incorporation of synthetic lysine at 0.097 per cent for a period of 16 weeks had no significant effect on feed consumption in Hy-Line hens of 21 weeks of age.

According to Novak *et al.* (2004) the overall feed consumption from 20-43 weeks of age was not significantly affected by lysine at 800 or 900 mg per hen per day or methionine at 349, 521 or 591 mg per hen per day in Dekalb delta laying hens and the feed consumption in various groups ranged from 96.3 to 98 g per hen per day.

Garcia *et al.* (2005) reported that daily feed intake of Japanese quails was not significantly affected by increasing the lysine content of feed from 1.1 to 1.375 per cent and it remained between 24.9 to 25 g per quail per day.

Lekshmi (2005) reported that the average feed consumption was 29 g per quail per day from 6 to 26 weeks of age in Japanese quail layers when fed a ration having 22 per cent CP and 2650 kcal per kg ME.

Liu *et al.* (2005) observed that the methionine plus cysteine to lysine ratio ranging from 0.75 to 0.90 had no influence on feed consumption (average 98.5 g per hen per day) in 37-week-old hens.

Sheena (2005) reported that the average feed consumption was 29.15 g per quail per day from 6 to 26 weeks of age in Japanese quail layers when fed a ration having 1.03 per cent lysine and 0.37 per cent methionine.

Solarte *et al.* (2005) noted that increasing methionine from 0.234 to 0.334 per cent increased feed intake from 91.9 to 108 g per hen per day in laying hens.

2.9 FEED CONVERSION RATIO (FCR)

Hummel *et al.* (1965) found that supplementing lysine at 0.1 per cent level did not influence feed efficiency in WL pullets fed 16 per cent CP diet. However, FCR was improved with each increment of supplemental methionine from zero to 0.3 per cent.

Arscott and Goeger (1981) reported that Japanese quails fed a positive control ration with 21 per cent protein, 1.13 per cent lysine and 0.31 per cent methionine required 373g of feed per dozen eggs while those fed a negative control ration with 15, 0.71 and 0.26 per cent protein, lysine and methionine respectively required 448 g. Addition of 0.05 per cent lysine or DL- methionine to the negative control ration gave values of 476 and 398 g, respectively and these values were comparable to that of the controls. Addition of either 0.1 or 0.15 per cent DL-methionine to the negative control ration significantly reduced the feed required per dozen eggs from 574g to 463 and 468 g respectively and these were comparable to the FCR of the positive control group (422 g).

Ichhponani *et al.* (1983) reported that the feed consumed per kg egg mass was significantly lower in lysine and methionine supplemented (0.1 or 0.2 per cent each) hens compared to the control group fed non-supplemented all vegetable protein diet with 15.5 per cent CP. Among the supplemented groups, FCR was numerically better in the group with 0.1 per cent each of lysine and methionine supplementation (2.459) than those with 0.2 per cent each of lysine and methionine supplementation (2.544).

Schutte *et al.* (1983) observed that feed utilisation for egg production (kg per kg egg) was improved significantly from 2.60 to 2.47 by increasing the supplemental level of methionine from 0.05 to 0.1 per cent in a basal diet with 14 per cent CP, 0.5 per cent SAA, and 0.73 per cent lysine during a 52 weeks laying period.

Shrivastav and Panda (1987) reported that the FCR in growing Japanese quails from zero to 3 weeks of age was improved significantly from 2.95 to 2.30 by increasing the dietary methionine level from 0.38 to 0.58 per cent. During 3 to 5 weeks of age FCR improved significantly from 4.13 to 3.57 as the methionine level increased from 0.38 to 0.48 per cent. Further increase in methionine up to 0.68 per cent did not show any significant effect.

According to Koelkebeck *et al.* (1991), WL hens at peak production fed a diet having 16 per cent CP and 0.55 per cent TSAA supplemented with 1 per cent of lysine or methionine for a period of 4 weeks had no significant variation in feed efficiency.

Shrivastav *et al.* (1993) found that breeding Japanese quails had a feed efficiency of 4.272 kg per kg egg mass for 100 days of production when fed a diet with 22 per cent CP, 2750 kcal ME per kg, 1 per cent lysine and 0.7 per cent methionine plus cystine.

Shukla *et al.* (1993) found that the FCR per kg egg mass was 2.98 in Japanese quails fed a diet with 21 per cent CP, 1.1 per cent lysine and 0.5 per cent methionine from 7 to 19 weeks of age.

Schutte *et al.* (1994) reported that feed conversion efficiency in laying hens improved with increasing dietary methionine levels, the effect of 0.165 per cent level being significantly different from those of lower levels of supplementation.

Sreenivasaiah (1998) stated that Japanese quails have an average feed efficiency of 3.8 on egg mass basis and during maximum production period the FCR was 3.3.

Vidhyadharan (1998) reported that the FCR of 2.11 kg per dozen eggs in layers fed diet with 0.83 per cent lysine and 0.31 per cent methionine from 20 to 48 weeks of age was comparable with the FCR (1.99) of layers fed an all vegetable protein diet with same CP, 0.75 per cent lysine and 0.24 per cent methionine supplemented with 0.3 per cent DL-methionine.

Pinto *et al.* (2003a) found that when the digestible methionine plus cystine level was 0.550, 0.683, 0.728 and 0.774 in a basal ration with 19.29 per cent CP, the feed to gain ratio was 2.12, 1.98, 2.08 and 2.06 respectively and was not significantly affected by the level of methionine plus cystine in Japanese quails from 45 to 161 days of age. In another experiment Pinto *et al.* (2003b) observed feed to gain ratio of 2.66, 2.57, 2.60 and 2.82 for Japanese quails fed diets having 0.998, 1.2, 1.3 and 1.4 per cent respectively of total lysine when the methionine plus cystine to lysine ratio was kept constant at 0.8.

Japanese quail layers showed an FCR of 0.44 kg per dozen egg when they were fed a diet having 22 per cent CP, 1.203 per cent lysine and 0.679 per cent methionine plus cystine from 42 to 98 days of age (Soares *et al.*, 2003).

Feed efficiency was linearly improved with increased intake of TSAA in Dekalb delta layers during 20-43 weeks of age due to non significant effects of reduced feed consumption and increased egg mass (Novak *et al.*, 2004).

Garcia *et al.* (2005) revealed that FCR in Japanese quails was 0.41 kg per dozen eggs irrespective of the levels of methionine plus cystine ranging from 0.7 to 1.05 per cent and when expressed as kg feed per kg eggs FCR was 3.01 with 0.7 per cent methionine plus cystine and it did not improve significantly with higher levels. Increasing the lysine level from 1.1 to 1.375 per cent depressed FCR significantly from 0.4 to 0.42 per dozen eggs and from 2.94 to 3.02 per kg eggs. They concluded that a lysine level between 1 to 1.1 per cent is adequate for the optimum FCR.

Lekshmi (2005) reported a feed efficiency of 0.53 per dozen eggs from 6 to 26 weeks of age in Japanese quail layers, when fed a ration having 22 per cent CP.

Liu *et al.* (2005) observed that the methionine plus cysteine to lysine ratio ranging from 0.75 to 0.90 had no influence on FCR per gram of egg (average 1.98) in 37-week-old hens.

Martinez *et al.* (2005) observed that according to increases in digestible lysine in a 15.69 per cent CP diet, the FCR was improved until the level of 0.67 per cent digestible lysine with the best FCR of 1.85 in 24-week-old WL hens for a period of 10 weeks. In a second experiment as the SAA level increased in the diet, the FCR improved up to a digestible SAA level of 0.59 per cent with the best FCR of 1.80.

Sheena (2005) reported a feed efficiency of 0.67 per dozen eggs from 6 to 26 weeks of age for Japanese quail layers when fed a ration having 22 per cent CP, 1.03 per cent lysine and 0.37 per cent methionine.

Solarte *et al.* (2005) noted that the FCR (gram feed per gram egg) was improved as methionine level increased from 0.234 to 0.434 per cent and further increase to 0.484 per cent had no significant effect on FCR in laying hens.

2.10 EGG QUALITY

Padmakumar (1993) observed that the shape index of eggs of Japanese quails ranged from 78.19 to 79.49 during 6 to 30 weeks of age when fed a ration with 22.9 per cent CP and reared on 250 cm^2 floor space in cage. The albumen index ranged from 0.087 to 0.112, yolk index ranged from 0.443 to 0.517, shell thickness ranged from 0.218 to 0.236 mm and Haugh unit ranged from 46.45 to 56.93.

Shrivastav *et al.* (1993) found that the eggs of breeder Japanese quails had a shape index of 77.79, albumen index of 0.107 and yolk index of 0.447 when fed a diet having 22 per cent CP, 1 per cent lysine and 0.7 per cent methionine plus cystine in 100 days production period.

Shukla *et al.* (1993) found shell thickness of 0.174 mm, albumen index of 0.103 and internal quality unit of 54.84 for Japanese quail eggs when they were fed a diet having 21 per cent CP, 1.1 per cent lysine and 0.5 per cent methionine from 7 to 19 weeks of age.

Sreenivasaiah (1998) stated that Japanese quail eggs have a shape index of 73 to 80, albumen index of 0.09 to 0.10, yolk index of 0.4 to 0.5, shell thickness of 0.1733 to 0.1833mm and Haugh unit score of 87 to 90.

Shrivastav and Panda (1999) reviewed the quail nutrition research in India and stated that a dietary lysine content of 0.8 per cent and SAA content of 0.6 per cent was adequate for optimum egg quality traits in Japanese quails and the requirements were not directly influenced by dietary protein concentrations between 16 and 22 per cent.

Amaefule *et al.* (2004) observed that 'Noven Nera' layers that had been in lay for 10 months when fed a control layer diet with 16 per cent CP and supplemented with 0.1 per cent of lysine, methionine or both, the Haugh units in different group ranged from 94.0 to 98.3. The shape index (diameter/length) and yolk index of eggs ranged from 0.72 to 0.73 and 0.38 to 0.41 respectively. The shell thickness values ranged from 0.72 to 0.73 mm. But none of the values differed significantly.

Novak *et al.* (2004) reported that Haugh units were not significantly affected by lysine or TSAA intake of hens. Shell quality with respect to specific gravity was reduced as TSAA intake increased during 44-63 weeks of age.

Lekshmi (2005) reported that Japanese quail eggs had an average shape index of 78.89, albumen index of 0.131, yolk index of 0.456, IQU of 60.16 and shell thickness of 0.184mm from 6 to 26 weeks of age when fed a ration having 22 per cent CP.

Sheena (2005) reported that Japanese quail eggs had an average shape index of 78.75, albumen index of 0.103, yolk index of 0.45, IQU of 54.59 and shell thickness of 0.188mm from 6 to 26 weeks of age when fed a ration having 22 per cent CP, 1.03 per cent lysine and 0.37 per cent methionine.

Solarte *et al.* (2005) noticed that increasing the methionine level from 0.234 to 0.484 per cent linearly reduced Haugh Unit of chicken egg from 97.07 to 94.57.

2.11 CARCASS YIELDS AND LOSSES

Pandey *et al.* (1979) reported that 5-week-old Japanese quails fasted for 12 hours had 87.17 per cent dressed weight, 65.97 per cent eviscerated weight, 5.66 per cent giblet, 2.51 per cent blood, 5.68 per cent feather and 19.66 per cent inedible portions.

Singh *et al.* (1980) noticed 93 per cent dressed yield, 65 per cent eviscerated yield and 6.1 per cent giblet yield for 8-week-old female Japanese quails. In another study Singh *et al.* (1981) concluded that skin constituted 8.5 per cent of the live weight in 8-week-old female Japanese quails.

Choudhary and Mahadevan (1983) observed that female Japanese quails lost 4.29 per cent blood and 10.5 per cent feather on slaughter at 8 weeks of age and had a dressing per cent of 86.36 and eviscerated yield of 58 per cent excluding giblet yield.

Hughes (1983) concluded that laying hens received a methionine deficient diet from 49 to 61 weeks of age had better plumage cover at neck region and crop and breast area than those received a diet with 0.33 per cent methionine. Correlation between the feather loss and the number of eggs produced was positive and significant.

Ichhponani *et al.* (1983) concluded that the effect of supplementation of lysine and methionine on weight of heart, liver and gizzard was non significant in laying hens.

Narayanankutty (1987) reported that 6-week-old Japanese quails fed a diet with 24 per cent CP and 2700 kcal ME per kg had 4.65 per cent blood loss, 6.95 per cent feather, 88.4 per cent dressed yield, 70.74 per cent eviscerated yield, 7.3 per cent giblet and 78.04 per cent R-to-C yield.

Shrivastav and Panda (1987) reported that the dressed yield of 68.95 per cent in 0.68 per cent methionine supplemented quails at 5 weeks of age was significantly higher than the 65 per cent yield in 0.38 per cent methionine supplemented group. The level of methionine from 0.38 to 0.68 per cent did not have any consistent effect on per cent feather weight at 5 weeks of age, although it was significantly higher in 0.58 per cent methionine group (5.55 per cent feather) than in 0.38 per cent methionine group (2.54 per cent). Further increase of methionine to 0.68 per cent reduced the per cent feather loss numerically to 4.98 per cent.

Hiramoto *et al.* (1990) observed that weight of the liver was significantly reduced from 42.3 to 31.8 g by the deficiency of lysine, whereas methionine deficiency did not affect liver weight when WL hens of 10 months of age were fed diets having 14.5 per cent CP and varying levels of lysine and methionine for a period of 14 days. Weight of the magnum was reduced numerically from 22.6 to 17.4 g and weight of remaining oviduct was significantly reduced from 27.2 to 20.6 g by the deficiency of lysine, while methionine deficiency did not affect these factors.

Mandal *et al.* (1993) reported 3.6 per cent blood loss, 6.81 per cent giblet and 56.43 per cent eviscerated weight when 8-week-old female Japanese quails were skin dressed.

Mishra *et al.* (1993) reported eviscerated yield of 70.1 per cent at 5 weeks of age in combined sex Japanese quails fed a starter diet with 24 per cent protein supplemented with 0.1 per cent each of DL-methionine and L-lysine giving 1.14 per cent total lysine and 0.75 per cent methionine plus cystine. The per cent eviscerated yield was 71.0 in non-supplemented group and 71.2 in those fed diet having 27 per cent CP, 1.21 per cent lysine and 0.75 per cent methionine plus cystine.

Ozbey *et al.* (2004a) reported that broiler Japanese quails of 6 weeks of age had a carcass yield of 65 to 69 per cent.

Shrivastav *et al.* (2004) found that the increase of methionine level from 0.37 to 0.52 per cent in the diet significantly increased dressed yield of Japanese quails from 68 to 69.57 per cent at 5 weeks of age.

Bunchasak and Silapasorn (2005) observed that hens fed with a low-CP (14 per cent) diet supplemented with methionine to a level of 0.26 per cent had significantly higher per cent of liver weight (1.85 per cent) than those fed a higher methionine level of 0.30 to 0.44 per cent (1.68 to 1.63 per cent liver) and the control group fed a diet with 16 per cent CP and 0.38 per cent methionine (1.62 per cent liver). The low CP diet with higher methionine levels produced similar per cent liver weight as the control group. Increasing methionine level from 0.26 to 0.44 per cent in the low CP diet improved ovary weight from 1.51 to 2.42 per cent of live weight while oviduct weight ranged from 2.66 to 3.37 per cent of live weight. Methionine addition to low-CP diet could not achieve development of reproductive organs comparable to that of the control group, in which the weights of ovary and oviduct were 2.49 and 4.30 per cent of live weight respectively.

2.12 SERUM PROTEIN AND CHOLESTEROL

Thomas and Combs (1965) reported that serum protein levels increased in 9-month-old WL hens with increasing levels of supplemental lysine from zero to 0.308 per cent in a diet with 13.3 per cent CP in an experiment for 9 weeks.

Narayanankutty (1987) reported that the serum protein level in Japanese quail was 5.87 g/dl at 6 weeks of age when a ration having 24 per cent CP and 2700kcal ME per kg was fed.

Majumdar *et al.* (1996) found that the serum cholesterol level in cage reared meat line female broiler quails ranged from 351.16 to 387.12 mg per 100 ml.

Ozbey *et al.* (2004b) reported that Japanese quails reared at a constant temperature of 35°C up to 14 weeks of age had a total protein level of 4.39 g/dl while it was significantly higher (5.06 g/dl) at temperature of 18 to 24°C. The total serum cholesterol at 18 to 24°C was 212.04 mg/dl and it increased significantly to 219.08 mg/dl at 35°C.

Sheena (2005) observed 5.51 g per cent serum protein at 26 weeks of age in layer Japanese quails fed a ration having 22 per cent CP, 1.03 per cent lysine and 0.37 per cent methionine.

2.13 LIVABILITY

In Japanese quails fed a ration with 21 per cent CP, 0.31 per cent methionine and 1.13 per cent lysine the cumulative mortality varied from 26.7 to 43.3 per cent in 40-week period. Feeding a negative control ration with 15 per cent CP, 0.26 per cent methionine and 0.71 per cent lysine resulted in cumulative mortality varying from 30 to 40 per cent. When the negative control ration was supplemented with 0.05 to 0.15 per cent methionine and 0.05 per cent lysine the per cent mortality rates did not differ significantly (Arscott and Goeger, 1981).

Schutte *et al.* (1983) found that WL hens from zero to 52 weeks of lay did not show any significant difference in mortality rates with dietary SAA levels varying from 0.5 to 1 per cent in different periods of lay.

Padmakumar (1993) reported that livability of Japanese quails ranged from 93.75 to 100 per cent for 28 day periods from 6 to 30 weeks of age when reared on 250 cm^2 floor space and fed a ration with 22.9 per cent CP.

Schutte *et al.* (1994) reported that laying hens fed different levels of supplemental DL-methionine ranging from 0.1 to 0.25 per cent in a basal diet with 0.24 per cent methionine and 15.4 per cent CP showed no difference in mortality between treatments and the overall mortality rate was 6 per cent from 25 to 77 weeks of age.

Shafer *et al.* (1998) observed that commercial layers fed methionine levels of 0.38, 0.46 and 0.53 per cent in a diet with 16.4 per cent crude protein did not show significant difference in mortality rates, which averaged 0.11 per cent.

'Noven Nera' layers that had been in lay for 10 months and fed a diet with 16 per cent CP or this diet supplemented with 0.1 per cent of lysine, methionine or both, did not exhibit significant difference in mortality rate (Amaefule *et al.*, 2004).

Bunchasak and Silapasorn (2005) observed that addition of synthetic methionine in a low protein (14 per cent) diet at 0.11 and 0.18 per cent levels to give total methionine of 0.38 and 0.44 per cent respectively, resulted in significant reduction in mortality rate compared to the low CP diet without supplementation or with lower level of supplementation (0.05 per cent) and the group fed high CP (16 per cent) diet.

Lekshmi (2005) reported a livability of 93.75 per cent from 6 to 26 weeks of age in Japanese quail layers when fed a ration having 22 per cent CP.

Sheena (2005) reported a livability of 90 per cent from 6 to 26 weeks of age in Japanese quail layers when fed a ration having 22 per cent CP, 1.03 per cent lysine and 0.37 per cent methionine.

2.14 ECONOMICS

Padmakumar (1993) recorded a return of Rs. 11.66 per quail from 5 to 50 weeks of age on rearing Japanese quails provided with 250 cm^2 floor space when the sale price of egg was 40 Paise and feed cost was Rs. 6.5 per kg.

Vidhyadharan (1998) reported a feed cost of Rs. 6.55 per kg for a layer diet with 18 per cent CP, 2730 kcal per kg ME, 0.83 per cent lysine and 0.31 per cent methionine while the cost of an all vegetable protein diet with 18 per cent CP, 2720 kcal per kg ME, 0.75 per cent lysine and 0.24 per cent methionine supplemented with 0.3 per cent DL-methionine was Rs.7.62 per kg. The mean feed cost per egg was Rs. 1.19 for layers fed the first diet while that for layers fed the methionine supplemented diet was Rs. 1.37 per egg.

Lekshmi (2005) reported that on an average 44.92 g feed was required to produce one egg in Japanese quails from 6 to 26 weeks of age and obtained a profit of 29.08 Paise per egg when the cost of feed was Rs. 9.11 per kg and sale price was 70 Paise per egg.

Sheena (2005) reported that Japanese quails required on an average 47.68 g feed to produce one egg from 6 to 26 weeks of age and the feed cost per egg was Rs. 0.46 at the rate of Rs. 9.55 per kg feed.

Materials and Methods

3. MATERIALS AND METHODS

An investigation was carried out in the Department of Poultry Science, College of Veterinary and Animal Sciences, Mannuthy to find out the effect of supplementation of lysine and methionine in quail layer rations on the production performance of Japanese quails under cage system of management. The experiment was conducted during the period from January to June 2006.

3.1 EXPERIMENTAL MATERIALS

3.1.1 Japanese quails

Two hundred and fifty six (256) Japanese quails at the age of five weeks, procured from University Poultry Farm, Mannuthy were housed in cages and used for the experiment.

3.1.2 Rations

The feed ingredients procured from UPF, Mannuthy were used for preparing the experimental rations. A basal ration for quail layers was formulated with 22 per cent crude protein and 2650 kcal metabolisable energy per kg diet and was supplemented with lysine and methionine as detailed below and that formed the experimental rations.

T1 -- Basal ration containing 1.0 per cent lysine and 0.45 per cent methionine

T2 -- The basal ration supplemented with 0.25 per cent L-lysine.

T3 -- The basal ration supplemented with 0.25 per cent DL-methionine.

T4 -- The basal ration supplemented with 0.25 per cent each of L-lysine and DL-methionine.

3.1.3 Lysine and Methionine

L-lysine monohydrochloride (98.5 per cent pure) manufactured by Ajinomoto Animal Nutrition, Thailand and DL-Methionine (99 per cent) manufactured by Sumitomo Chemical Co. Ltd, Japan, were procured from Cure and Care Ltd, Palakkad and were utilised for the study.

The composition of the basal ration is given in Table 1.

Table 1. Ingredient composition of experimental rations, per cent

Sl. No:	Ingredients	Per cent
1	Yellow maize	40 .00
2	Soybean meal	22 .00
3	Rice polish	12 .50
4	Unsalted dried fish	10 .00
5	Gingelly oil cake	8 .00
6	Shell grit	5 .50
7	Mineral mixture*	1.75
8	Salt	0.25
	Total	100
	Added per 100 kg feed	
1	Alvimix forte (g)**	25
2	Alusil premix (g)***	300
3	Bio choline (g)****	50

** Supermin P mineral mixture without salt (Kwality Agrovet Industries, Salem) Composition: Calcium - 30.0 %, Phosphorus - 9.0 %, Iron - 0.2 %, Iodine - 0.01 %, Zinc - 0.05 %, Manganese - 0.4 %, Copper - 0.4 %, Flourine (max) - 0.05 %, Acid insoluble ash (max) - 2.5 % and moisture – 3 %.*

*** Alvimix forte (Alembic, Vadodara) Each gram contains: Vitamin A – 40,000 IU, Vitamin D_3 – 10,000 IU, Vitamin B_1 – 3.2 mg, Vitamin B_2 – 24 mg, Vitamin B_6 – 6.4 mg, Vitamin B_{12} – 82 mcg, Niacin – 48 mg, Vitamin K – 4 mg, Calcium D pantothenate – 32 mg, Vitamin E – 32 mg, Folic acid – 3.2 mg*

**** Alusil premix (Stallen AG, Switzerland)*
Composition per gram: SIO_2 – 400-500 mg, Al_2O_3 – 320-400 mg, Fe_2O_3 – 3-10 mg, MgO – 5-20 mg, CaO - 30-50 mg, Na_2O – 25-45 mg, K_2O – 5-10 mg, Inert ingredients – made up to 1 g

***** Bio choline (Indian herbs research and supply Co Ltd, Uttar Pradesh)*
1g can replace 2 g synthetic choline chloride (60%) and 0.3 mg biotin

The proximate composition of the ration estimated according to AOAC (1990) is presented in Table 2.

Table 2. Chemical composition of experimental ration, dry matter basis, per cent

Sl.No:	Parameters	Per cent
	Analysed values	
1	Dry matter	91.57
2	Crude protein	22.34
3	Ether extract	4.16
4	Crude fibre	4.13
5	Nitrogen free extract	57.39
6	Total ash	11.98
7	Acid insoluble ash	2.15
8	Calcium	3.27
9	Phosphorus	0.84
	Calculated values	
1	ME (kcal/kg)	2665.71
2	Lysine (%)	1.04
3	Methionine (%)	0.45

3.2 EXPERIMENTAL METHODS

3.2.1 Housing of Quails

The cages used for housing of quails in each replicate were having a dimension of 60 x 60 cm with a height of 25 cm providing 225 cm^2 floor space per quail. The cage house, cages, feeders and water troughs were thoroughly cleaned and disinfected one week prior to housing and the quails were housed in cages at five weeks of age for cage adaptation.

3.2.2 Experimental Layout

The experiment was conducted during the laying phase of Japanese quails from six to twenty six weeks of age. At six weeks of age, two hundred and fifty six Japanese quail pullets were weighed individually and sixteen birds of almost the same initial average body weight were distributed randomly to four treatment groups with four replicates of sixteen birds each. The observations were recorded for five periods of 28 days each during the twenty weeks of experiment.

3.2.3 Management

The quails were provided with feed and water *ad libitum* throughout the experimental period. Standard managemental procedures were adopted identically to all treatment groups during the entire period of experiment.

3.2.4 Meteorological Parameters Inside the House

The maximum and minimum temperatures were recorded daily and the dry and wet bulb readings were recorded in the forenoon (F.N.) and afternoon (A.N.), throughout the experimental period.

3.2.5 Body Weight

Individual body weights of all the quails were recorded at the end of 6 (BW6) and 26 weeks of age (BW26).

3.2.6 Age at Sexual Maturity (ASM)

The age at first egg (AFE) and the age at 50 per cent production (days) were recorded in each replicate and from this data age at sexual maturity was determined.

3.2.7 Egg Production

Replicate wise egg production was recorded daily from 7 to 26 weeks of age and the mean egg production was expressed on quail housed and quail day number and per cent basis.

3.2.8 Egg Weight

Replicate wise egg mass was recorded daily and period wise and overall mean egg weights and egg mass per quail were calculated.

3.2.9 Feed Consumption

The weight of feed issued was recorded for each replicate period wise. The balance feed available at the end of each period was also noted. From this data, period wise mean daily feed consumption per bird was worked out for each replicate.

3.2.10 Feed Conversion Ratio (FCR)

Feed consumed per dozen eggs and per kilogram of egg mass were calculated replicate wise during each period.

3.2.11 Egg Quality

Five eggs were collected at random from each replicate at the end of each 28-day period for egg quality studies. Length and breadth of eggs, width of albumen and diameter of yolk were measured using Vernier calipers. Ame's tripod stand micrometer was used to measure the heights of albumen and yolk. Shell thickness was measured using Mitutoyo digimatic micrometer. The shape index, albumen and yolk indices and internal quality unit (IQU) were calculated using the following formulae as detailed below.

Shape Index = Greatest breadth of egg x 100/ Greatest length of egg

Albumen Index = Maximum height of thick albumen (mm) / Average width of thick albumen (mm)

Yolk Index = Maximum height of yolk (mm) / Diameter of yolk (mm)

IQU = $100 \log (H + 4.18 - 0.8989\ W^{0.6674})$ Where, H = Height of thick albumen in mm and W = Weight of egg in gram

3.2.12 Carcass yields and losses

At the end of 26 weeks of age two quails from each replicate were selected randomly, fasted overnight giving drinking water *ad libitum* and slaughtered to study the carcass yields and losses. The loss due to bleeding and the per cent skin and feather loss were worked out over the live weight. The weight of ovary and oviduct and its per cent yield was recorded. The per cent eviscerated yield, per cent liver weight and the giblet and the ready to cook (R-to-C) yields were determined in each quail and the mean values in each treatment group was worked out.

3.2.13 Serum Protein and Cholesterol

At the end of 26th week of age two birds in each replicate were selected randomly and blood samples were collected at the time of slaughter by severing the jugular vein for the estimation of serum protein and total cholesterol. The serum protein was estimated by modified Biuret method and serum total cholesterol by Wybenga and Pileggi's method.

3.2.14 Livability

Period-wise livability per cent was calculated based on the number of quails alive at the end of each period after recording the mortality in each replicate. Post mortem examination was conducted in each case to find out the cause of death.

3.2.15 Economics

Economics of dietary supplementation of lysine and methionine was calculated based on the prevailing cost of feed in each treatment group. The sale price of quail eggs during the experimental period, quantity of feed consumed and number of eggs produced by each replicate were utilised to work out the margin of returns over feed cost in each treatment group.

3.3 Statistical Analysis

Data collected on various parameters were statistically analysed by using Completely Randomised Design (CRD) as described by Snedecor and Cochran (1994). Means were compared by Least Significant Difference (LSD) test using MSTAT-C.

Results

4. RESULTS

The results of the experiment carried out to study the effect of dietary supplementation of lysine and methionine on production performance of Japanese quail layers reared in cages are presented in this chapter.

4.1 METEOROLOGICAL OBSERVATIONS

The mean maximum and minimum temperatures (^{0}C) and the mean per cent relative humidity (R.H) in the F.N and A.N. inside the experimental house from January to June 2006 are presented in Table 3 and are graphically depicted in Figure 1. The maximum temperature averaged 34.73, 36.68, 37.07, 35.82 and 34.05°C in periods I, II, III, IV and V respectively with an overall mean of 35.67°C. In the above periods, the minimum temperature averaged 22.91, 23.59, 25.66, 26.09 and 25.02°C with an overall mean of 24.65°C during the entire period of experiment.

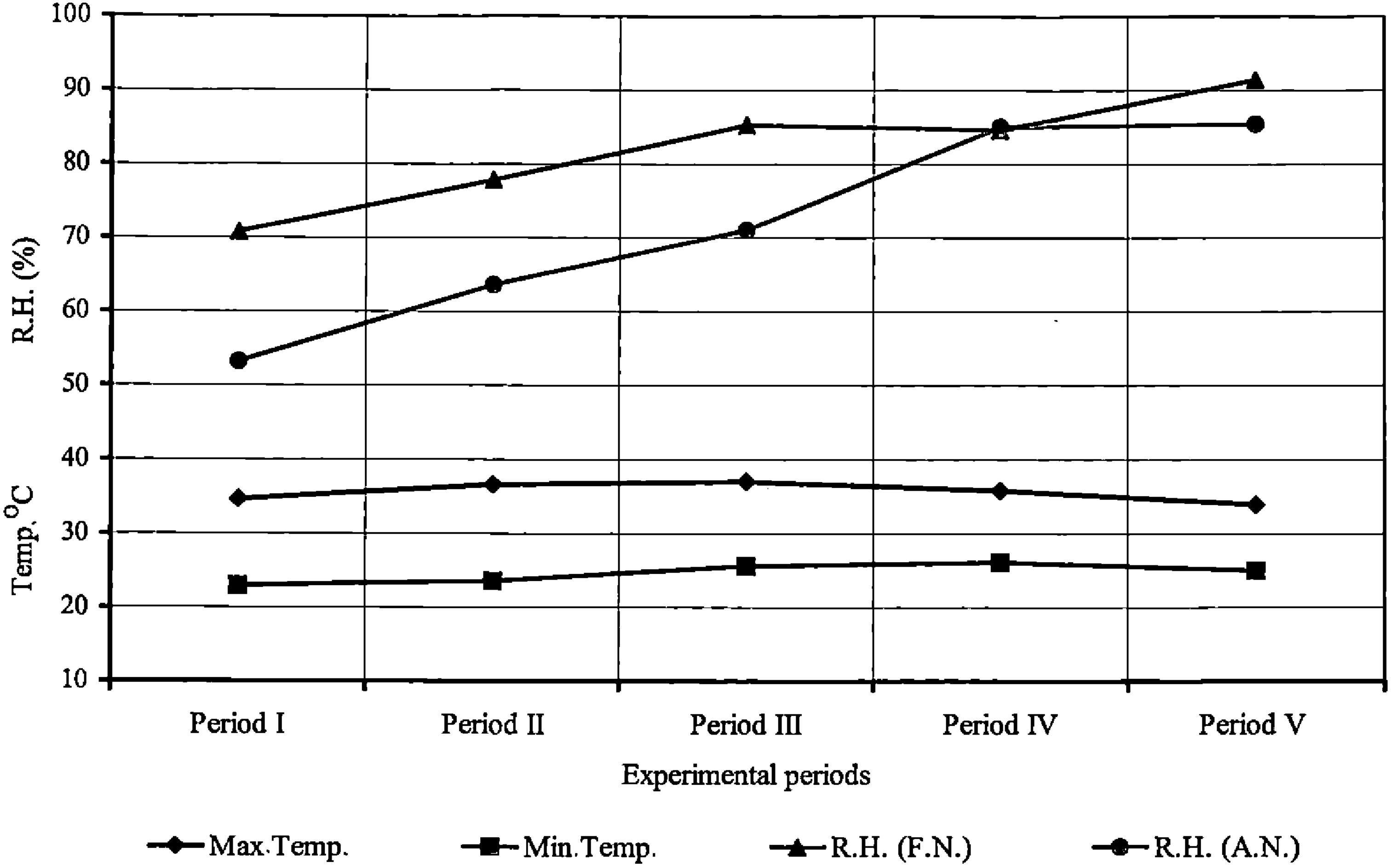
The maximum temperature, which was 34.73^{0}C in period I, increased to 36.68^{0}C in period II, rose further and recorded the highest temperature of 37.07°C in period III and thereafter lowered to 35.82°C in period IV and reached 34.05°C in period V. It was significantly higher during period III compared to that in periods I, IV and V ($P \leq 0.05$) and was comparable in period II. The maximum temperature in periods I and V were almost same and was significantly lower compared to all other periods ($P \leq 0.05$). The minimum temperature, which was 22.91°C in the first period, increased gradually and reached 26.09°C in period IV and reduced to 25.02°C in period V. It was significantly higher during period IV compared to periods I, II and V ($P \leq 0.05$) and was comparable in period III. The minimum temperature was significantly lower during periods I and II compared to all other periods ($P \leq 0.05$).

Table 3. Mean (±S.E.) maximum and minimum temperature and per cent R.H. inside the experimental house during the period from January to June 2006

Periods	Age in weeks	Temperature (^{0}C)		Relative Humidity (%)	
		Maximum	Minimum	F.N.	A.N.
I : Jan 13 – Feb 9	7-10	34.73^{c} ±0.19	22.91^{c} ±0.41	70.79^{d} ±2.20	53.25^{d} ±1.98
II : Feb 10 – Mar 9	11-14	36.68^{ab} ±0.32	23.59^{c} ±0.34	77.89^{c} ±1.90	63.54^{c} ±2.23
III : Mar 10 – Apr 6	15-18	37.07^{a} ±0.25	25.66^{ab} ±0.25	85.36^{b} ±0.96	71.07^{b} ±2.04
IV : Apr 7 – May 4	19-22	35.82^{b} ±0.19	26.09^{a} ±0.22	84.72^{b} ±1.48	85.07^{a} ±1.27
V : May 5 – Jun 1	23-26	34.05^{c} ±0.65	25.02^{b} ±0.26	91.43^{a} ±0.69	85.43^{a} ±1.30
Overall mean	7-26	35.67 ±0.19	24.65 ±0.17	82.04 ±0.91	71.67 ±1.32

Note: Mean values bearing the same superscript within a column did not differ significantly ($P \leq 0.05$)

Fig. 1 Meteorological parameters inside the experimental house during the period from January to June 2006



The period wise relative humidity in the morning averaged 70.79, 77.89, 85.36, 84.72 and 91.43 per cent in various periods I to V, with an overall mean of 82.04 per cent. The mean values of R.H. in the afternoon in different periods were 53.25, 63.54, 71.07, 85.07 and 85.43 per cent with an overall mean of 71.67 per cent.

The relative humidity in the forenoon, which was 70.79 per cent in period I, increased to 77.89 per cent in period II and remained high from third period onwards. Highest F.N. relative humidity was during period V and lowest during period I, which were significantly different from that of other periods ($P \leq 0.05$). In the afternoon, R.H. showed a steady increase from 53.25 to 85.43 per cent in periods I to V. Thus, moderately low R.H. was observed in early periods in the afternoon. In periods IV and V, the per cent relative humidity inside the experimental house was high both in the F.N and A.N.

4.2 BODY WEIGHT

The mean body weights at the end of 6 and 26 weeks of age among the dietary groups are shown in Table 4. A comparison of BW6 with that of BW26 influenced by supplementation of lysine and methionine in quail layer rations is graphically represented in Figure 2.

At sixth week of age, the body weight (BW6) was almost uniform and the mean values were 180.00, 181.17, 180.23 and 182.66 g in dietary groups T1, T2, T3 and T4 respectively. In the corresponding groups, the mean body weights at 26 weeks of age were 225.83, 225.60, 215.04 and 219.81 g showing marked increase in body weight in all groups. The gain in weight at 26 weeks of age in the different dietary groups T1, T2, T3 and T4 were 45.83, 44.43, 34.80 and 37.16 g respectively.

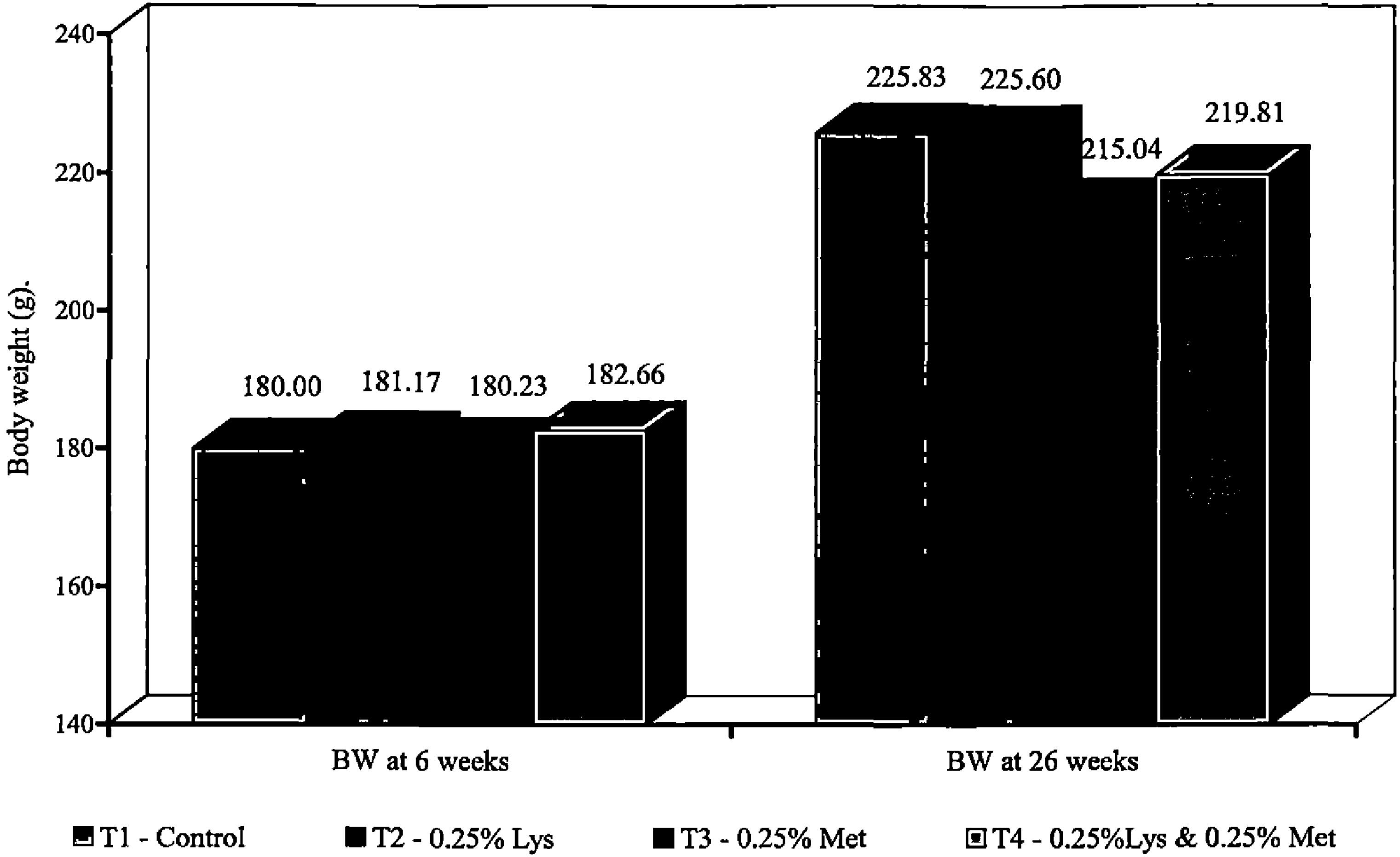
The mean body weight of quails at the beginning of the experiment in T1 to T4 was statistically comparable among each other, at sixth week of age. At the end of 26 weeks of age, the mean BW of dietary groups T1 and T2 was almost similar

Table 4. Mean (±S.E.) body weight (g) at 6 and 26 weeks of age and age at sexual maturity in layer quails influenced by experimental diets

Trait	Dietary supplementation of lysine (L) and methionine (M) levels (%)				Overall mean
	T_1 L - 0 M - 0	T_2 L - 0.25 M - 0	T_3 L - 0 M - 0.25	T_4 L - 0.25 M - 0.25	
Body weight at 6 weeks of age (g)	180.00 ±1.70	181.17 ±2.03	180.23 ±2.85	182.66 ±1.72	181.02 1.98±
Body weight at 26 weeks of age (g)	225.83^{a} ±2.88	225.60^{a} ±2.54	215.04^{b} ±3.93	219.81^{ab} ±3.00	221.57 ±1.58
Gain in body weight (g)	45.83^{a} ±1.20	44.43^{a} ±2.31	34.80^{b} ±4.74	37.16^{ab} ±3.01	40.56 ±1.84
Age at First Egg (days)	42	42	42	42	42
Age at 50 per cent production (days)	51	54	49	52	52

Note: Mean values bearing the same superscript within a row did not differ significantly (P≤0.05)

Fig. 2 Body weight of layer quails affected by lysine and methionine supplementation in the diet



and was significantly higher than that of group T3 ($P \leq 0.05$) and numerically higher than that of group T4.

4.3 AGE AT SEXUAL MATURITY

The age at first egg (AFE) in the flock and the ages at 50 per cent production influenced by dietary supplementation of lysine and methionine are presented in Table 4. The age at first egg in the flock in each dietary group was 42 days. Whereas, age at 50 per cent production was 51, 54, 49 and 52 days in groups T1, T2, T3 and T4 respectively.

4.4 EGG PRODUCTION

4.4.1 Weekly Quail Housed Egg Number (QHN) and Per cent (QHP) Production

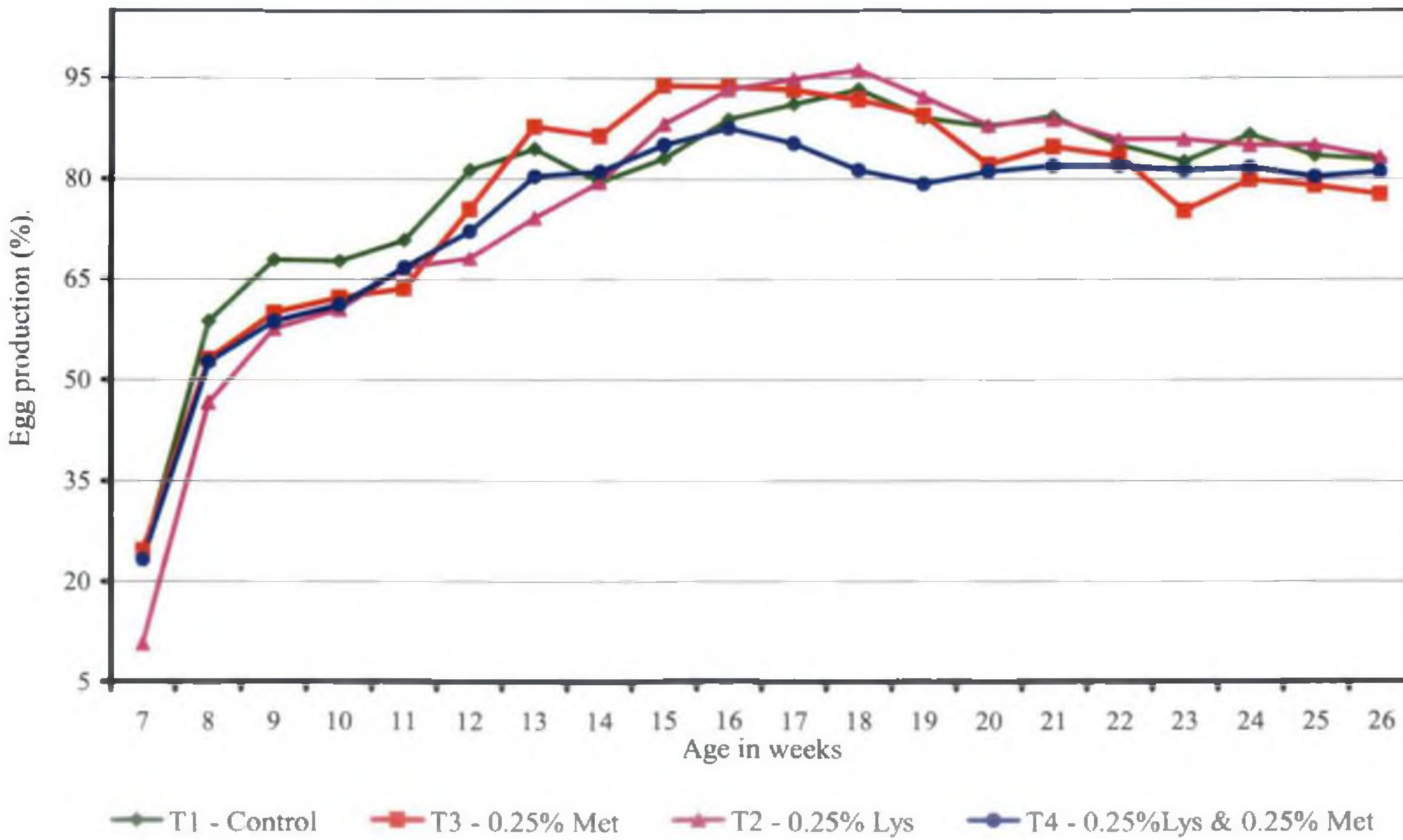
The weekly mean egg production in various dietary groups was calculated based on the number of quails housed in each group at the beginning of the experiment and are set out in Table 5 and the weekly fluctuations in egg production due to supplementation of lysine and methionine in quail layer rations is depicted in Figure 3.

The weekly quail housed egg number and per cent production presented in Table 5 showed a gradual increase in production in the control group T1 until peak production at 18th week of age. There was drop in production at 10 and 14 weeks of age. The group T1 reached 91.07 per cent production by 17th week of age and registered mean peak production of 6.53 eggs per quail per week (93.30 per cent) at 18th week. The control group maintained the production above 90 per cent only at 17 and 18 weeks of age and thereafter showed fluctuations in production. The dietary group T2 supplemented with 0.25 per cent lysine showed a consistent increase in quail housed production until peak production of 6.73 eggs per quail per week (96.21

Table 5. Weekly mean quail housed number (QHN) and quail housed per cent (QHP) production as influenced by lysine and methionine supplementation in experimental diets.

Age in weeks	Mean QHN per week				Mean QH per cent per week			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
7	1.66	0.75	1.72	1.63	23.66	10.71	24.55	23.21
8	4.11	3.27	3.72	3.69	58.71	46.65	53.13	52.68
9	4.75	4.03	4.20	4.11	67.86	57.59	60.04	58.71
10	4.73	4.23	4.36	4.28	67.63	60.49	62.28	61.16
11	4.95	4.67	4.45	4.67	70.76	66.74	63.62	66.74
12	5.69	4.77	5.28	5.05	81.25	68.08	75.45	72.10
13	5.91	5.19	6.14	5.63	84.38	74.11	87.72	80.36
14	5.56	5.56	6.05	5.67	79.46	79.46	86.38	81.03
15	5.81	6.17	6.58	5.95	83.04	88.17	93.97	85.04
16	6.22	6.53	6.56	6.13	88.84	93.30	93.75	87.50
17	6.38	6.64	6.53	5.97	91.07	94.87	93.30	85.27
18	6.53	6.73	6.42	5.69	93.30	96.21	91.74	81.25
19	6.23	6.45	6.27	5.55	89.06	92.19	89.51	79.24
20	6.14	6.16	5.75	5.67	87.72	87.95	82.14	81.03
21	6.25	6.22	5.94	5.73	89.29	88.84	84.82	81.92
22	5.95	6.02	5.84	5.73	85.04	85.94	83.48	81.92
23	5.78	6.02	5.27	5.69	82.59	85.94	75.22	81.25
24	6.06	5.95	5.59	5.72	86.61	85.04	79.91	81.70
25	5.84	5.95	5.53	5.63	83.48	85.04	79.02	80.36
26	5.80	5.83	5.44	5.67	82.81	83.26	77.68	81.03
7-26 week	110.36	107.14	107.64	103.84	78.83	76.53	76.89	74.17

Fig. 3 Weekly quail housed per cent production influenced by lysine and methionine supplementation in quail layer diet



per cent) at 18th week of age. The egg production in the lysine-supplemented group was consistently above 90 per cent from 16 to 19 weeks of age.

The methionine supplemented group (T3) showed gradual increase in production until 13 weeks of age. It registered the peak production of 6.58 eggs (93.97 per cent) in the 15th week. The group T3 consistently maintained high production above 90 per cent from 15 to 18 weeks of age and thereafter showed decline in production. The dietary group supplemented with both methionine and lysine (T4) showed gradual and consistent increase in weekly quail housed production and recorded peak production of 87.50 per cent at 16th week of age. This group did not reach the production level of 90 per cent in any of the weeks.

4.4.2 Period wise Quail Housed Number and Per cent Production

4.4.2.1 *Quail Housed Egg Number (QHN)*

The egg production per quail in each period from I to V based on the number of quails housed at the beginning of that period and the cumulative mean egg production during the entire period of experiment from 7 to 26 weeks of age in various dietary groups are presented as quail housed egg number (QHN) in Table 6.

The results presented in Table 6 revealed that the cumulative mean egg production per quail during the entire period from 7 to 26 weeks of age was 110.36, 107.14, 107.64 and 103.84 in groups T1, T2, T3 and T4 respectively.

In the control group T1, the egg production per quail in 28-day period from 7 to 10 weeks of age averaged 15.25 eggs and increased to 22.11 eggs in period II at 11-14 weeks of age. The mean egg production was further increased to 25.33 eggs in period III at 15-18 weeks of age, registering peak production in this group (T1). Thereafter, QHN declined to 24.97 eggs in period IV at 19-22 weeks of age and 24.64

Table 6. Period wise mean (±S.E.) quail housed number of eggs as influenced by lysine (L) and methionine (M) supplementation in experimental diets.

Periods	Age in weeks	Mean Quail housed number				Overall mean
		T_1 L - 0 % M - 0%	T_2 L - 0.25% M - 0%	T_3 L - 0% M -0.25%	T_4 L - 0.25% M- 0.25%	
I	7-10	15.25 ±2.05	12.28 ±2.42	14.00 ±1.63	13.70 ±2.52	13.81 ±1.01
II	11-14	22.11 ±0.92	20.19 ±3.14	21.92 ±1.14	21.02 ±2.11	21.31 ±0.93
III	15-18	25.33^{ab} ±0.79	26.08^{ab} ±0.44	26.94^{a} ±0.38	24.50^{b} ±0.76	25.71 ±0.36
IV	19-22	24.97 ±0.64	24.84 ±1.60	24.97 ±0.66	24.20 ±0.82	24.75 ±0.46
V	23-26	24.64 ±1.00	25.33 ±0.62	24.09 ±0.63	24.63 ±0.88	24.68 ±0.37
Cumulative QHN	7-26	110.36 ±3.31	107.14 ±6.11	107.64 ±5.28	103.84 ±5.38	107.25 ±2.37

Note: Mean values bearing the same superscript within a row did not differ significantly ($P \leq 0.05$)

eggs in period V at 23-26 weeks of age. In the dietary group T2 supplemented with 0.25 per cent lysine, the QHN averaged 12.28, 20.19, 26.08, 24.84 and 25.33 in periods I, II, III, IV and V respectively showing highest mean yield in the period III at 15-18 weeks of age.

In the dietary group T3 supplemented with 0.25 per cent methionine, the QHN averaged 14.00, 21.92, 26.94, 24.97, and 24.09 in periods I, II, III, IV and V respectively showing the highest yield within the group T3 in period III. In the dietary group T4 supplemented with lysine and methionine each at 0.25 per cent level, the period wise QHN averaged 13.70, 21.02, 24.50, 24.20 and 24.63 in periods I, II, III, IV and V respectively showing gradual increase in egg production up to period III and a slight decline in period IV followed by a slight increase in period V. The overall QHN was the lowest in this group (103.84 eggs) in comparison with all other groups.

Statistical analysis of the overall QHN revealed no significant difference due to dietary treatments. However, during period III the dietary group T3 had a significantly higher QHN than group T4 ($P \leq 0.05$) but was comparable to that of T1 and T2.

4.4.2.2 *Quail Housed Per cent (QHP) Production*

The data on period wise quail housed egg production based on the number of quails housed at the beginning of each period is also expressed as quail housed per cent (QHP) production in various dietary groups and presented in Table 7.

The cumulative mean Quail Housed Per cent (QHP) Production over the entire period of experiment from 7 to 26 weeks of age was 78.83, 76.53, 76.89 and 74.17 per cent in dietary groups T1, T2, T3 and T4 respectively. The period wise variations indicated that the highest mean QHP was 90.48, 93.14, 96.20 and 87.95 for the dietary groups T1, T2, T3 and T4 respectively registered in period III in all groups except T4, which registered in period V during 23-26 weeks of age.

The mean QHP in the control group T1, which was 54.46 in period I increased to 78.96 per cent in period II and registered the peak yield of 90.48 per cent in period III and declined to 89.17 per cent in period IV and to 88.00 per cent in period V. In the dietary group T2 supplemented with 0.25 per cent lysine, the QHP was low in period I (43.86 per cent) increased to 72.10 per cent in period II and registered the peak yield of 93.14 per cent in period III, indicating a higher peak than that of control group, declined to 88.73 per cent in period IV and showed slight increase to 90.48 per cent in period V.

In the dietary group T3 supplemented with 0.25 per cent methionine, the QHP averaged 50.00, 78.29, 96.20, 89.17 and 86.02 in periods I, II, III, IV and V respectively showing the highest yield of 96.20 per cent in period III, recording the highest period wise yield in the experiment. However, the overall QHN in T2 and T3 were almost equal (107.14 and 107.64 eggs) and the corresponding percentages were 76.53 and 76.89. In the dietary group T4 supplemented with lysine and methionine each at 0.25 per cent level, the QHP averaged 48.94, 75.06, 87.50, 86.43 and 87.95 in periods I, II, III, IV and V respectively showing lower level of peak production (period V) compared to other dietary groups. The overall mean QHP in the group T4 was only 74.17 per cent.

In the period III, QHP was significantly higher in the group T3 compared to that in T4 ($P \leq 0.05$) but was statistically comparable to the QHP in T1 and T2. The overall and period wise quail housed per cent production did not show significant difference among dietary groups.

Table 7. Period wise mean (±S.E.) quail housed per cent production as influenced by lysine (L) and methionine (M) supplementation in experimental diets.

Periods	Age in weeks	Mean quail housed per cent production				Overall mean
		T_1 L - 0 % M - 0%	T_2 L - 0.25% M - 0%	T_3 L - 0% M -0.25%	T_4 L - 0.25% M- 0.25%	
I	7-10	54.46 ±7.31	43.86 ±8.64	50.00 ±5.81	48.94 ±9.01	49.32 ±3.62
II	11-14	78.96 ±3.28	72.10 ±11.23	78.29 ±4.08	75.06 ±7.52	76.10 ±3.32
III	15-18	90.48^{ab} ±2.83	93.14^{ab} ±1.58	96.20^{a} ±1.35	87.50^{b} ±2.73	91.83 ±1.29
IV	19-22	89.17 ±2.29	88.73 ±5.70	89.17 ±2.34	86.43 ±2.93	88.39 ±1.63
V	23-26	88.00 ±3.56	90.48 ±2.22	86.02 ±2.26	87.95 ±3.15	87.76 ±1.33
Cumulative QHP	7-26	78.83 ±2.37	76.53 ±4.37	76.89 ±3.77	74.17 ±3.84	76.60 ±1.69

Note: Mean values bearing the same superscript within a row did not differ significantly ($P \leq 0.05$)

4.4.3 Weekly Quail Day Number (QDN) and Per cent (QDP) Production

The weekly mean egg production, from 7 to 26 weeks of age, in various dietary groups on quail day basis is set out in Table 8 and is graphically depicted in Figure 4.

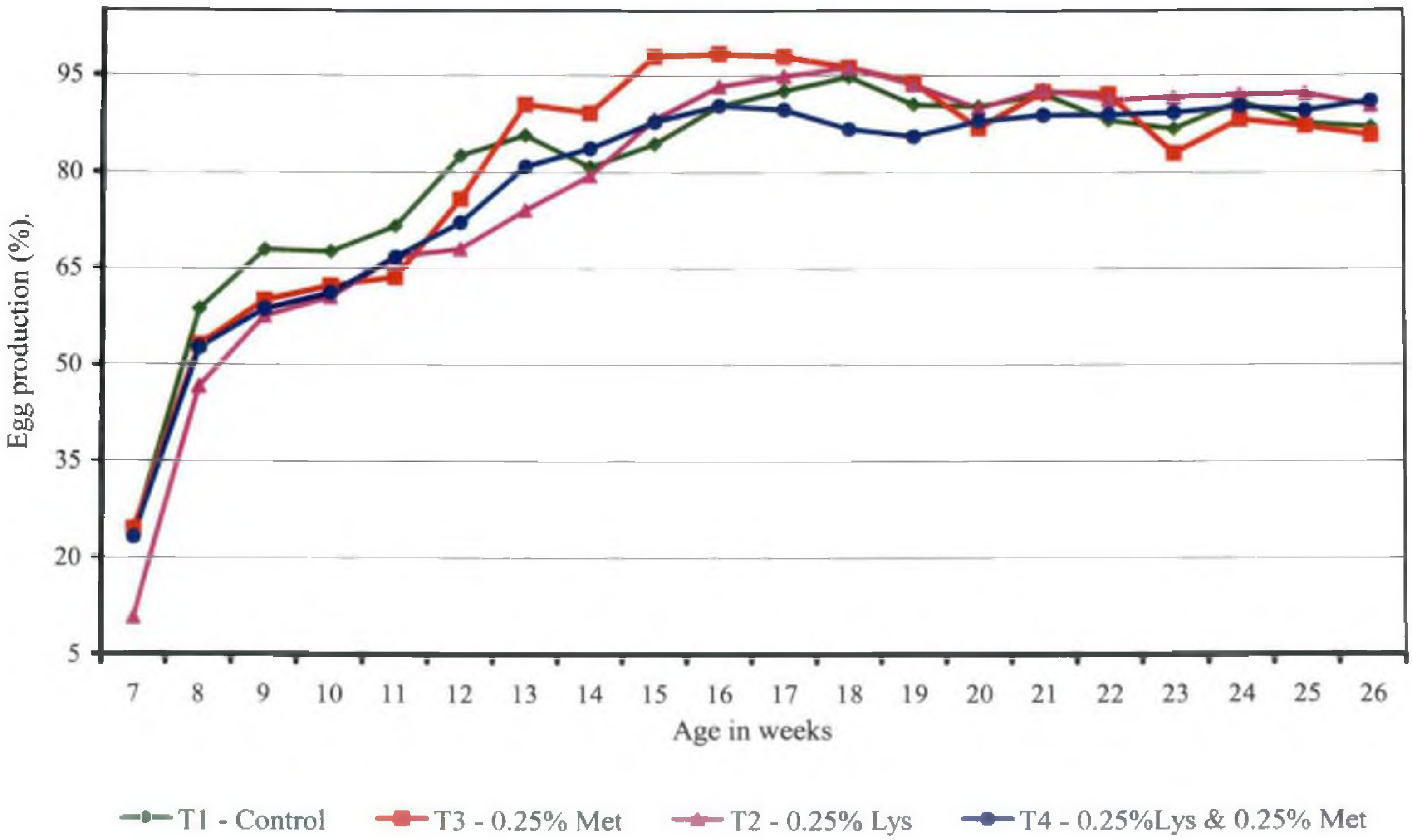
The weekly quail day egg production showed a similar trend as weekly quail housed egg production. The group T1 reached above 90 per cent production by 16th week of age and registered weekly mean peak production of 6.63 eggs (94.78 per cent) at 18th week. The T1 group maintained the production above 90 per cent consistently from 16 to 21 weeks of age and then shown fluctuations in production. Then the production reached above 90 per cent only during 24th week of age in T1. In the dietary group T2 supplemented with 0.25 per cent lysine production was consistently above 90 per cent from 16 to 26 weeks of age except at 20th week.

The methionine supplemented group T3 also shown gradual increase in production until its peak production except at 14th week of age. It registered the highest peak production among the dietary groups and was 6.89 eggs (98.36 per cent) during 16th week, which was earlier than that of T1 and T2. The group T3 consistently maintained the production above 90 per cent from 15 to 19 weeks of age and then shown fluctuations in production. The dietary group T4 supplemented with both methionine and lysine shown gradual and consistent increase in weekly quail day production until 16th week of age when the production was 6.32 eggs per quail per week (90.32 per cent). But this group could not maintain the production above 90 per cent further, except at 24 and 26 weeks of age. The peak weekly quail day production in the group T4 was 6.37 eggs (90.98 per cent) recorded during the 26th week of age.

Table 8. Weekly mean quail day number (QDN) and quail day per cent (QDP) production as influenced by lysine and methionine supplementation in experimental diets.

Age in weeks	Mean QDN per week				Mean QD per cent per week			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
7	1.66	0.75	1.72	1.63	23.66	10.71	24.55	23.21
8	4.11	3.27	3.72	3.69	58.71	46.65	53.13	52.68
9	4.75	4.03	4.20	4.11	67.86	57.59	60.04	58.71
10	4.73	4.23	4.36	4.28	67.63	60.49	62.28	61.16
11	5.01	4.67	4.45	4.67	71.56	66.74	63.62	66.74
12	5.78	4.77	5.30	5.05	82.54	68.08	75.78	72.10
13	6.00	5.19	6.34	5.66	85.71	74.11	90.55	80.90
14	5.65	5.56	6.24	5.85	80.73	79.46	89.17	83.64
15	5.90	6.17	6.85	6.15	84.35	88.17	97.91	87.79
16	6.32	6.53	6.89	6.32	90.25	93.30	98.36	90.32
17	6.48	6.64	6.85	6.28	92.52	94.87	97.89	89.67
18	6.63	6.73	6.74	6.07	94.78	96.21	96.25	86.67
19	6.33	6.56	6.57	5.99	90.48	93.65	93.91	85.54
20	6.31	6.30	6.08	6.15	90.14	89.95	86.79	87.89
21	6.45	6.49	6.47	6.22	92.17	92.77	92.46	88.86
22	6.16	6.39	6.45	6.22	87.99	91.23	92.12	88.86
23	6.07	6.42	5.81	6.25	86.65	91.67	83.00	89.22
24	6.36	6.44	6.17	6.31	90.87	92.03	88.18	90.15
25	6.13	6.46	6.10	6.27	87.59	92.25	87.19	89.55
26	6.08	6.32	6.00	6.37	86.89	90.31	85.71	90.98
7-26 week	112.70	109.51	112.71	108.82	80.50	78.22	80.51	77.73

Fig. 4 Weekly quail day per cent production influenced by lysine and methionine supplementation in quail layer diet



4.4.4 Period wise Quail Day Number and Per cent Production

4.4.4.1 *Quail Day Egg Number (QDN)*

The egg production based on the survivors is expressed as quail day egg number (QDN) and quail day per cent (QDP) production among the dietary groups in Tables 9 and 10 respectively.

The mean cumulative egg number on quail day basis in quails from 7 to 26 weeks of age was 112.70, 109.51, 112.71 and 108.82 in groups T1, T2, T3 and T4 respectively. In these groups, the cumulative QHN values were 110.36, 107.14, 107.64 and 103.84 respectively. A comparison of the cumulative quail housed and quail day numbers is presented in Figure 5.

In the first period, during 7 to 10 weeks of age, the QDN was the same as that of QHN, since there was no mortality in any of the dietary groups. In the T1 group QDN was 22.43 in period II and 25.25 in period IV. In the group T2, QDN was 25.73 and 25.64 in period IV and V respectively. The QDN in T3 were 22.30, 27.33 and 25.57 in periods II, III and IV and the mean values of QDN in T4 were 21.22, 24.81, 24.58 and 25.19 in periods II, III, IV and V respectively.

Statistical analysis of the overall QDN revealed no significant difference due to dietary treatments. In period III dietary group T3 had significantly higher QDN than that of T1 and T4 ($P \leq 0.05$), but was statistically comparable to that of T2.

4.4.4.2 *Quail Day Per cent (QDP) Production*

The mean cumulative per cent production on quail day basis from 7 to 26 weeks of age was 80.50, 78.22, 80.51 and 77.73 in groups T1, T2, T3 and T4 respectively. In these groups, the overall mean QHP values were 78.83, 76.53, 76.89 and 74.17 per cent.

Fig. 5 Cumulative quail housed egg number and quail day egg number influenced by lysine and methionine supplementation in quail layer diet

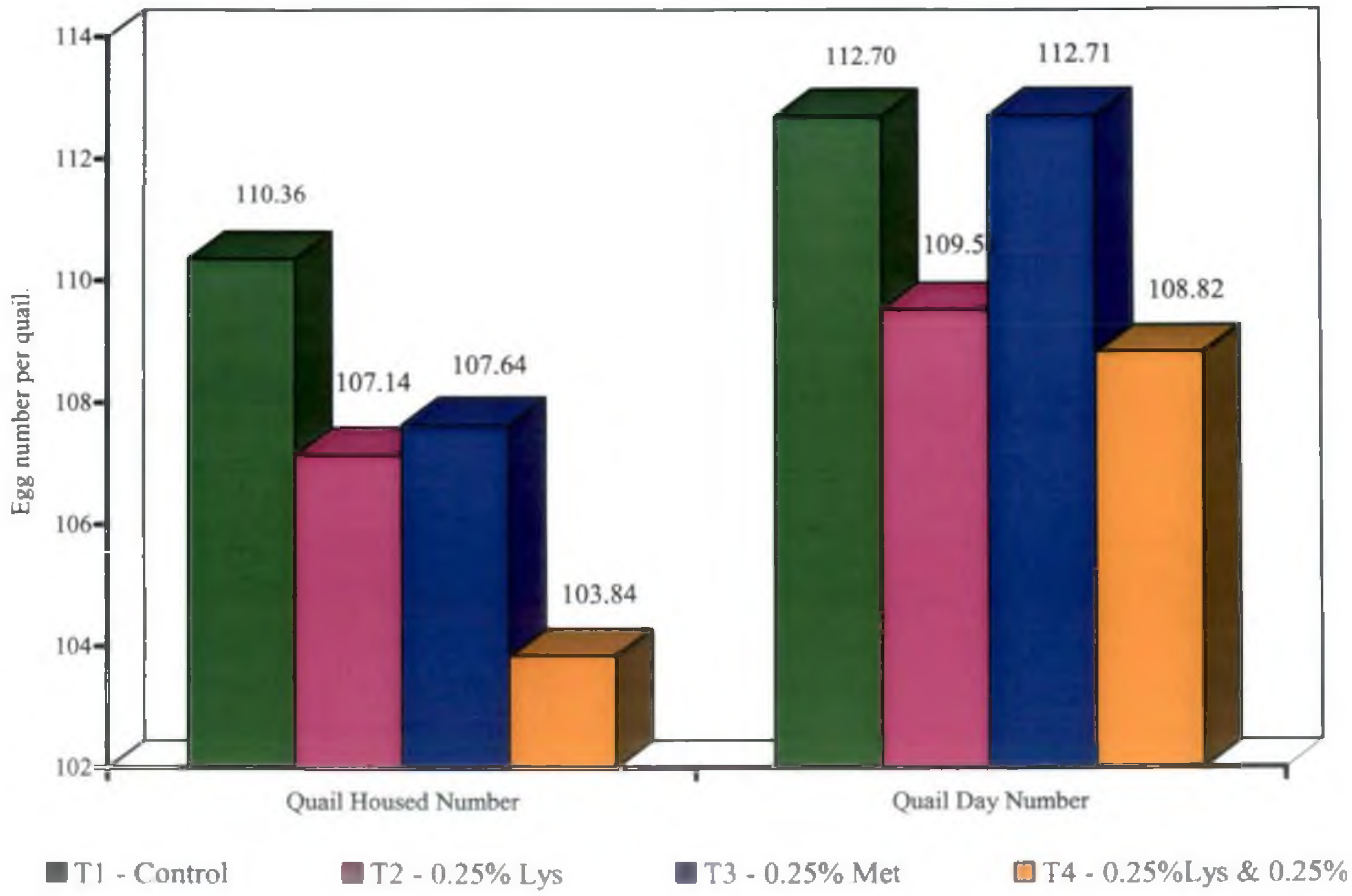


Table 9. Period wise mean (±S.E.) quail day number of eggs as influenced by lysine (L) and methionine (M) supplementation in experimental diets.

Periods	Age in weeks	Mean quail day number				Overall mean
		T_1 L - 0 % M - 0%	T_2 L - 0.25% M - 0%	T_3 L - 0% M- 0.25%	T_4 L - 0.25% M -0.25%	
I	7-10	15.25 ±2.05	12.28 ±2.42	14.00 ±1.63	13.70 ±2.52	13.81 ±1.01
II	11-14	22.43 ±1.06	20.19 ±3.14	22.30 ±1.05	21.22 ±2.15	21.53 ±0.94
III	15-18	25.33[b] ±0.79	26.08[ab] ±0.44	27.33[a] ±0.30	24.81[b] ±0.73	25.89 ±0.36
IV	19-22	25.25 ±0.46	25.73 ±0.88	25.57 ±0.38	24.58 ±0.93	25.29 ±0.33
V	23-26	24.64 ±1.00	25.64 ±0.39	24.09 ±0.63	25.19 ±0.40	24.89 ±0.32
Cumulative QDN	7-26	112.70 ±4.36	109.51 ±6.05	112.71 ±2.39	108.82 ±6.37	110.94 2.30±

Note: Mean values bearing the same superscript within a row did not differ significantly ($P \leq 0.05$)

Table 10. Period wise mean (±S.E.) quail day per cent production as influenced by lysine (L) and methionine (M) supplementation in experimental diets.

Periods	Age in weeks	Mean quail day per cent production				Overall mean
		T_1 L - 0 % M - 0%	T_2 L - 0.25% M - 0%	T_3 L - 0% M- 0.25%	T_4 L - 0.25% M -0.25%	
I	7-10	54.46 ±7.31	43.86 ±8.64	50.00 ±5.81	48.94 ±9.01	49.32 ±3.62
II	11-14	80.12 ±3.77	72.10 ±11.23	79.63 ±3.76	75.77 ±7.69	76.89 ±3.37
III	15-18	90.48^{b} ±2.83	93.14^{ab} ±1.58	97.60^{a} ±1.08	88.62^{b} ±2.61	92.45 ±1.30
IV	19-22	90.20 ±1.64	91.91 ±3.16	91.31 ±1.37	87.79 ±3.33	90.32 ±1.19
V	23-26	88.00 ±3.56	91.57 ±1.38	86.02 ±2.26	89.97 ±1.42	88.89 ±1.16
Cumulative QDP	7-26	80.50 ±3.11	78.22 ±4.32	80.51 ±1.71	77.73 ±4.55	79.24 ±1.64

Note: Mean values bearing the same superscript within a row did not differ significantly ($P \leq 0.05$)

In period I, during 7 to 10 weeks of age, the quail day percentages were the same as that of quail housed percentages. The quail day per cent (QDP) varied from QHP in group T1 during periods II and IV, in T2 during period IV and V, in T3 during period II, III and IV and in T4 during periods II, III, IV and V and the changes did not show significant variations over the respective quail housed percentages.

The QDP in T1 was 80.12 and 90.20 per cent during period II and IV respectively and in T2 group the QDP was 91.91 per cent in period IV and 91.57 per cent in period V. In the group T3, the QDP was 79.63, 97.60 and 91.31 per cent in the periods II, III and IV respectively and in T4 it was 75.77 per cent in period II, 88.62 per cent in period III, 87.79 per cent in period IV and 89.97 per cent in period V. The QDP did not show significant difference either in the overall mean values of dietary treatments or in the period wise means except in period III. During period III the dietary group T3 had a significantly higher QDP than the groups T1 and T4 ($P \leq 0.05$), but was statistically comparable to that of T2.

4.5 MEAN EGG WEIGHT

The period wise and overall mean egg weights in quails of different dietary groups from 7 to 26 weeks of age are given in Table 11 and the variations in cumulative mean egg weight (EW) is represented graphically in Figure 6.

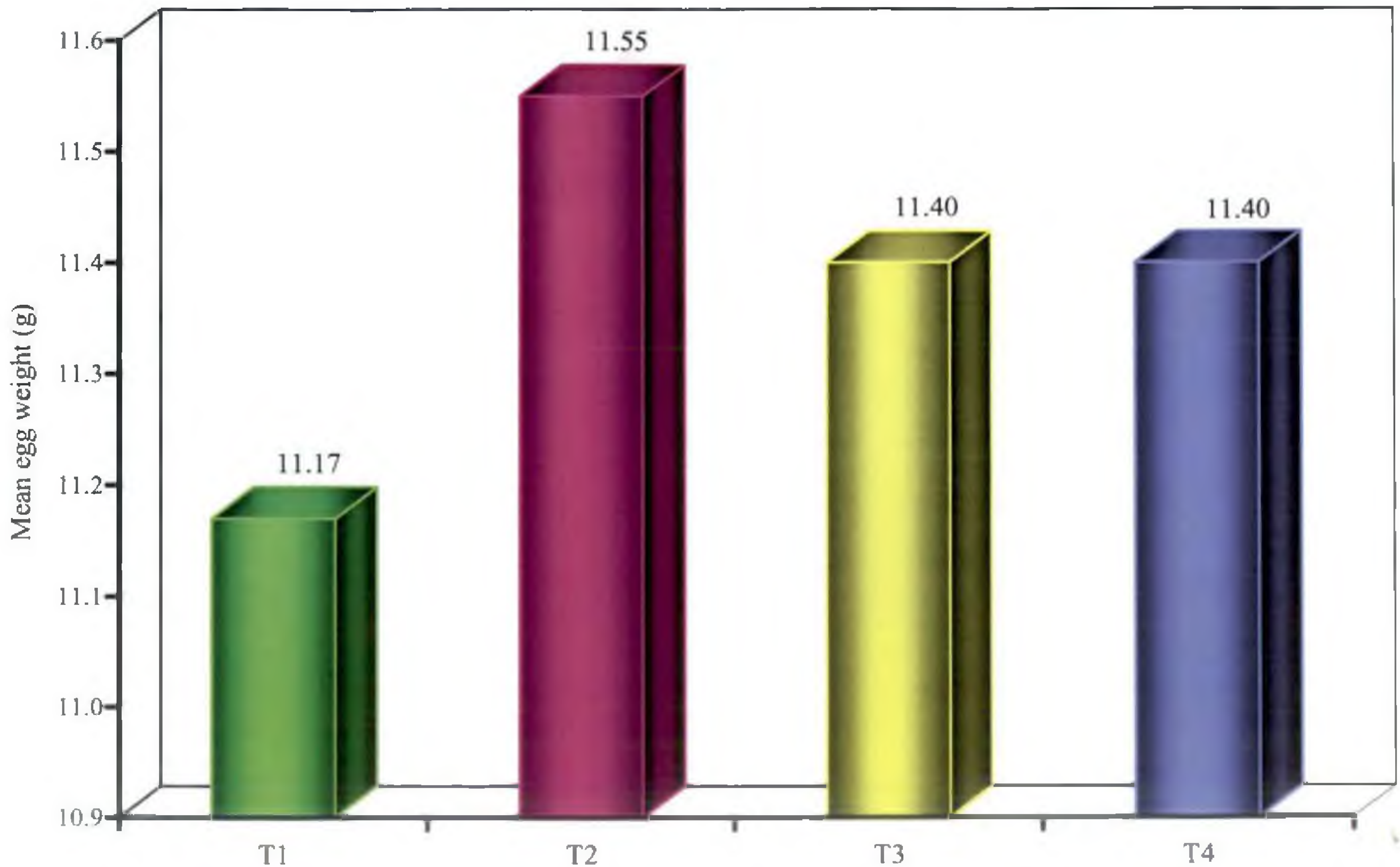
The cumulative mean egg weight recorded was 11.17, 11.55, 11.40 and 11.40 g in groups T1, T2, T3 and T4 respectively and it was lowest in group (T1) fed control diet and highest in dietary group T2 supplemented with 0.25 per cent lysine. The mean EW in groups T3 and T4 were equal and the mean value was intermediary between T1 and T2. The Statistical analysis of the data pertaining to the cumulative mean EW showed significantly lower EW in the control group T1 than that of other groups ($P \leq 0.05$).

Table 11. Period wise mean (±S.E.) egg weight (g) based on egg mass as influenced by lysine (L) and methionine (M) supplementation in experimental diets.

Periods	Age in weeks	Mean egg weight (g)				Overall mean
		T_1 L - 0 % M - 0%	T_2 L - 0.25% M - 0%	T_3 L - 0% M- 0.25%	T_4 L - 0.25% M -0.25%	
I	7-10	10.43^{b} ±0.11	10.58^{ab} ±0.09	10.38^{b} ±0.04	10.80^{a} ±0.10	10.55 ±0.06
II	11-14	11.25 ±0.11	11.66 ±0.17	11.52 ±0.14	11.51 ±0.13	11.48 ±0.07
III	15-18	11.29^{b} ±0.10	11.62^{a} ±0.05	11.49^{ab} ±0.08	11.47^{ab} ±0.06	11.47 ±0.05
IV	19-22	11.28^{b} ±0.13	11.72^{a} ±0.01	11.52^{ab} ±0.11	11.47^{ab} ±0.05	11.50 ±0.06
V	23-26	11.35^{b} ±0.09	11.72^{a} ±0.10	11.68^{a} ±0.09	11.54^{ab} ±0.10	11.57 ±0.06
Cumulative mean	7-26	11.17^{b} ±0.09	11.55^{a} ±0.07	11.40^{a} ±0.07	11.40^{a} ±0.03	11.38 ±0.05

Note: Mean values bearing the same superscript within a row did not differ significantly ($P \leq 0.05$)

Fig.6 Overall mean egg weight (g) influenced by lysine and methionine supplementation in quail layer diet



The average egg weight from period I to V ranged from 10.43 to 11.35 g in T1, 10.58 to 11.72 g in T2, 10.38 to 11.68 g in T3 and 10.80 to 11.54 g in T4 groups. During 7 to 10 weeks of age, the mean EW varied between 10.38 and 10.80 g among dietary groups (10.43, 10.58, 10.38 and 10.80 g) lowest being in the group T3 and the highest in the group T4. Whereas, in all other periods, the mean EW was lower in the control group compared to the lysine and methionine supplemented groups.

During the experiment, the control group T1 recorded the lowest mean egg weight in comparison with other dietary groups in each period from II to V and resulted in significantly lower cumulative mean egg weight ($P \leq 0.05$). The period wise mean EW recorded in the experiment was the lowest in T3 during 7-10 weeks (10.38 g) and the highest in T2 during 19-22 and 23-26 weeks of age (11.72 g).

Statistical interpretation of the results showed significant difference between dietary groups in all the periods except period II. In period II the EW was numerically higher in T2, intermediate in T3 and lowest in T1. During the periods I, III and IV, significantly higher egg weight was shown by the groups T4, T2 and T2, respectively than the control group ($P \leq 0.05$). While in the period V, T2 and T3 had comparable egg weights that were significantly higher than that of T1 ($P \leq 0.05$). The group T4 recorded intermediary egg weight compared with other groups in all periods except in period I.

4.6 EGG MASS

The mean egg mass per quail on quail day basis was arrived based on all eggs obtained from 16 quails. The period wise and overall mean is presented in Table 12.

The overall mean egg mass per quail for the dietary groups in descending order is given by 1283.8 g for T3, 1263.7 g for T2, 1259.1 g for T1 and 1240.3 g for T4. The results showed that the egg mass did not differ significantly between groups

Table 12. Period wise mean (±S.E.) egg mass per quail (g) on quail day basis as influenced by lysine (L) and methionine (M) supplementation in experimental diets.

Periods	Age in weeks	Mean egg mass per quail (g)				Overall mean
		T_1 L - 0 % M - 0%	T_2 L - 0.25% M - 0%	T_3 L - 0% M- 0.25%	T_4 L - 0.25% M -0.25%	
I	7-10	159.0 ±21.41	130.0 ±25.94	145.3 ±16.67	147.6 ±26.58	145.5 ±10.63
II	11-14	252.7 ±11.95	234.2 ±34.56	256.5 ±11.13	244.4 ±24.99	247.0 ±10.45
III	15-18	286.6^{b} ±10.90	302.9^{ab} ±4.64	314.2^{a} ±4.67	284.9^{b} ±8.43	297.2 ±4.63
IV	19-22	285.2 ±8.08	300.8 ±10.27	294.3 ±4.69	283.0 ±11.17	290.8 ±4.39
V	23-26	279.4 ±11.15	299.9 ±3.17	282.6 ±8.60	290.7 ±3.79	288.2 ±3.92
Cumulative mean	7-26	1259.1 ±55.24	1263.7 ±64.41	1283.8 ±16.26	1240.3 ±71.56	1261.7 ±25.40
Total egg mass (kg)	7-26	78.91	79.13	78.47	75.75	312.26

Note: Mean values bearing the same superscript within a row did not differ significantly ($P \leq 0.05$)

from 7 to 26 weeks of age except in period III. In period III, T3 showed a significantly higher egg mass per quail (314.2 g) than that of T1 (286.6 g) and T4 (284.9 g) ($P \leq 0.05$), while T2 had an intermediate value of 302.9 g.

4.7 FEED CONSUMPTION

The period wise and overall mean daily feed consumption from 7 to 26 weeks of age in quails as influenced by lysine and methionine supplementation is presented in Table 13 and the variation in overall mean is depicted in Figure 7.

The overall mean daily feed consumption per quail over the entire period of experiment (7 to 26 weeks) among different dietary groups averaged 30.67, 31.53, 30.71 and 30.62 g in T1, T2, T3 and T4 respectively showing almost similar feed intake in all dietary groups except T2 which registered numerically higher feed intake.

Table 13 indicated the period wise variations in feed intake at different ages. The difference was narrow between the lowest and highest values in each period. The magnitude of low feed intake, in periods I, II, III, IV and V were 26.30, 28.82, 32.08, 31.99 and 31.61 g in groups T2, T3, T1, T4 and T3 respectively. Thus, the lower range of feed intake in the control group was observed in period III only.

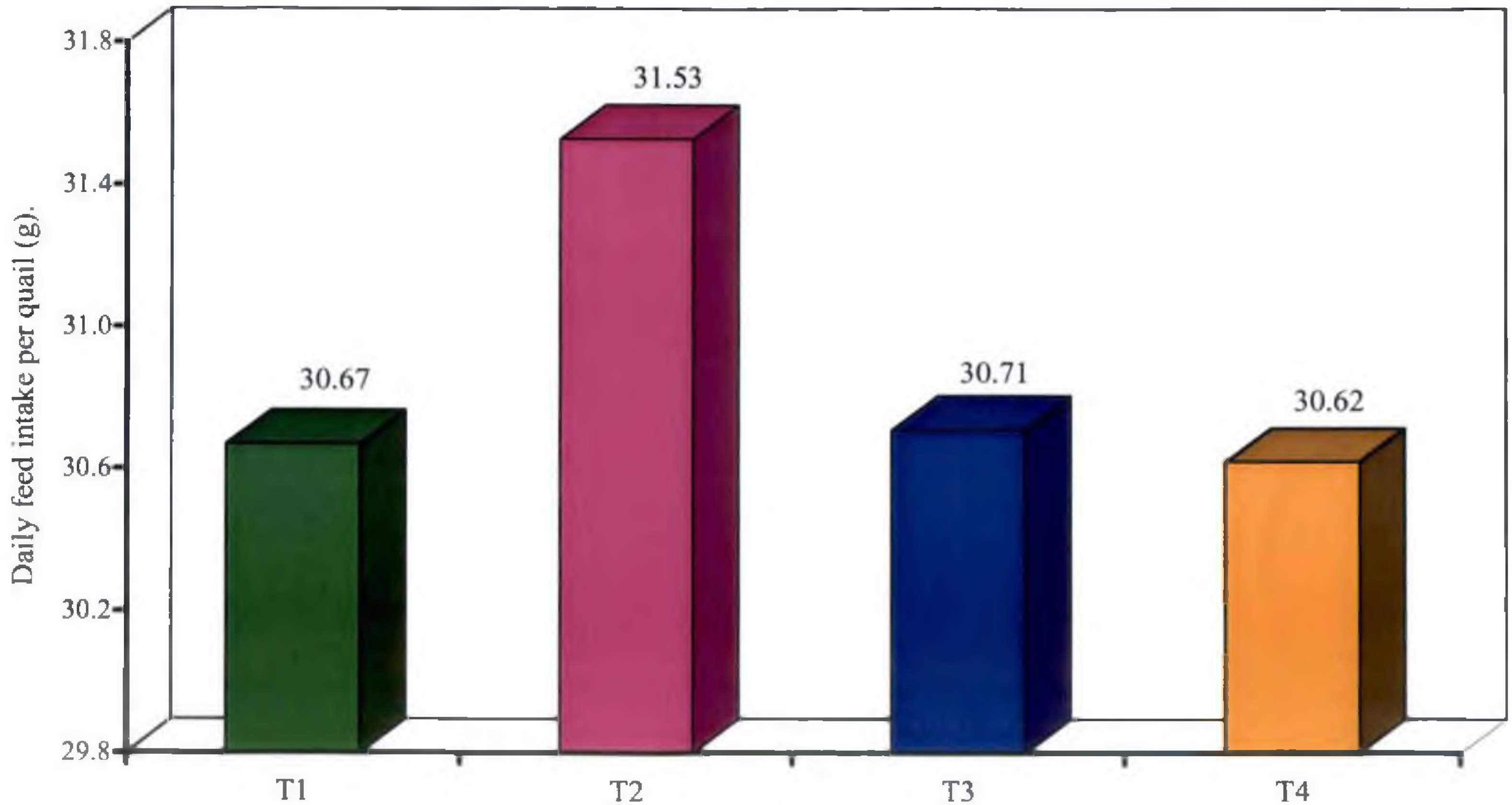
The highest mean daily feed intake in period I, from 7 to 10 weeks of age was 27.32 g in the group T4 supplemented with both lysine and methionine. In the period II (11 to 14 weeks of age), the highest value was 29.64 g in the control group T1. In periods III, IV, and V, the group T2 showed the highest daily feed intake and the values were 34.32, 34.57 and 33.09 g respectively. In period III the daily feed intake of group T2 was significantly higher than that of control group and group T4 ($P \leq 0.05$), but was comparable to that of T3. But in period IV, T2 had shown a significantly higher daily feed intake than all other groups ($P \leq 0.05$) while the feed

Table 13. Period wise mean (±S.E.) daily feed consumption per quail (g) as influenced by lysine (L) and methionine (M) supplementation in experimental diets.

Periods	Age in weeks	Mean daily feed consumption per quail(g)				Overall mean
		T_1 L - 0 % M - 0%	T_2 L - 0.25% M - 0%	T_3 L - 0% M- 0.25%	T_4 L - 0.25% M -0.25%	
I	7-10	27.01 ±0.99	26.30 ±1.89	27.17 ±0.08	27.32 ±2.06	26.95 ±0.58
II	11-14	29.64 ±0.56	29.35 ±1.53	28.82 ±0.02	29.36 ±1.32	29.29 ±0.41
III	15-18	32.08^{c} ±0.71	34.32^{a} ±0.34	33.88^{ab} ±0.11	32.52^{bc} ±0.09	33.20 ±0.38
IV	19-22	32.00^{b} ±0.58	34.57^{a} ±0.49	32.05^{b} ±0.55	31.99^{b} ±0.27	32.65 ±0.46
V	23-26	32.61 ±0.53	33.09 ±0.38	31.61 ±0.99	31.90 ±0.21	32.30 ±0.32
Cumulative mean	7-26	30.67 ±0.46	31.53 ±0.93	30.71 ±0.09	30.62 ±0.79	30.88 ±0.28

Note: Mean values bearing the same superscript within a row did not differ significantly ($P \leq 0.05$)

Fig. 7 Mean daily feed consumption per quail (g) affected by lysine and methionine supplementation in quail layer diet



intake in other groups were comparable with each other. Thus, the overall mean feed intake was slightly higher in quails fed 0.25 per cent lysine.

The highest daily feed consumption within groups T1 (32.61 g) and T2 (34.57 g) were recorded during the periods V and IV respectively. While, within groups T3 (33.88 g) and T4 (32.52 g) the highest feed consumption per quail per day occurred during the period III.

The statistical analysis of the data showed no significant difference in overall mean feed intake between dietary groups.

4.8 FEED CONVERSION RATIO (FCR)

The feed conversion ratio per dozen eggs is presented in Table 14 and FCR per kg egg mass is presented in Table 15.

4.8.1 Feed Conversion Ratio (FCR) per Dozen Eggs

Period wise feed conversion ratio per dozen eggs presented in Table 14 revealed that the ratios were very high during the 7 to 10 weeks of age since the rate of egg production was very low during this period in all dietary groups.

In period I, the FCR was poorest in T2 (0.81), followed by T4 (0.73), T3 (0.68) and T1 (0.63) in that order. In the control group T1, the period wise variations in FCR showed that it was 0.63 in period I and improved further and maintained as 0.45, 0.43, 0.43 and 0.45 in periods II to V respectively.

In the lysine supplemented group, T2, the FCR was 0.81, 0.53, 0.44, 0.45 and 0.43 in periods I to V and was the poorest in periods I to IV. In the methionine supplemented group, T3, the FCR values were 0.68, 0.44, 0.42, 0.42 and 0.44 in

Table 14. Period wise mean (±S.E.) Feed Conversion Ratio (kg feed per dozen eggs) as influenced by lysine (L) and methionine (M) supplementation in experimental diets.

Periods	Age in weeks	Mean Feed Conversion Ratio (kg feed per dozen eggs) ^{ns}				Overall mean
		T_1 L - 0 % M - 0%	T_2 L - 0.25% M - 0%	T_3 L - 0% M- 0.25%	T_4 L - 0.25% M -0.25%	
I	7-10	0.63 ±0.08	0.81 ±0.15	0.68 ±0.08	0.73 ±0.10	0.71 ±0.05
II	11-14	0.45 ±0.02	0.53 ±0.08	0.44 ±0.02	0.48 ±0.04	0.47 ±0.02
III	15-18	0.43 ±0.01	0.44 ±0.01	0.42 ±0.01	0.44 ±0.01	0.43 ±0.00
IV	19-22	0.43 ±0.00	0.45 ±0.02	0.42 ±0.00	0.44 ±0.01	0.43 ±0.01
V	23-26	0.45 ±0.02	0.43 ±0.01	0.44 ±0.01	0.43 ±0.01	0.44 ±0.01
Cumulative FCR	7-26	0.46 ±0.01	0.49 ±0.02	0.46 ±0.01	0.47 ±0.02	0.47 ±0.01

ns : non significant

periods I to V respectively and was better in period I, compared to the other groups. In T4, the lysine and methionine combination group, the FCR values were 0.73, 0.48, 0.44, 0.44 and 0.43 in periods I to V respectively.

The diet supplemented with lysine (T2) showed inferior FCR values in periods I to IV and hence the overall value was the poorest in this group. The best FCR value was 0.42 in periods III and IV in group T3 followed by 0.43 in group T1 in the same two periods, while, T2 and T4 registered 0.43 only in period V. The cumulative FCR from 7 to 26 weeks of age was better in T1 and T3 (0.46) followed by T4 (0.47) and T2 (0.49) in that order.

Statistical analysis revealed no significant differences in FCR due to supplementation of lysine and methionine. A comparison of overall mean FCR per dozen eggs in various dietary groups is given in Figure 8.

4.8.2 FCR per kg Egg Mass

The FCR per kg egg mass in various periods and the overall mean FCR from 7 to 26 weeks are presented in Table 15 and the overall means are depicted graphically in Figure 9.

The cumulative FCR from 7 to 26 weeks of age in T1, T2, T3 and T4 were 3.42, 3.51, 3.35 and 3.47 respectively and revealed that the FCR in T3 and T1 were relatively better than that of T2 and T4, the poorest being T2 supplemented with 0.25 per cent lysine. Similar trend was observed with FCR per dozen-egg basis. However, the magnitude of variation between groups T1 and T2 was wide with regard to FCR per kg egg mass.

All the dietary groups showed poorest FCR during the first period. In the control group, the FCR per kg egg mass was 5.00, 3.30, 3.14, 3.15 and 3.28 in

Table 15. Period wise mean (±S.E.) Feed Conversion Ratio (kg feed per kg egg mass) as influenced by lysine (L) and methionine (M) supplementation in experimental diets.

Periods	Age in weeks	Mean Feed Conversion Ratio (kg feed per kg egg mass) ^{ns}				Overall mean
		T_1 L - 0 % M - 0%	T_2 L - 0.25% M - 0%	T_3 L - 0% M- 0.25%	T_4 L - 0.25% M -0.25%	
I	7-10	5.00 ±0.62	6.36 ±1.22	5.45 ±0.63	5.61 ±0.78	5.61 ±0.40
II	11-14	3.30 ±0.14	3.73 ±0.54	3.16 ±0.13	3.45 ±0.30	3.41 ±0.15
III	15-18	3.14 ±0.09	3.18 ±0.05	3.02 ±0.05	3.20 ±0.09	3.14 ±0.04
IV	19-22	3.15 ±0.06	3.23 ±0.11	3.05 ±0.05	3.18 ±0.11	3.15 ±0.04
V	23-26	3.28 ±0.14	3.09 ±0.04	3.14 ±0.08	3.07 ±0.03	3.15 ±0.04
Cumulative FCR	7-26	3.42 ±0.12	3.51 ±0.13	3.35 ±0.06	3.47 ±0.15	3.43 ±0.05

ns : non significant

Fig. 8 Mean feed conversion ratio (kg feed per dozen egg) affected by supplementation of lysine and methionine in quail layer diet

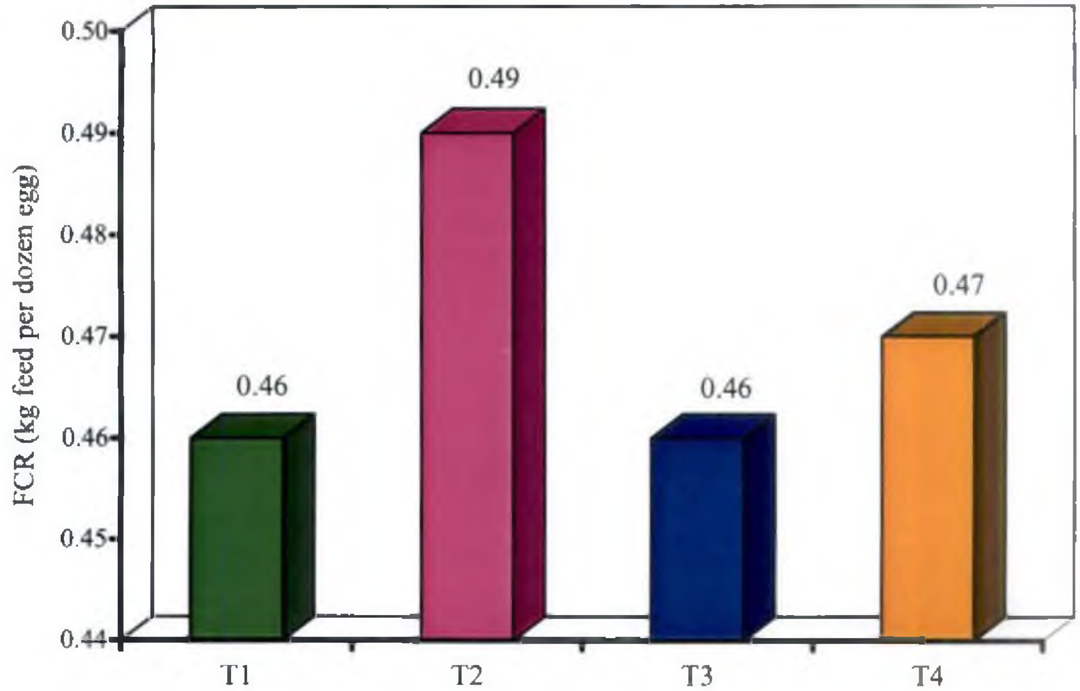
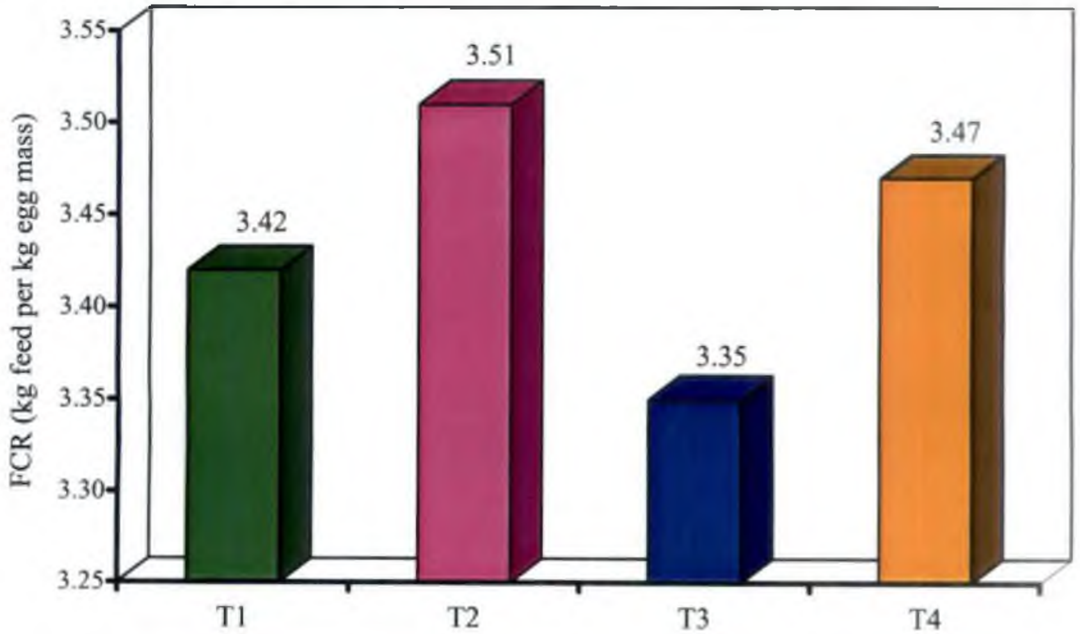


Fig. 9 Mean feed conversion ratio (kg feed per kg egg) affected by supplementation of lysine and methionine in quail layer diet



periods I to V respectively and the best FCR of 3.14 synchronized with the peak production in this group in period III. The FCR during the periods I to V in T2 was 6.36, 3.73, 3.18, 3.23 and 3.09 respectively and resulted in poorest overall FCR in this group. The period wise better FCR of 3.09 in this group was recorded late and during period V in spite of peak production in period III.

The FCR during the periods I to V in T3 was 5.45, 3.16, 3.02, 3.05 and 3.14 respectively and showed better FCR in period III. Thus, the best FCR within dietary groups T1 (3.14) and T3 (3.02) were during the period III, at 15-18 weeks of age. The FCR during the periods I to V in T4 was 5.61, 3.45, 3.20, 3.18 and 3.07 respectively and showed a better FCR in period V, synchronized with peak production.

4.9 EGG QUALITY CHARACTERISTICS

The results pertaining to egg quality traits, at different ages, are presented in Tables 16 to 20. The statistical analysis of the period wise and overall mean revealed no significant difference between dietary groups in any of the characteristics studied except the albumen index in period II.

4.9.1 Shape Index

The mean values of shape index in eggs obtained from quail layers as influenced by different dietary treatments are presented in Table 16.

The overall mean values of shape indices in eggs of quail from 7 to 26 weeks of age for the dietary groups T1, T2, T3 and T4 were 77.86, 76.81, 78.20 and 77.11 respectively. The overall mean values of shape indices at 10, 14, 18, 22 and 26 weeks of age were 78.46, 77.56, 77.11, 77.01 and 77.34, respectively showing higher mean values in period I whereas it was almost similar in all other periods.

Table 16. Period wise mean (±S.E.) shape index in quail eggs as influenced by lysine (L) and methionine (M) supplementation in experimental diets.

Periods	Age in weeks	Mean shape index ^{ns}				Overall mean
		T_1 L - 0 % M - 0%	T_2 L - 0.25% M - 0%	T_3 L - 0% M - 0.25%	T_4 L - 0.25% M - 0.25%	
I	10	79.77 ±2.51	78.80 ±0.44	78.74 ±1.08	76.55 ±0.25	78.46 ±1.38
II	14	77.41 ±0.89	76.97 ±0.82	78.01 ±0.30	77.83 ±0.80	77.56 ±0.70
III	18	77.10 ±0.64	76.72 ±0.22	77.33 ±0.70	77.28 ±0.62	77.11 ±0.53
IV	22	77.47 ±0.93	75.39 ±1.53	78.62 ±0.60	76.55 ±0.93	77.01 ±0.11
V	26	77.53 ±0.84	76.17 ±0.74	78.31 ±0.53	77.34 ±0.39	77.34 ±0.70
Mean	10-26	77.86 ±1.07	76.81 ±0.56	78.20 ±0.32	77.11 ±0.45	77.49 ±0.66

ns : non significant

4.9.2 Albumen Index

The mean albumen index values in quail eggs as influenced by supplementation of lysine and methionine at different ages are presented in Table 17. The overall mean values in T1, T2, T3 and T4 were 0.109, 0.103, 0.105 and 0.105 respectively. The period wise data revealed that it was significantly higher with the diet supplemented with methionine (0.116) in period II compared to that of T2 (0.095) and T4 (0.097) but was statistically comparable with that of T1 (0.111).

4.9.3 Yolk Index

The mean yolk index in eggs of quails as influenced by supplementation of lysine and methionine from 7 to 26 weeks of age are presented in Table 18. The mean values of yolk indices were 0.481, 0.471, 0.480 and 0.468 for the dietary groups T1, T2, T3 and T4 respectively.

4.9.4 Internal Quality Unit (IQU)

The mean internal quality units (Table 19) in eggs of quail in dietary groups T1, T2, T3 and T4 were 60.81, 58.03, 58.38 and 58.68 respectively. The statistical analysis revealed no significant difference among dietary groups.

4.9.5 Shell Thickness

The mean values of shell thickness in eggs of quails as influenced by supplementation of lysine and methionine from 7 to 26 weeks of age presented in Table 20 for the dietary groups T1, T2, T3 and T4 were 205.1, 205.8, 203.6 and 208.1 µm respectively.

Table 17. Period wise mean (±S.E.) albumen index in quail eggs as influenced by lysine (L) and methionine (M) supplementation in experimental diets.

Periods	Age in weeks	Mean albumen index				Overall mean
		T_1 L - 0 % M - 0%	T_2 L - 0.25% M - 0%	T_3 L - 0% M - 0.25%	T_4 L - 0.25% M - 0.25%	
I	10	0.104 ±0.00	0.102 ±0.01	0.104 ±0.01	0.112 ±0.01	0.106±0.01
II	14	0.111±0.01^{ab}	0.095±0.01^{b}	0.116±0.01^{a}	0.097±0.01^{b}	0.105±0.01
III	18	0.105 ±0.01	0.109 ±0.01	0.095 ±0.01	0.102 ±0.01	0.103±0.01
IV	22	0.104 ±0.01	0.098 ±0.01	0.103 ±0.01	0.105 ±0.01	0.102±0.01
V	26	0.123 ±0.01	0.112 ±0.01	0.105 ±0.01	0.109 ±0.01	0.112±0.01
Mean	10-26	0.109 ±0.01	0.103 ±0.01	0.105 ±0.01	0.105 ±0.01	0.106±0.01

Note: Mean values bearing the same superscript within a row did not differ significantly ($P \leq 0.05$)

Table 18. Period wise mean (±S.E.) yolk index in quail eggs as influenced by lysine (L) and methionine (M) supplementation in experimental diets.

Periods	Age in weeks	Mean yolk index ^{ns}				Overall mean
		T_1 L - 0 % M - 0%	T_2 L - 0.25% M - 0%	T_3 L - 0% M- 0.25%	T_4 L - 0.25% M -0.25%	
I	10	0.476 ±0.02	0.462 ±0.02	0.472 ±0.01	0.464 ±0.01	0.468±0.01
II	14	0.483 ±0.01	0.471 ±0.02	0.484 ±0.01	0.463 ±0.01	0.475±0.01
III	18	0.475 ±0.01	0.466 ±0.01	0.474 ±0.01	0.458 ±0.01	0.468±0.01
IV	22	0.477 ±0.01	0.462 ±0.01	0.477 ±0.02	0.471 ±0.02	0.472±0.01
V	26	0.495 ±0.01	0.490 ±0.01	0.493 ±0.00	0.486 ±0.01	0.491±0.01
Mean	10-26	0.481 ±0.01	0.471 ±0.01	0.480 ±0.01	0.468 ±0.01	0.475±0.01

ns : non significant

Table 19. Period wise mean (±S.E.) internal quality unit in quail eggs as influenced by lysine (L) and methionine (M) supplementation in experimental diets.

Periods	Age in weeks	Mean internal quality unit [ns]				Overall mean
		T_1 L - 0 % M - 0%	T_2 L - 0.25% M - 0%	T_3 L - 0% M- 0.25%	T_4 L - 0.25% M -0.25%	
I	10	60.77±0.27	60.58±1.83	60.23±2.37	63.87±1.72	61.36±1.72
II	14	60.07±3.68	56.07±2.03	63.30±1.00	55.61±1.37	58.76±2.60
III	18	57.71±2.03	58.54±2.26	53.26±4.06	55.53±1.16	56.26±2.56
IV	22	59.71±2.09	54.19±2.18	56.56±2.31	58.36±1.09	57.20±2.07
V	26	65.76±2.60	60.75±2.77	58.55±2.04	60.01±0.70	61.27±2.40
Mean	10-26	60.81±1.25	58.03±1.06	58.38±1.55	58.68±0.53	58.97±1.18

ns : non significant

Table 20. Period wise mean (±S.E.) shell thickness (µm) in quail eggs as influenced by lysine (L) and methionine (M) supplementation in experimental diets.

Periods	Age in weeks	Mean shell thickness (µm) [ns]				Overall mean
		T_1 L - 0 % M - 0%	T_2 L - 0.25% M - 0%	T_3 L - 0% M- 0.25%	T_4 L - 0.25% M -0.25%	
I	10	207.9 ±3.79	212.6 ±5.49	204.9 ±4.26	207.6 ±2.47	208.2±3.97
II	14	202.6 ±2.44	203.3 ±2.57	195.8 ±6.68	203.6 ±5.49	201.3±4.49
III	18	209.5 ±4.65	209.4 ±7.09	210.2 ±7.64	209.5 ±4.00	209.6±5.41
IV	22	195.0 ±8.80	188.1 ±6.16	196.9 ±2.94	204.9 ±5.16	196.2±6.30
V	26	210.5 ±2.41	215.7 ±3.09	210.4 ±3.43	215.1 ±5.73	212.9±3.69
Mean	10-26	205.1 ±0.77	205.8 ±1.93	203.6 ±3.46	208.1 ±2.87	205.7±2.37

ns : non significant

4.10 CARCASS YIELDS AND LOSSES

The carcass yields and losses pertaining to dressed, eviscerated and ready-to-cook yield, liver and giblet yield over the live weight at 26weeks of age in layer quails as influenced by dietary supplementation of lysine and methionine are presented in Table 21. The percentages of blood, skin and feather put together, and ovary and oviduct put together are also presented in Table 21.

The per cent dressed yield without skin were 85.78, 84.98, 86.63 and 83.90 in groups T1, T2, T3 and T4 respectively and was significantly higher in T3 compared to that of T2 and T4 ($P \leq 0.05$). In the above groups, the eviscerated yields without skin were 54.79, 55.07, 52.01 and 54.05 per cent.

The liver alone contributed 2.98, 2.87, 2.83 and 2.55 per cent of the live weight in groups T1, T2, T3 and T4 respectively, the lowest being in the group T4. The giblet yields were 5.55, 5.59, 5.56 and 5.15 in the respective groups. The ready to cook yield (R-to-C) without skin were 60.34, 60.66, 57.58 and 59.21 per cent in T1, T2, T3 and T4 respectively.

The results indicated that the mean values of per cent blood loss were 3.74, 3.83 4.42 and 4.10 in groups T1, T2, T3 and T4 respectively. The skin and feather put together in the above groups were 10.48, 11.19, 8.95 and 12.00 per cent and was significantly higher in T2 and T4 supplemented with lysine alone and in combination with methionine, in comparison with supplementation of methionine alone ($P \leq 0.05$). The ovary and oviduct put together were 6.13, 5.53, 6.23 and 6.21 per cent in T1, T2, T3 and T4 respectively.

The overall results pertaining to carcass yields and losses indicated that none of the above traits varied significantly except significantly lower skin and feather per cent and significantly higher per cent dressed yield without skin in methionine supplemented group T3 than that of its combination with lysine T4 and T2

Table 21. Mean (±S.E.) carcass yields and losses (%), serum total protein (g/dl) and total cholesterol (mg%) at 26weeks of age in layer quails as influenced by lysine (L) and methionine (M) supplementation in experimental diets.

Carcass yields and losses on live weight basis (per cent)	Dietary supplementation of lysine and methionine levels (%)			
	T_1 L - 0 M - 0	T_2 L - 0.25 M - 0	T_3 L - 0 M - 0.25	T_4 L - 0.25 M - 0.25
Blood	3.74 ±0.24	3.83 ±0.34	4.42 ±0.42	4.10 ±0.50
Skin and feather	10.48^{ab} ±0.45	11.19^{a} ±0.70	8.95^{b} ±0.93	12.00^{a} ±0.64
Eviscerated yield (without skin)	54.79 ±0.75	55.07 ±1.02	52.01 ±1.38	54.05 ±0.78
Liver	2.98 ±0.33	2.87 ±0.22	2.83 ±0.28	2.55 ±0.14
Giblet	5.55 ±0.35	5.59 ±0.19	5.56 ±0.25	5.15 ±0.12
Ovary and oviduct	6.13 ±0.35	5.53 ±0.19	6.23 ±0.25	6.21 ±0.12
Dressed yield (without skin)	85.78^{ab} ±0.37	84.98^{bc} ±0.48	86.63^{a} ±0.64	83.90^{c} ±0.58
R-to-C yield (without skin)	60.34 ±0.58	60.66 ±0.87	57.58 ±1.25	59.21 ±0.77
Serum total protein and total cholesterol				
Serum total protein (g/dl)	6.83 ±0.73	5.74 ±0.77	6.86 ±0.61	7.31 ±0.92
Serum total cholesterol (mg%)	190.33^{b} ±20.70	190.19^{b} ±15.44	215.75^{ab} ±11.57	248.62^{a} ±21.92

Note: Mean values bearing the same superscript within a row did not differ significantly (P≤0.05) supplemented with lysine alone. The mean value of skin and feather per cent in the control group was intermediary and comparable with all other groups.

4.11 SERUM PROTEIN AND CHOLESTEROL

The mean serum protein and total cholesterol values in quails at 26 weeks of age in various dietary treatments are set out in Table 21. The mean values of serum protein were 6.83, 5.74, 6.86 and 7.31 g/dl and total cholesterol were 190.33, 190.19, 215.75 and 248.62 mg/dl for T1, T2, T3 and T4 respectively. The group T4 supplemented with lysine and methionine showed significantly higher serum total cholesterol than T1 and T2 groups ($P \leq 0.05$). The values were statistically comparable in groups T4 and T3.

A comparison of the cholesterol levels in various dietary groups is given in Figure 10.

4.12 LIVABILITY

The mean livability per cent of Japanese quails from 7 to 26 weeks of age as influenced by supplementation of lysine and methionine are presented in Table 22. A total of 21 birds died during 20 weeks of experimental period from 7 to 26 weeks of age. The overall livability per cent among dietary groups T1, T2, T3 and T4 were 95.31, 92.19, 90.62 and 89.06 respectively. T1 showed a higher livability per cent followed by T2, T3 and T4.

The overall mortality per cent of T1, T2, T3 and T4 were 4.69, 7.81, 9.38 and 10.94, respectively. T4 recorded a higher mortality per cent compared to other groups. Necropsy of dead birds was conducted to detect the cause of death and they did not show any signs that are attributable to the effects of supplementation of lysine and methionine alone or in combination.

Fig. 10 Serum total cholesterol (mg%) affected by lysine and methionine supplementation in quail layer diet

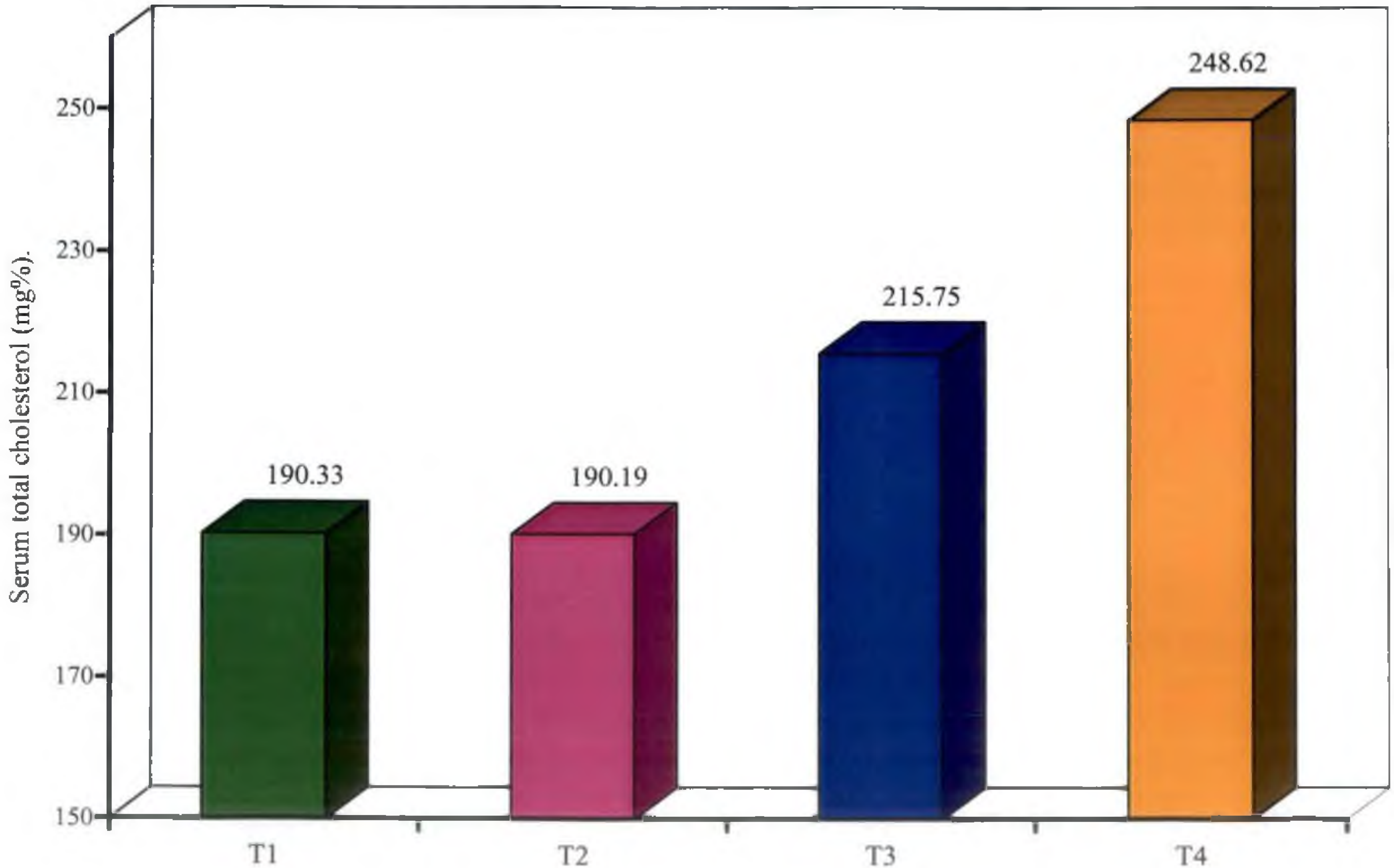


Table 22. Period wise mean (±S.E.) livability per cent as influenced by lysine (L) and methionine (M) supplementation in experimental diets.

Periods	Age in weeks	Mean livability per cent [ns]				Overall mean
		T_1 L - 0 % M - 0 %	T_2 L - 0.25% M - 0 %	T_3 L - 0 % M- 0.25%	T_4 L - 0.25% M -0.25%	
I	7-10	100.00 ±0.00	100.00 ±0.00	100.00 ±0.00	100.00 ±0.00	100.00 ±0.00
II	11-14	98.44 ±0.08	100.00 ±0.00	96.88 ±0.09	96.88 ±0.16	98.05 ±0.10
III	15-18	100.00 ±0.00	100.00 ±0.00	96.88 ±0.08	98.44 ±0.09	98.83 ±0.07
IV	19-22	96.88 ±0.09	93.75 ±0.34	95.31 ±0.16	98.44 ±0.08	96.09 ±0.18
V	23-26	100.00 ±0.00	98.44 ±0.08	100.00 ±0.00	96.88 ±0.16	98.83 ±0.09
Cumulative mean	7-26	95.31 ±0.08	92.19 ±0.32	90.62 ±0.32	89.06 ±0.25	91.80 ±0.24
Mortality %	7-26	4.69 ±0.25	7.81 ±0.95	9.38 ±0.96	10.94 ±0.75	8.20 ±0.36

ns : non significant

4.13 ECONOMICS

The economics of egg production over feed cost in Japanese quail as influenced by supplementation of lysine and methionine are presented in Table 23. The profit obtained per egg in various dietary groups is graphically depicted in Figure 11.

The total egg production for T1, T2, T3 and T4 were 7063, 6857, 6889 and 6646, respectively during the 20 weeks of experimental period. The corresponding total feed consumption were 268.83, 275.88, 262.12 and 261.15 kg respectively. The cost of one kg feed for T1, T2, T3 and T4 were Rs.9.25, 9.67, 9.74 and 10.16 respectively. The cost of feed per egg was significantly lower in T1 (35.21 paise) compared to T4 (39.92 paise) ($P \leq 0.05$) and was intermediate in T3 (37.06 paise) and T2 (38.91 paise). The margin of returns over feed cost per quail housed for the period from 7 to 26 weeks of age were Rs. 27.36, 22.60, 24.69 and 20.85 and that per period were Rs. 5.47, 4.52, 4.94 and 4.17 in T1, T2, T3 and T4 respectively.

4.14 SUMMARY OF PRODUCTION PERFORMANCE

The results obtained in the study are summarized in Table 24. The methionine supplementation at 0.25 per cent level (T3) resulted in significantly lower body weight at 26 weeks of age in comparison with diets T1 and T2 ($P \leq 0.05$). The skin plus feather was significantly lower in the group T3 ($P \leq 0.05$). The mean egg weight was increased significantly by the supplementation of 0.25 per cent lysine and methionine independently and in combination in layer quail rations ($P \leq 0.05$).

The cumulative egg production during the period from 7 to 26 weeks of age did not differ significantly among each other. However, the feed cost was high due to the addition of lysine and methionine and so the margin of returns was lowest with diet T4.

Table 23. Economics of quail rearing in cages from 7 to 26 weeks of age influenced by lysine (L) and methionine (M) supplementation in experimental diets.

Sl. No:	Particulars	Dietary supplementation of lysine and methionine levels (%)			
		T_1 L - 0 M - 0	T_2 L - 0.25 M - 0	T_3 L - 0 M - 0.25	T_4 L - 0.25 M - 0.25
1	Total feed intake (kg)	268.83	275.88	262.12	261.15
2	Feed cost per kg (Rs.)	9.25	9.67	9.74	10.16
3	Total feed cost (Rs.)	2486.7	2667.8	2553.0	2653.3
4	Total number of eggs	7063	6857	6889	6646
5	Total returns by sale of eggs (Rs.)*	4237.8	4114.2	4133.4	3987.6
6	Cumulative return over feed cost (Rs.)	1751.12	1446.44	1580.35	1334.32
7	Feed cost per egg (Ps.)	35.21^{b}	38.91^{ab}	37.06^{ab}	39.92^{a}
8	Margin of returns over feed cost per egg (Ps.)	24.79^{a}	21.09^{ab}	22.94^{ab}	20.08^{b}
9	Margin of returns over feed cost / quail housed (Rs.)	27.36	22.60	24.69	20.85
10	Margin of returns per quail housed per period (Rs.)	5.47	4.52	4.94	4.17

Note: Mean values bearing the same superscript within a row did not differ significantly ($P \leq 0.05$)

* Sale price of egg – 60 Paise / egg

Fig. 11 Margin of return over feed cost per egg (Ps.) affected by lysine and methionine supplementation in quail layer diet

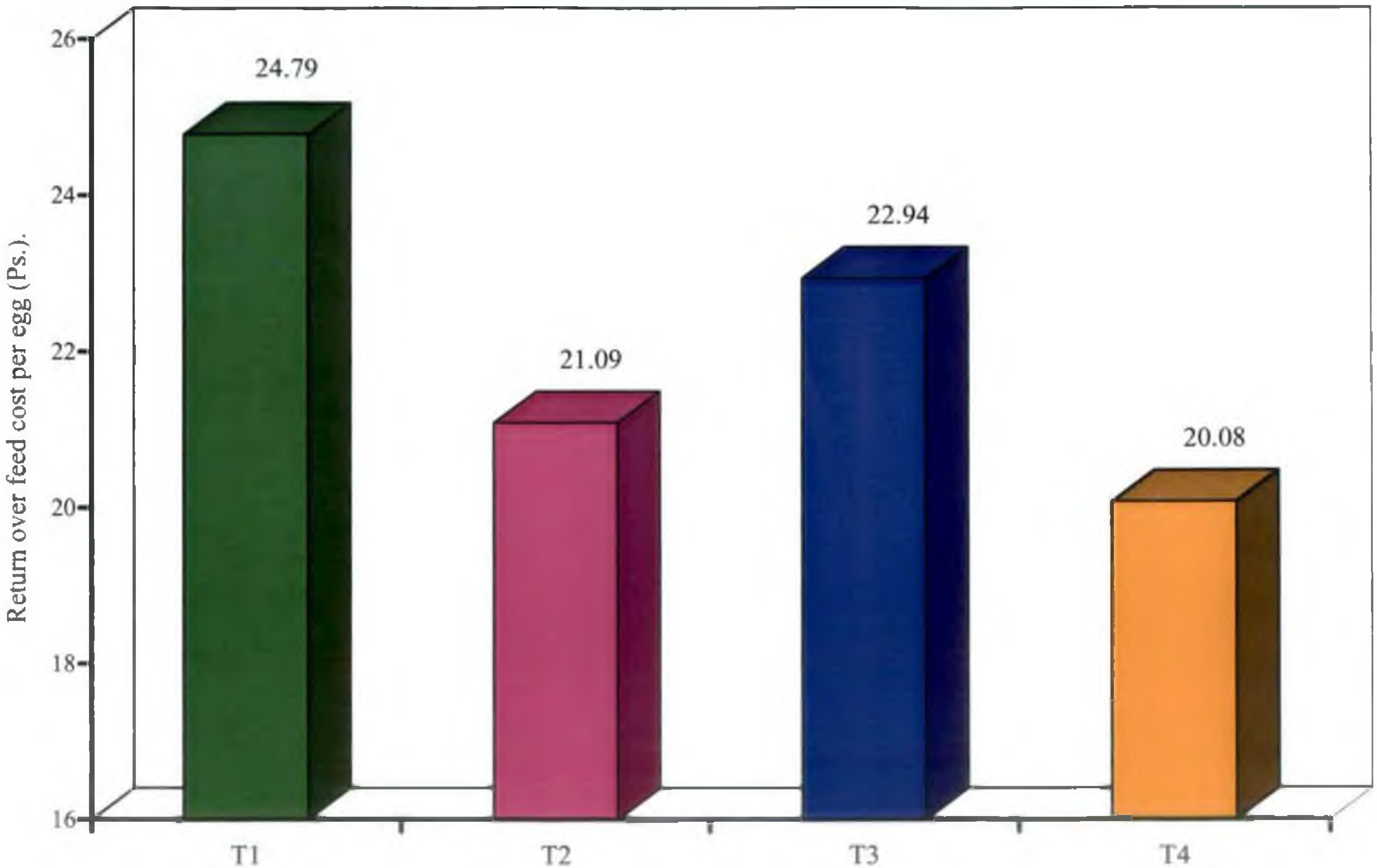


Table 24. Summary of performance of Japanese quail layers (7 to 26 wk) influenced by lysine (L) and methionine (M) supplementation in experimental diets.

Sl. No:	Characteristic	Dietary supplementation of lysine and methionine levels (%)			
		T1 (control)	T2 (0.25 % L)	T3 (0.25% M)	T4 (L+M)
1	BW 6th wk (g)	180.00	181.17	180.23	182.66
2	BW 26th wk (g)*	225.83^{a}	225.60^{a}	215.04^{b}	219.81^{ab}
3	AFE / 50% production (days)	42 / 51	42 / 54	42 / 49	42 / 52
4	QH egg number	110.36	107.14	107.64	103.84
5	QH per cent	78.83	76.53	76.89	74.17
6	QD egg number	112.7	109.51	112.71	108.82
7	QD per cent	80.50	78.22	80.51	77.7
8	Egg weight (g) *	11.17^{b}	11.55^{a}	11.40^{a}	11.40^{a}
9	Total egg mass (kg)	78.91	79.13	78.47	75.75
10	Feed intake / day (g)	30.67	31.53	30.71	30.62
11	FCR / dozen eggs	0.46	0.49	0.46	0.47
12	FCR/ kg egg mass	3.42	3.51	3.35	3.47
13	Shape index	77.90	76.81	78.20	77.11
14	Albumen index	0.109	0.103	0.105	0.105
15	Yolk index	0.481	0.471	0.48	0.468
16	Internal quality unit (IQU)	60.81	58.03	58.38	58.68
17	Shell thickness (μm)	205.1	205.8	203.6	208.1
18	Margin /quail housed (Rs.)	27.36	22.60	24.69	20.85
19	Margin per egg (Ps.) *	24.79^{a}	21.09^{ab}	22.94^{ab}	20.08^{b}
20	Dressed yield % (except skin)	85.78^{ab}	84.98^{bc}	86.63^{a}	83.90^{c}
21	R-to-C yield % (without skin)	60.34	60.66	57.58	59.21
22	Skin and feather % (26wk)*	10.48^{ab}	11.19^{a}	8.95^{b}	12.00^{a}
23	Serum cholesterol (mg %)*	190.33^{b}	190.19^{b}	215.75^{ab}	248.62^{a}
24	Serum total protein (g/dl)	6.83	5.74	6.86	7.31
25	Livability (%)	95.31	92.19	90.63	89.06

*Mean values bearing same superscripts did not differ significantly ($P \leq 0.05$)

Discussion

5. DISCUSSION

5.1 METEOROLOGICAL OBSERVATIONS

The results presented in Table 3 revealed that the maximum temperature inside the experimental house which was 34.73°C during the first period increased significantly to 36.68°C during the second period ($P \leq 0.05$) and continued high during the third period (37.07°C) and indicated that the experimental quails were subjected to high ambient temperature during the period from 11 to 22 weeks of age (Figure 1). The severity of stress due to temperature was comparatively low during periods I and V. The overall mean maximum temperature inside the house during the experimental period was 35.67°C. The maximum temperature recorded in present study is slightly higher than the results of Somanathan *et al.* (1980) who reported a maximum temperature ranging from 31.14 to 35.14°C at Mannuthy region during the period from January to June in the years 1974 to 1978.

The minimum temperature of 22.91°C in period I and 23.59°C in period II were significantly lower than that in all other periods ($P \leq 0.05$) and was close to the comfortable temperature zone for poultry. It was significantly higher in period IV ($P \leq 0.05$) and was intermediary in period III.

The relative humidity (R.H.), which was 70.79 per cent in the forenoon (F.N.) during period I showed significant increase of 7.10 per cent in period II and further increased by 7.47 per cent in period III ($P \leq 0.05$). The R.H. (F.N.) continued high in period IV (84.72 per cent) and was increased significantly by 6.71 per cent during the period V ($P \leq 0.05$) and thereby the humid environment existed in the F.N. throughout the experimental period. The R.H. in the afternoon (A.N.) also showed significant increase until period IV ($P \leq 0.05$) and continued high during period V. It was 53.25

per cent in period I and showed progressive increase of 10.29, 7.53 and 14.0 per cent in periods II, III and IV respectively. These results indicated that the per cent R.H. was very high during the periods IV and V, both in the F.N and A.N. Thus the entire experiment was carried out during periods of hot and humid environment.

5.2 BODY WEIGHT

The overall mean body weight of quails at 6 weeks of age (BW6) was 181.02 g and the differences between dietary groups were statistically non significant. The BW6 in the present experiment was higher than that of the 160.05g reported by Lekshmi (2005) and 172.24g reported by Sheena (2005) in quails. This variation might be due to the better quality of feed provided at the starter and grower phase of the quails, before the commencement of the experiment. The BW6 observed in the present study falls within the range of 161 to 200 g reported by Sachdev and Ahuja (1986) in egg line Japanese quails at 6 weeks of age.

The results presented in Figure 2 clearly showed that mean body weight at 26 weeks of age (BW26) was similar in the control group and lysine supplemented group (225.83 and 225.60 g). However, in the methionine supplemented group (T3) BW26 was significantly lower (215.04g) than that of the control group and the lysine supplemented group ($P \leq 0.05$). Whereas, the BW26 in the group (T4) supplemented with both lysine and methionine was intermediary and comparable with all other groups. The reason for lower body weight in T3 may be attributed to the higher ratio of methionine to lysine (0.70) in the diet T3 compared to the narrow ratios of 0.56, 0.45 and 0.36 in the diets T4, T1 and T2 respectively, leading to comparatively higher intake of methionine and lower intake of lysine daily in this group. In the group T2, the methionine to lysine ratio was narrow and thus the daily intake of lysine was higher and that of methionine was lower leading to a higher body weight. Latshaw (1976) in laying hens observed higher body weight on lysine supplementation.

The BW gain of 45.83 g in T1 and 44.43 g in T2 from 7 to 26 weeks of age were significantly higher compared to the methionine supplemented group ($P \leq 0.05$). This indicated that the availability of lysine and methionine in the diets T1 and T2 was sufficient to support higher body weight gain in 140 days of production period for layer quails. The intermediary body weight gain observed in the group T4 fed diet supplemented with 0.25 per cent each of lysine and methionine was 37.16 g and was comparable with all other groups. Solarte *et al.* (2005) noticed a quadratic effect of total sulphur amino acid level on body weight gain of laying hens.

5.3 AGE AT AGE AT SEXUAL MATURITY

In the present study, quails in all the experimental groups started laying at the age of 42 days, the normal age at sexual maturity in quails and this is in agreement with Sreenivasaiah (1998), who stated that Japanese quails started production by the end of sixth week.

The age at 50 per cent production was early in the methionine supplemented group (49 days) compared to a delayed age at 50 per cent production (54 days) in the group supplemented with 0.25 per cent lysine. In the group T3, methionine to lysine ratio was the highest with a value of 0.70 and in T2 it was the lowest with a value of 0.36 and indicated the role of methionine in early development of the reproductive organs. In the dietary groups T1 and T4 age at 50 per cent production were 51 and 52 days, wherein the ratio between methionine and lysine in the feed was 0.45 and 0.56 respectively, showing intermediary values. Bunchasak and Silapasorn (2005) noticed improved ovary weight on increasing the methionine level in a low crude protein (14 per cent) diet for hens. Lekshmi (2005) reported that the average age at first egg was 45.25 days and mean age at 50 per cent production was 62.5 days in quails fed standard layer ration, while Sheena (2005) reported the same at 47 and 58 days respectively.

5.4 EGG PRODUCTION

5.4.1 Weekly Quail Housed Egg Number (QHN) and Per cent (QHP) Production

Results pertaining to egg production presented in Table 5 indicated the weekly pattern of egg production in quails housed in cages and the production curve depicted in figure 3 precisely indicated weekly fluctuations in egg production at different ages. Up to 12 weeks of age, the egg production in the control group (T1) was numerically high at every week compared to the amino acid supplemented groups (T2, T3 and T4) and indicated the satisfactory utilisation of lysine and methionine in practical ration even without supplementation. Egg production in the group T1 was above 80 per cent from 12th week onwards until the end of the experiment at 26 weeks of age. The peak production was recorded at 18th week of age (93.30 per cent) resulting in cumulative mean quail housed egg production of 78.83 per cent over a period of 20 weeks with mean value of 110.36 eggs per quail. Lekshmi (2005) reported 90.32 HHN and 93.52 HDN with corresponding percentages of 64.38 and 66.86 and Sheena (2005) reported HHN of 83.71, HDN of 85.10 and corresponding percentages of 59.64 and 61.05 in Japanese quail layers from 6 to 26 weeks of age on feeding standard quail layer ration.

In the lysine supplemented group (T2), the egg production was very low during seventh week of age due to delayed sexual maturity. The production improved gradually, and reached 79.46 per cent at 14th week of age. From 15 weeks of age onwards, egg production in T2 was higher than the control group in every week till the end of the experiment except at 21 and 24 weeks of age. The peak production of 96.21 per cent was reached at 18th week of age. The cumulative QH production in T2 (76.53 per cent) was 2.30 per cent lower than that of the control group, with 107.14 eggs showing a reduction of 3.22 eggs per quail.

In the methionine supplemented group (T3), the egg production was higher than that of the lysine supplemented group up to 16 weeks of age except at 11th week. At 16th week, the peak production of 93.97 per cent was recorded in the group T3. The egg production from 17 to 26 weeks of age was lower than that of the group T2 at the respective ages. However, the cumulative production in T3 (76.89 per cent) was 107.64 eggs per quail and was similar to that of the group T2.

The combined supplementation of lysine and methionine in the group T4 resulted in lower egg production than the methionine supplemented group up to 22 weeks of age except at 11th week and poorer production than the lysine supplemented group from 15 to 26 weeks of age. However, the egg production in T4 was higher than that of T3 from 23 to 26 weeks of age and was better than T2 from 7 to 14 weeks of age except at 11 weeks. In spite of these variations, the cumulative egg production in T4 (74.17 per cent) was 103.84 eggs and was 3.8 and 3.3 eggs per quail lower than that of the groups T3 and T2 respectively. The peak production in T4 was at 16th week (87.50 per cent) based on the 64 quails housed at the beginning of the experiment.

5.4.2 Period wise Quail Housed Egg Number (QHN) and Per cent (QHP) Production

The period wise variations in QHN and QHP revealed significant difference only in period III, wherein the QHN in the methionine supplemented group (T3) was 26.94 eggs per quail and was significantly higher than the 24.50 eggs per quail recorded in the lysine and methionine combination group T4 ($P \leq 0.05$), but was comparable to that of T1 and T2. However, significant difference could not be achieved in the cumulative egg production in this group due to the lowered egg production during period V. This showed that the supplemented methionine could be used more efficiently during the peak production period and that methionine was better utilised when supplemented individually than in combination with lysine.

The cumulative QHN and QHP production did not show significant variations among dietary groups even though it was numerically better in the control group. The numerically lower QH production in all the amino acid supplemented groups might be due to the humidity and temperature stress that affected the efficient utilisation of the supplemented amino acids. These results indicated that the effect of lysine and methionine supplementation independently and in combination was not advantageous in respect of egg number on quail housed basis in comparison with the control diet. Therefore, it can be presumed that the lysine and methionine available in the control ration based on yellow maize, soyabean meal, fish meal and gingelly oil cake was adequate to support optimum egg production, and these amino acids were efficiently utilised by the quails. Thus the addition of lysine and methionine as crystalline amino acids was proved to be of no added advantage in a basal ration containing 22 per cent crude protein.

In an experiment conducted by Garcia *et al.* (2005) egg production in Japanese quails was not improved by methionine plus cystine levels higher than 0.7 per cent. Ichhponani *et al.* (1983) reported a numerical reduction in egg production when the supplemental level of lysine and methionine was increased from 0.1 to 0.2 per cent each in WL hens. Solarte *et al.* (2005) noticed that increasing the methionine level from 0.434 to 0.484 per cent did not improve egg production in laying hens.

5.4.3 Weekly Quail Day Egg Number (QDN) and Per cent (QDP) Production

The weekly and cumulative quail day egg number and per cent production presented in Table 8 and graphically depicted in Figure 4 revealed that the intensity of production among the quails actually survived during the experiment was lower in the group T4 in comparison with other groups. The difference in cumulative QDN between T1 and T3 was negligible (0.01) and indicated that efficiency of production and utilisation of methionine in diet T3 was similar to that of control diet. Similarly, inferior quail day egg production in T2 and T4 compared to that of T1 and T3 was indicative of poor utilisation of lysine in diets T2 and T4. The cumulative egg number in the control group was 3.19 eggs higher than that of T2 and 3.88 eggs higher than that of T4.

Among the amino acid supplemented groups, the diet supplemented with 0.25 per cent methionine (T3) was superior over T2 and T4. The rate of egg production in the group T3 was excellent during the period from 15 to 19 weeks of age maintaining higher intensity for longer duration after peak production. The fall in egg production in T3 during period V might be due to severe humidity stress.

5.4.4 Period wise Quail Day Egg Number (QDN) and Per cent (QDP) Production

The period wise quail day production was significantly different between treatments only in period III ($P \leq 0.05$). Also the peak production in dietary groups T1, T2 and T3 coincide with this period. In these groups, higher utilisation of nutrients for peak production occurred evidently in period III. In the group T4, both lysine and methionine were present in higher levels, but the production was lowest in period III. Compared to the peak production in other groups, group T4 showed the peak production in period V and indicated better utilisation of lysine and methionine in combination as age advanced. However, this effect is not clear as the production reduced with increasing age when methionine was supplemented alone.

The trend of non significant difference among dietary groups in cumulative QH egg production was exhibited with quail day production also and indicated that mortality did not intervene the overall production. The QD production in period III was significantly higher in the methionine supplemented group than the control group and T4, but was intermediary in the lysine supplemented group. This significantly higher QD production in T3 compared to the control group, which was not seen with QH production, is due to the 1.4 per cent difference between QD and QH per cent production in T3 during period III. It could be seen that the quail day per cent production in the dietary group T3 (97.60 per cent) was 7.12 per cent higher than that of control group in period III. Among the amino acid supplemented groups, the QDP in T3 was 4.46 per cent higher than that of lysine supplemented group (T2) and 8.98 per cent higher than that of lysine and methionine combination (T4), indicating better utilisation of nutrients in the group supplemented with methionine alone during period III. The cumulative QD production was 80.51 per cent in T3 compared to 80.50 per cent in the control group, 78.22 per cent in the lysine supplemented group and 77.73 per cent in the group supplemented with both lysine and methionine (Figure 5).

The non significant effect of lysine and methionine supplementation at 0.25 per cent level on egg production is in full agreement with the findings of Hummel *et al.* (1965) who observed non significant response in egg production to supplemental levels of 0.225 and 0.3 per cent methionine and 0.1 per cent lysine in White Leghorn (WL) pullets. Schutte *et al.* (1994) reported that the egg production per hen-day was not significantly different in WL layers fed different levels of methionine from 0.1 to 0.25 per cent. Amaefule *et al.* (2004) observed non significant variation in the HD egg production in layers by supplementing 0.1 per cent of methionine or lysine or their combination.

5.5 EGG WEIGHT

The cumulative means presented in Table 11 and Figure 6 indicated that in the groups supplemented with lysine and methionine individually or in combination, mean egg weight was significantly higher than that of the control group ($P \leq 0.05$). This effect is beneficial as the QH and QD egg numbers were comparable in the control group and in the amino acid supplemented. Therefore, it was ascertained that utilisation of nutrients was higher in amino acid supplemented groups for the production of heavier eggs.

Period wise variations revealed that in period I, group T4 showed significantly higher egg weight than the control group and T3 ($P \leq 0.05$). This showed that the combination of lysine and methionine supplemented in diet T4 were utilised effectively during the initial period. The reason for lower egg weight in T3 during period I may be the early sexual maturity in this group as evidenced by the early 50 per cent production compared to other groups. In period II, egg weights showed non significant variation among dietary groups with T2, T3, T4 and T1 having egg weights in descending order. In periods III and IV, the egg weight in dietary group T2 was significantly higher than that of the control group T1 ($P \leq 0.05$) due to significantly higher feed intake in T2 (Table 13). In period V, both T2 and T3 had significantly higher egg weight than that of T1 ($P \leq 0.05$). The significantly higher egg weight in T3 during period V was due to the comparatively lower egg number in this period. In spite of the similar body weight in T1 and T2 (225.83 and 225.60g) at 26 weeks of age, consistently higher egg weight was seen in T2 during periods III, IV and V. This can be considered as a correlated response to the higher body weight coupled with higher feed intake due to lysine supplementation.

The amino acid supplemented groups showed comparable cumulative mean egg weights and thereby indicated that lysine and methionine independently and in combination helped to improve mean egg weight. Considering the trait egg weight, it is evident that the amino acid supplemented groups are superior over the control group. Therefore, it is surmised that the lysine and methionine present in the control diet (T1) was not adequate to support higher egg weight in quails. However among the lysine and methionine supplemented groups (singly or in combination) the differences between egg weight were statistically non significant. Since the egg weight has negative correlation with egg number, the significantly lower egg weight in the control group can be related with the numerically higher egg number in this group.

The results obtained in the present study agree with the reports of Latshaw (1976) in laying hens and Pinto *et al.* (2003b) in Japanese quails, who observed higher egg weight with increasing levels of lysine in the diet. Shafer *et al.* (1998) and Solarte *et al.* (2005) noticed that increasing methionine increased egg weight in laying hens. Garcia *et al.* (2005) observed that quails fed 0.875 per cent methionine plus cystine had significantly higher egg weight (11.63 g) than those fed 0.7 per cent methionine plus cystine (11.38 g). Damron and Harms (1973) in laying pullets and Pinto *et al.* (2003a) in Japanese quails found significant improvement in average egg weight with increasing SAA level in the feed.

5.6 EGG MASS

The egg mass recorded in various dietary groups was evaluated based on the results pertaining to egg number and egg weight and is presented in Table 12.

The results indicated no significant difference between the dietary groups in mean cumulative egg mass worked out on quail day basis. The egg mass being a function of egg number and mean egg weight, the effects represented by egg mass did not show marked variation in cumulative values among the dietary groups. However in period III, dietary group (T3) supplemented with 0.25 per cent of methionine showed significantly higher egg mass per quail (314.2g) than that of T1 and T4 ($P \leq 0.05$). This effect simulates the quail day egg production that was significantly higher in T3 than in T1 and T4, in period III ($P \leq 0.05$). On the contrary, Koelkebeck *et al.* (1991) reported non significant difference in egg mass in WL hens at peak production fed diets supplemented with 1.0 per cent of lysine or methionine for a period of 4 weeks compared to the birds fed un-supplemented diet. The cumulative egg mass per quail from 7 to 26 weeks of age on quail day basis was numerically higher in the group T3 (1283.8g). However, the total egg mass in dietary groups T2, T1, T3 and T4 were 79.13, 78.91, 78.47and 75.75 kg respectively, from 64 quails housed in each group at the beginning of the experiment.

Schutte *et al.* (1994) observed that the egg mass per hen per day was not significantly affected by supplementing varying levels of DL-methionine from 0.1 to 0.25 per cent in WL layer diets. Garcia *et al.* (2005) revealed that methionine plus cystine levels ranging from 0.7 to 1.05 per cent did not affect egg mass of Japanese quails significantly. Solarte *et al.* (2005) noted that increasing methionine level from 0.434 to 0.484 per cent of diet produced no improvement in egg mass of laying hens.

5.7 FEED CONSUMPTION

Period wise variations in daily feed consumption indicated significant variations among dietary groups in periods III and IV ($P \leq 0.05$). In period III, T2 had significantly higher feed intake than that of control group and diet T4, but was comparable with that of the methionine supplemented group T3. Whereas, in period IV group T2 showed significantly higher feed intake compared to all other groups ($P \leq 0.05$). In spite of this higher feed intake in the group T2, the cumulative feed intake was not statistically significant because of the numerically low feed intake registered in this group during period I. This in turn resulted in lower egg production during period I in the group T2. The results obtained in the study proved that the supplementation of lysine and methionine separately or in combination did not affect the cumulative feed intake in layer quails (Figure 7).

The mean daily feed intake from 7 to 26 weeks of age indicated a trend of higher feed intake in the group T2 leading to significantly higher BW26 and better mean egg weight in comparison with T3. The period wise variations were indicative of the definite trend towards higher feed intake in periods III and IV in the group supplemented with 0.25 per cent lysine. It is not clear whether this effect was due to the interaction between age of the quail, microenvironment and lysine supplementation.

Although the cumulative mean feed intake in groups T1, T2, T3 and T4 (30.67, 31.53, 30.71 and 30.62 g) was quite similar, the quantum of lysine and methionine intake varied greatly between dietary groups. All the experimental diets contained 1.0 per cent lysine and 0.45 per cent methionine from the feed ingredients and this level was raised to 1.25 per cent lysine in the diets T2 and T4 and to 0.7 per cent methionine in the diets T3 and T4 by supplementing L-lysine and DL-methionine.

In the diet T1, the ratio between lysine and methionine was 2.22 and based on the cumulative feed intake, the actual intake was worked out to 306.7 mg lysine and 138.0 mg methionine per quail per day from 7 to 26 weeks of age. In other dietary groups, the intake of lysine and methionine was worked out to 394.1 and 141.9 mg in T2, 307.1 and 215.0 mg in T3 and 382.7 and 214.3 mg in T4, respectively. Considering the overall performance of dietary groups T1 and T3, the ideal ratio between lysine and methionine in quail layer diet may be in between 1.43 as in T3 and 2.22 as in T1.

Latshaw (1976) in laying hens and Garcia *et al.* (2005) in Japanese quails observed that the feed consumption was not significantly affected by increasing the lysine content of feed. Arscott and Goeger (1981) in Japanese quails and Koelkebeck *et al.* (1991) and Novak *et al.* (2004) in laying hens did not find significant difference in feed intake by the supplementation of lysine or methionine. Penz and Jensen (1991) found no significant difference in daily feed consumption among the WL pullets fed diet supplemented with lysine, methionine or both.

5.8 FEED CONVERSION RATIO (FCR) PER DOZEN EGGS AND PER kg EGG MASS

Feed conversion ratio per dozen eggs as well as per kg egg mass did not show any significant difference either in the cumulative FCR or in period wise value due to the supplementation of lysine, methionine or both. Table 14 indicated that the FCR per dozen eggs in the dietary groups T1 and T3 was 0.46 and with T2 and T4 were 0.49 and 0.47 respectively. The better FCR per dozen eggs in T1 and T3 was due to the similar feed intake and better quail day egg production. The poor FCR per dozen eggs in T2 was due to the higher feed intake in the absence of proportionate increase in egg number.

The cumulative FCR per kg egg mass was relatively better in T3 and was 3.35 followed by 3.42, 3.47 and 3.51 in T1, T4 and T2 in that order. This indicated that diet T3 supplemented with 0.25 per cent methionine was comparatively better than 0.25 per cent supplementation of lysine. Even though supplementation of lysine alone favoured mean egg weight numerically among the amino acid supplemented groups, this trend was not reflected in FCR per kg egg mass due to the higher feed consumption in this group. Total feed intake (Table 23) in the group T3 was numerically lower than that of T2 and T1 and lead to the better FCR per kg egg mass even though total egg mass (Table 12) was slightly lower in T3. This indicated that supplementation of methionine was favourable for improving egg weight and FCR per kg egg mass.

Koelkebeck *et al.* (1991) observed no significant variation in feed efficiency in WL hens by supplementing 1.0 per cent of lysine or methionine. Hummel *et al.* (1965) found that supplementing lysine at 0.1 per cent level did not influence feed efficiency in WL pullets. Pinto *et al.* (2003a) reported that the feed to gain ratio was not significantly affected by methionine plus cystine levels in Japanese quails. Garcia *et al.* (2005) revealed that FCR in Japanese quails was 0.41 kg per dozen eggs irrespective of the levels of methionine plus cystine and increasing the lysine level from 1.1 to 1.375 per cent depressed FCR per kg egg significantly. Arscott and Goeger (1981) in Japanese quails and Schutte *et al.* (1994) in laying hens reported improved feed conversion efficiency with increasing dietary methionine levels.

5.9 EGG QUALITY TRAITS

The egg quality traits were studied at 4-week intervals from tenth week onwards and the results presented in Tables 16 to 20 indicated that only the albumen index at 14 weeks of age differed significantly among the dietary groups.

5.9.1 Shape Index

The overall mean values of shape indices in quail eggs from 10 to 26 weeks of age for the dietary groups T1, T2, T3 and T4 were 77.86, 76.81, 78.20 and 77.11 respectively. Table 16 indicated that shape index was consistently higher in T3 except at 10 weeks of age and the overall mean indicated numerically higher shape index in this group. This effect was due to the broader eggs in T3 with a shorter length. The overall mean shape index in group T2 was the lowest and showed the same trend at 14, 18, 22 and 26 weeks of age due to the comparatively longer eggs produced in this group. However, none of the values differed significantly agreeing with the report of Amaefule *et al.* (2004) in laying hens. The mean egg weights in T2 were numerically higher than that of T3 in all periods and this may have contributed to the lower shape index in T2.

5.9.2 Albumen Index

The overall mean albumen index presented in Table 17 was 0.109, 0.103, 0.105 and 0.105 in T1, T2, T3 and T4 respectively and did not show any significant dietary effect. But the albumen index was better in T1 with the lowest mean egg weight, intermediary in T3 and T4 with medium egg weights and lowest in T2 with the higher mean egg weight. This indicated a negative relationship of albumen index with egg weight. At 14 weeks of age, T3 had significantly higher albumen index due to better height of albumen ($P \leq 0.05$) even though egg weight was similar in all dietary groups in period II. However, this significant difference could not be observed in other periods and also in the overall mean value. The results obtained in the present study partially agrees with Padmakumar (1993) who observed that the albumen index ranged from 0.087 to 0.112, but is lower than the value of 0.131 reported by Lekshmi (2005) in Japanese quail eggs.

5.9.3 Yolk index

Yolk indices presented in Table 18 did not show significant difference due to supplementation of lysine and methionine independently or in combination in quail layer diets. But the overall mean yolk index value was numerically better in T1 and T3 compared to T4 and T2 and this trend was consistent from the beginning itself, which might be a combined effect of better height and lesser diameter of the yolk. The non significant variation in yolk index is in agreement with Amaefule *et al.* (2004).

5.9.4 Internal Quality Unit (IQU)

The overall mean internal quality unit in the dietary groups T1, T2, T3 and T4 were 60.81, 58.03, 58.38 and 58.68 respectively (Table 19), which did not show any significant effect due to dietary supplementation. Statistical comparison of the data at 10, 14, 18, 22 and 26 weeks of age also did not reveal any significant difference. The mean IQU in T1 was numerically better than that of other groups, but this effect was not consistent at different ages studied. The present results are in agreement with Novak *et al.* (2004) who reported a non significant effect of lysine or TSAA intake on Haugh unit in chicken eggs. Amaefule *et al.* (2004) also observed that Haugh unit was not affected significantly by the supplementation of lysine, methionine or their combination in layer diets. Solarte *et al.* (2005) noticed lower Haugh unit in methionine supplemented hens and is not in line with the present result.

5.9.5 Shell Thickness

Statistical analysis of the shell thickness at various ages as well as its overall mean values (Table 20) did not reveal significant differences due to dietary supplementation of lysine and methionine independently or in combination, agreeing with the findings of Amaefule *et al.* (2004) in laying hens. The mean value of shell thickness in dietary group T4 (208.1µm) was slightly higher than that of T1 (205.1µm), T2 (205.8µm) and T3 (203.6µm) groups. Novak *et al.* (2004) reported that shell quality with respect to specific gravity was reduced as TSAA intake increased. In the present study no relationship between egg weight and shell thickness could be noticed.

5.10 CARCASS YIELDS AND LOSSES

The per cent dressed yield in quails fed diet supplemented with 0.25 per cent methionine (T3) was significantly higher than that of T2 and T4 ($P \leq 0.05$), but was comparable with that of the control group (Table 21). Shrivastav *et al.* (2004) also reported higher per cent dressed yield in methionine supplemented group of Japanese quails. Shrivastav and Panda (1987) reported that per cent dressed yield in 0.68 per cent methionine supplemented quails was significantly higher than those fed 0.38 per cent methionine. The present result showed that the body weight of T3 was significantly lower than the control group (Table 4), while the per cent dressed yield was high in T3 due to significantly lower per cent of skin and feather loss in this group compared to T2 and T4 ($P \leq 0.05$). This is in partial agreement with the findings of Hughes (1983) who observed a positive correlation between feather loss and number of eggs produced. But it is difficult to explain whether the above effect was influenced either by feather loss or per cent skin as the same was not measured separately in the present study.

The per cent R-to-C yield was numerically lower in the group T3 even though the per cent dressed yield was significantly higher ($P \leq 0.05$) and this effect might be due to higher per cent of inedible portions. The eviscerated yield excluding skin was statistically comparable among dietary groups and this non significant effect of lysine and methionine supplementation is in agreement with Mishra *et al.* (1993). The eviscerated yield excluding skin found in the present trial agrees with Mandal *et al.* (1993) who reported 56.43 per cent eviscerated weight when 8-week-old female Japanese quails were skin dressed.

In the present study, the per cent liver was higher in T1 (2.98) followed by T2 (2.87), T3 (2.83) and T4 (2.55) in that order and did not differ significantly and suggested a lower liver weight in methionine supplemented groups T3 and T4 (Table 21). Bunchasak and Silapasorn (2005) observed that hens fed a low-CP (14 per cent) diet supplemented with a lower level of methionine (0.26 per cent) had significantly higher per cent of liver weight than those fed a higher methionine level. The per cent giblet weight showed non significant variation among the dietary groups. The results pertaining to liver and giblet percentages are in agreement with Ichhponani *et al.* (1983) who opined that the effect of supplementation of lysine and methionine on weight of heart, liver and gizzard was non significant in laying hens. The per cent blood loss in the dietary groups T1, T2, T3 and T4 were 3.74, 3.83, 4.42 and 4.10 respectively and it did not differ significantly. The percentage of ovary and oviduct weight in various groups did not vary significantly and this showed that the nutrients present in the control ration were sufficient for the development of reproductive organs. This result is not in agreement with the findings of Bunchasak and Silapasorn (2005), who observed improved ovary and oviduct weight in hens fed methionine supplemented low CP diet.

5.11 SERUM PROTEIN AND CHOLESTEROL

The serum total protein levels in different dietary groups presented in Table 21 revealed no significant differences. Narayanankutty (1987) reported that the serum protein level in Japanese quail was 5.87g/dl at 6 weeks of age. Sheena (2005) observed 5.51g per cent serum protein at 26 weeks of age in layer Japanese quails.

The serum total cholesterol in the group supplemented with lysine and methionine combination (T4) was significantly higher than that of control group and lysine supplemented group but was statistically comparable with that of the group supplemented with methionine. This suggested a cholesterol elevating effect of dietary supplementation of lysine and methionine combination at the level of 0.25 per cent each in caged Japanese quail layers. The lower per cent liver weight in the group T4 might have contributed to the higher cholesterol level as liver is the principal organ of cholesterol metabolism. Wide variations are seen in the serum cholesterol level of Japanese quails reported by different researchers. Majumdar *et al.* (1996) found that the serum cholesterol level in cage reared meat line female broiler quails ranged from 351.16 to 387.12 mg per 100ml. Ozbey *et al.* (2004b) reported that Japanese quails reared at a constant temperature of 35°C up to 14 weeks of age had a total serum cholesterol level of 219.08mg/dl.

5.12 LIVABILITY

The livability percentages among the various dietary groups were comparable each other (Table 22) although the number of dead quails were 3 in T1, 5 in T2, 6 in T3 and 7 in T4, in that order. However, autopsy of the dead birds revealed no specific reasons that can be attributed to the effect of dietary supplementation of lysine, methionine or their combination. This is in agreement with the results of

Arscott and Goeger (1981) in laying Japanese quails, Schutte *et al.* (1983), Schutte *et al.* (1994), Shafer *et al.* (1998) and Amaefule *et al.* (2004) in laying hens.

5.13 ECONOMICS

The cost of one kg feed for T1, T2, T3 and T4 were Rs.9.25, 9.67, 9.74 and 10.16 respectively in the ascending order and the higher feed cost in amino acid supplemented groups was due to the high cost of lysine (Rs.167.02 per kg) and methionine (Rs.194.84 per kg). The feed cost per egg in the control group (35.21 Ps.) was significantly lower than that of T4 ($P \leq 0.05$) followed by T3 (37.06 Ps.), T2 (38.91 Ps.) and T4 (39.92 Ps.) in that order while the mean egg weight in T1 was significantly lower compared to other groups ($P \leq 0.05$). The significantly larger egg size in the amino acid supplemented groups ($P \leq 0.05$) also contributed to higher feed cost per egg than the control group. The total return over feed cost was highest in the control group T1 (Rs.4237.8) due to the higher egg number. The Margin of returns over feed cost per quail housed was Rs. 27.36 in T1 followed by Rs. 22.60, 24.69 and 20.85 in dietary groups T2, T3 and T4 respectively. Vidhyadharan (1998) reported a higher feed cost per egg for layers fed 0.3 per cent methionine supplemented diet compared to those fed control diet.

Based on the above findings it was concluded that 1.0 per cent lysine and 0.45 per cent methionine present in practical quail layer rations containing 22 per cent protein and 2650 kcal per kg ME support egg number, FCR per dozen eggs and economics. On comparing the supplementation of 0.25 per cent methionine (T3) and 0.25 per cent lysine (T2), T3 is advantageous to improve QD egg production, mean egg weight, FCR per kg eggs, dressed yield and economics and to reduce the body weight at 26 weeks of age in cage reared quail layers. Supplementation of 0.25 per cent lysine also improved egg weight, but QD egg production, FCR and economics were poor. Combined supplementation of 0.25 per cent each of lysine and methionine is not advantageous, as it did not support egg production, FCR and economics. Further, the exact role of climatic variants on dietary requirements of amino acids can be delineated by detailed studies.

Summary

6. SUMMARY

An experiment was carried out at the Department of Poultry Science, College of Veterinary and Animal Sciences, Kerala Agricultural University, Mannuthy, during the period from January to June 2006, to study the effect of dietary supplementation of lysine and methionine on the production performance of Japanese quail layers. Two hundred and fifty six (256) Japanese quails were weighed individually at six weeks of age and allocated randomly to four dietary groups viz., T1, T2, T3 and T4, with four replicates consisting of sixteen quails each. Each replicate was housed in separate cages and standard managemental practices were followed uniformly. Quail layer ration containing 22 per cent crude protein, 2650 kcal metabolisable energy per kg feed, 1.0 per cent lysine and 0.45 per cent methionine formed the basal diet (T1). The basal diet supplemented with 0.25 per cent L-lysine formed the diet T2 and diet T3 was formed by supplementing the basal diet with 0.25 per cent DL-methionine. Supplementation of the basal diet with 0.25 per cent each of L-lysine and DL-methionine formed the diet T4.

The data were collected for five periods of 28 days each from 7 to 26 weeks of age. The maximum and minimum temperature (^{0}C) and per cent relative humidity in the F.N and A.N. inside the experimental house were recorded daily. Egg production was recorded daily and expressed as quail housed and quail day egg number and per cent production week wise and period wise. The period wise mean egg weight and egg mass per quail were computed from replicate wise egg mass measured daily. Feed consumption was recorded and the feed conversion ratio per dozen eggs and per kg egg mass was calculated period wise. At the end of each period, five eggs were collected at random from each replicate for assessing the egg quality traits namely, shape index, albumen index, yolk index, internal quality unit and shell thickness. At the end of 26 weeks of age, body weight of the quails was recorded individually and two quails at random from each replicate were slaughtered to study the carcass yields and losses. The per

cent losses of blood, skin and feather, ovary and oviduct were determined. Per cent yields of dressed, eviscerated and R-to-C weight excluding skin were recorded. Liver and giblet per cent were recorded separately in each quail slaughtered. Serum collected at the time of slaughter was used to estimate the total protein and total cholesterol levels. The economics of lysine and methionine supplementation in the diet was worked out based on the cost of feed ingredients and sale price of quail eggs prevailed during the period of study.

The salient findings in the study are presented below.

1. The overall mean maximum temperature was 35.67^{0}C, minimum temperature was 24.65^{0}C and relative humidity was 82.04 per cent in the F.N and 71.67 per cent in the A.N., inside the experimental house from January to June 2006.

2. The average body weight of the quails for different dietary groups, ranged from 180 to 182.66 g at 6 weeks of age. At 26 weeks of age, the mean body weight of quails in the groups T1, T2, T3 and T4 were 225.83, 225.60, 215.04 and 219.81 g respectively. The body weight of group T3 at 26 weeks of age was significantly lower than that of T1 and T2 ($P \leq 0.05$).

3. The age at first egg in the flock was 42 days in all dietary groups, whereas age at 50 per cent production was 51, 54, 49 and 52 days in groups T1, T2, T3 and T4 respectively.

4. The quail housed cumulative egg number during the entire period of experiment was 110.36, 107.14, 107.64 and 103.84 in groups T1, T2, T3 and T4 respectively and the corresponding percentages were 78.83, 76.53, 76.89 and 74.17 and the differences between mean values were non significant.

5. The trend observed with quail housed egg production was exhibited with cumulative quail day production also. The mean cumulative egg number on quail day basis was 112.70, 109.51, 112.71 and 108.82 in the groups T1, T2,

T3 and T4 respectively and corresponding percentages were 80.50, 78.22, 80.51 and 77.73 and were comparable among each other.

6. The cumulative mean egg weight was 11.17, 11.55, 11.40 and 11.40 g in the groups T1, T2, T3 and T4 respectively. The mean EW in the control group T1 was significantly lower than that of amino acid supplemented groups ($P \leq 0.05$) and among the amino acid supplemented groups, egg weights were comparable.

7. The overall mean egg mass per quail on quail day basis in T1, T2, T3 and T4 were 1259.1, 1263.7, 1283.8 and 1240.3 g respectively and did not show significant difference.

8. The overall daily feed consumption per quail during the entire period of experiment averaged 30.67, 31.53, 30.71 and 30.62 g in the groups T1, T2, T3 and T4 respectively and did not differ significantly among each other.

9. The feed conversion ratio per dozen eggs as well as per kg eggs did not show significant difference either in the cumulative or period wise values. The cumulative FCR per dozen eggs in the dietary groups T1 and T3 was same (0.46) and that in T2 and T4 were 0.49 and 0.47 respectively. The cumulative FCR per kg egg mass in T1, T2, T3 and T4 were 3.42, 3.51, 3.35 and 3.47 respectively.

10. The overall mean values of egg quality traits revealed no significant difference between dietary groups. The overall mean values of shape index, albumen index, yolk index and IQU were 77.49, 0.106, 0.475 and 58.97 respectively and the overall mean shell thickness was 205.7 μm.

11. The per cent dressed yield excluding skin were 85.78, 84.98, 86.63 and 83.90 in groups T1, T2, T3 and T4 respectively and was significantly higher in T3 compared to that of T2 and T4 ($P \leq 0.05$). Per cent yields of eviscerated

carcass and R-to-C yield excluding skin, liver and giblet did not differ significantly among the dietary groups.

12. The skin and feather put together in the groups T1, T2, T3 and T4 were 10.48, 11.19, 8.95 and 12.00 per cent respectively and was significantly lower in T3 in comparison with T2 and T4 ($P \leq 0.05$). There was no significant difference in per cent losses of blood and ovary and oviduct among the dietary groups.

13. The mean values of serum total cholesterol were 190.33, 190.19, 215.75 and 248.62 mg/dl for T1, T2, T3 and T4 respectively and the group T4 showed significantly higher value than that of T1 and T2 ($P \leq 0.05$). Serum protein level in various dietary groups did not differ significantly among each other.

14. The overall livability among dietary groups T1, T2, T3 and T4 were 95.31, 92.19, 90.62 and 89.06 per cent respectively.

15. The feed cost in the groups T1, T2, T3 and T4 were Rs. 9.25, 9.67, 9.74 and 10.16 per kg diet respectively. The cost of feed per egg was significantly lower in T1 (35.21 paise) compared to T4 (39.92 paise) ($P \leq 0.05$) and was intermediate in T3 (37.06 paise) and T2 (38.91 paise). The margin of returns over feed cost was higher in T1 and T3 (Rs. 27.36 and 24.69) on quail housed basis compared to the low returns in T2 and T4 (Rs. 22.60 and 20.85).

Based on the above findings, it was concluded that addition of L-lysine and DL-methionine at 0.25 per cent levels, separately or in combination in practical quail layer rations containing 22 per cent crude protein, 1.0 per cent lysine and 0.45 per cent methionine is not advantageous in terms of egg production. The supplementation of 0.25 per cent DL-methionine was beneficial to improve mean egg weight in quails reared in cages. Considering the economics of quail production, it is proved that the basal diet without supplementation of lysine or methionine is feasible.

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EFFECT OF DIETARY SUPPLEMENTATION OF LYSINE AND METHIONINE ON PRODUCTION PERFORMANCE OF JAPANESE QUAIL (*Coturnix coturnix japonica*)

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ABSTRACT

An experiment was carried out to study the effect of dietary supplementation of lysine and methionine on production performance of Japanese quail layers. Two hundred and fifty six Japanese quails at 6 weeks of age were allocated randomly to four dietary groups with four replicates of sixteen quails each. Quail layer ration containing 22 per cent crude protein, 2650 kcal ME per kg feed with 1.0 per cent lysine and 0.45 per cent methionine formed the basal diet T1. The other three diets were formulated by supplementing the basal diet with 0.25 per cent L-lysine (T2), 0.25 per cent DL-methionine (T3) and a combination of both at 025 per cent level (T4). The experiment was carried out for five periods of 28 days each from 7 to 26 weeks of age.

The mean body weight of the quails in all the dietary groups was comparable at the beginning of the experiment, but at 26 weeks of age the group T3 (215.04 g) had significantly lower mean body weight than that of T1 and T2 (225.83 and 225.60 g). Even though the age at first egg in the flock in each dietary group was 42 days, the group T3 attained 50 per cent production early (49 days) and T2 late (54 days). The overall mean quail housed and quail day number and per cent production were statistically comparable among the dietary groups. The mean EW in the group T1 (11.17 g) was significantly ($P \leq 0.05$) lower than that of amino acid supplemented groups. The cumulative mean egg mass per quail on quail day basis did not differ significantly between groups. The overall daily feed consumption per quail was numerically higher in T2 (31.53 g). Feed conversion ratio per dozen eggs as well as per kg egg mass did not show any significant difference among dietary groups. Statistical analysis of the overall mean values of egg quality traits revealed no significant difference between dietary groups. The per cent dressed yield excluding skin was significantly higher in T3 (86.63) compared to T2 and T4 while per cent of skin and feather put together showed the opposite trend. The per cent losses of blood and ovary and

oviduct were comparable among the dietary groups. The per cent yield of eviscerated carcass and ready-to-cook yield excluding skin, liver and giblet did not show significant difference between the dietary groups. The mean value of serum protein was comparable in all groups. Serum total cholesterol was significantly higher in T4 (248.62 mg/dl) compared to T1 and T2 and was comparable to that of T3. The overall livability per cent did not differ significantly among dietary groups. The cost of feed per egg was significantly lower in T1 (35.21 paise) compared to T4 (39.92 paise) and was intermediate in T3 (37.06 paise) and T2 (38.91 paise).

The critical evaluation of the results revealed that the supplementation of 0.25 per cent L-lysine, 0.25 per cent DL-methionine or its combination significantly improved mean egg weight in cage reared quails. The quail layer ration containing 22 per cent crude protein with 1.0 per cent lysine and 0.45 per cent methionine was the most economical without supplementation of crystalline amino acids. The supplementation of the ration with 0.25 per cent DL-methionine was the next cost-effective, followed by the ration with 0.25 per cent L-lysine supplementation. The combined supplementation of L-lysine and DL-methionine was economically not feasible in quail layer diets.