EFFECT OF DIETARY SUPPLEMENTATION OF AZOLLA (*Azolla pinnata*) ON PRODUCTION PERFORMANCE IN JAPANESE QUAIL (*Coturnix coturnix japonica*)

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DECLARATION

I hereby declare that this thesis, entitled **"EFFECT OF DIETARY SUPPLEMENTATION OF AZOLLA *(Azolla pinnata)* ON PRODUCTION PERFORMANCE IN 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 AZOLLA (*Azolla pinnata*) ON PRODUCTION PERFORMANCE IN JAPANESE QUAIL (***Coturnix coturnix japonica***)" is a record of research work done independently by **Raseena Karim,** 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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CERTIFICATE

We, the undersigned members of the Advisory Committee of **Raseena Karim,** a candidate for the degree of Master of Veterinary Science in Poultry Science, agree that this thesis entitled **"EFFECT OF DIETARY SUPPLEMENTATION OF AZOLLA *(Azolla pinnata)* ON PRODUCTION PERFORMANCE IN JAPANESE QUAIL (*Coturnix coturnix japonica*)"** may be submitted by Raseena Karim, in partial fulfilment of the requirement for the degree.

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Raseena karim

Dedicated to
My beloved parents, sisters and teachers

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Introduction

1. INTRODUCTION

Poultry farming in India has emerged as the most efficient enterprise in the Animal Husbandry sector. Poultry segment itself is in the virtue of diversification during the last two decades. Among various enterprises quail rearing has been accepted as a potential alternative to traditional chicken and other poultry farming because of its unique characteristics like rapid growth, short generation interval, early sexual maturity, high rate of egg production, requirement of less floor space, short incubation period and less susceptibility to diseases. It offers the quickest means of increasing the production of high quality protein.

In commercial quail production feed cost accounts for 65 to 70 per cent of the total cost of production. The shortage of cereal products in the developing countries is one of the impediments to animal production in general, and poultry production in particular. Replacing cereals with agricultural by-products less exploited by man is one solution to this situation. Leaf protein has long been recognized as the cheapest and potential source of protein. One of the problems observed with leaves from tropical tree species is the presence of secondary plant compounds, especially phenolic compounds which makes the leaf unpalatable. This is especially true with respect to monogastric animals. Aquatic plant species, because of their growth habit, appear not to accumulate secondary plant compounds and therefore offer a greater potential than tree leaves as a source of protein for monogastric animals.

Protein is the costliest item among the different nutrients in the poultry feed. The problem of continued scarcity and consequent escalating prices of conventional protein and energy sources for livestock in the tropics has stimulated a lot of interest in animal nutritionist to consider alternative sources of protein. In the light of these the water fern Azolla (*Azolla pinnata*) has been getting attention of the researchers. It is an aquatic cosmopolitan fern and it grows in association with its symbiotic cyanobacterial partner *Anabaena azollae*, which is a nitrogen-fixing organism. It is capable of assimilating atmospheric nitrogen due to the presence of this algal symbiont in its leaves. Moreover, it is most promising because of ease of cultivation, high productivity and rich in nutritive value. It is rich in protein and contains almost all essential amino acids, carotene, and several growth promoter intermediaries, minerals like calcium, phosphorus, magnesium, potassium, iron and copper. All these make Azolla an economic and efficient feed substitute cum feed supplement for livestock.

Azolla has been used for centuries in Asia, as green manure, as fertilizer for rice fields and as supplement in diets for pigs, poultry and fish. The concept of using Azolla for feeding cattle, duck, quails and chickens is now receiving special attention because of its high biomass and protein production. Little or no information is available about their inclusion level in various livestock and poultry diets. Elaborate studies were not carried out to recommend it as a feed substitute for poultry. Moreover, no work seems to be done to assess the effect of supplementation of Azolla on the production traits of Japanese quails. Hence an experiment was planned to study the effect of dietary supplementation of Azolla in Japanese quail layers with the following objectives.

1. To determine the effect of supplementation of dried Azolla on egg production and related traits in Japanese quails.
2. To evaluate the economics of feeding dried Azolla in Japanese quails.

Review of Literature

2. REVIEW OF LITERATURE

Azolla has the unique potential to fix atmospheric nitrogen and hence it could provide cheap source of nutrients for poultry and a substitute for costly ingredients like soybean meal and fish meal. Feeding trials in broiler type chicken with Azolla supplementation have largely been successful in bringing forth improved growth and weight gain. There are meagre reports addressing the influence of this fern in egg type chicken. All the more, studies on quails with Azolla veritably lack in published literature. Therefore, literatures available about the effect of Azolla and other aquatic plants in chicken and other poultry species are also reviewed in this chapter.

2.1 METEOROLOGICAL OBSERVATIONS

Somanathan (1980) reported that maximum temperature ranged from 31.14 to 35.14°C, minimum temperature ranged from 21.15 to 25.80°C. The range of average relative humidity (R.H.) was from 58.49 to 84.39 per cent during the period from January to June in the years 1974 to 1978 at Mannuthy.

2.2 NUTRITIVE VALUE OF AZOLLA

Buckingham *et al.* (1978) studied the proximate composition of *Azolla filliculoides* and reported that it contained 23.42 per cent total protein, 5.05 per cent ether extract (EE), 15.54 per cent ash, 26.58 per cent acid detergent fibre (ADF), 39.16 per cent neutral detergent fibre (NDF), 15.19 per cent cellulose and 9.27 per cent lignin. The composition of essential amino acids in the Azolla (g per 100 g protein) compared well with the reference protein sources like alfalfa, soybean and corn. They compared Azolla with corn and reported low methionine value (1.88 per cent) in Azolla with lysine content twice (6.45 %) as that in corn (2.76 %). Relative to alfalfa meal, major minerals in Azolla were adequate and the calcium and phosphorus ratio were 2. Some of the trace minerals in Azolla were higher than in alfalfa; iron 4 times (1 mg/g), copper 3 times (28.05 μg/g) and manganese 22 times higher (771 μg/g).

Subudhi and Singh (1978) observed 93 per cent moisture in Azolla. On dry matter basis it contained 24 to 30 per cent crude protein (CP), 3.0 to 3.36 per cent crude fat, 0.4 to1.0 per cent calcium and 10.5 per cent ash. Azolla was found to be rich in vitamins, minerals, chlorophylls and carotenoids also.

Sanginga and Van Hove (1989) analysed the mean protein content of Azolla (28 %), which was comparable to that of some rich legumes eg. Alfalfa. Adequate amounts of essential amino acids (leucine, lysine, arginine and phenyl alanine+tyrosine) were present in most of the Azolla strains at the linear phase of growth, but the sulfur containing amino acids methionine and cysteine did not reach the recommended values of 3.5 g /100 g protein. All Azolla strains contained similar proportions of essential (55 %) and non-essential amino acids (45 %).

Becerra *et al.* (1990) revealed that water plants such as *Azolla filliculoides* were highly productive sources of protein rich biomass and are an ideal complement for the low fiber tropical feed resources being developed as alternatives to cereals in poultry and pig diets.

Ali and Leeson (1995) reported that *Azolla pinnata* contained 9.2 per cent dry matter, 16.5 per cent crude protein, 12.5 per cent crude fiber, 1.6 per cent fat, 36.1 per cent total ash, 47.8 per cent NFE, 46.7 per cent ADF, 1.4 per cent calcium, 0.31 per cent phosphorus and 4.38 MJ/kg apparent metabolisable energy value on dry matter basis. In comparison with alfalfa meal (314.6 g/kg DM), Azolla had less crude fiber and similar crude protein value. Amino acid composition of Azolla revealed that it contained 1.5 per cent methionine, 0.9 per cent cystine, 3.8 per cent lysine, 5 per cent arginine, 0.5 per cent tryptophan, 3 per cent tyrosine, 4 per cent threonine, 4 per cent serine, 4.6 per cent phenyl alanine, 8.3 per cent aspartic acid, 9.6 per cent glutamic acid, 4 per cent proline, 5.2 per cent glycine, 5.8 per cent alanine, 5.1 per cent valine, 4.2 per cent isoleucine, 7.7 per cent leucine and 1.6 per cent histidine. These amino acid values of Azolla were comparable with those found in other aquatic plants and alfalfa meal.

Becerra *et al.* (1995b) analysed the chemical composition of *Azolla microphylla* and reported 5.6 per cent dry matter, 26.7 per cent crude protein, 11.0 per cent crude fibre, 4.6 per cent ether extract, 0.8 per cent calcium and 0.4 per cent phosphorus.

Sarria and Preston (1995) compared amino acid balance in Azolla and soybean with the ideal protein (expressed as per cent of lysine =100) and reported superior balance of amino acids in Azolla compared with soybean, with values of lysine (100 %, 100 %), methionine+cystine (63 %, 48 %), threonine (93 %, 72 %), tryprophan (31 %, 22 %), valine (103 %, 83 %), isoleucine (83 %, 90 %), leucine (139 %, 133 %) and phenyl alanine+tyrosine (149 %, 139 %) in Azolla and soybean, respectively.

Ardakani *et al.* (1996) reported 17.67 per cent crude protein, 21.5 per cent crude fiber, 2.49 per cent ether extract, 3.2 per cent calcium, 0.17 per cent phosphorus and 3949 kcal/kg gross energy in Azolla.

Khatun *et al.* (1999) assessed the nutrient content of *Azolla pinnata* and stated that it contained dry matter 905.8 g/kg, crude protein 285.4 g/kg, digestible protein 219.8 g/kg, crude fibre 123.8 g/kg, and metabolisable energy value of 7.59 MJ/kg.

Lejune *et al.* (2000) revealed that carotene content of fresh material of Azolla during the linear phase of growth ranged from 369 to 619 mg/kg dry matter, values comparable to the 451 and 556 mg/kg dry matter obtained for carrot and spinach respectively, two plants generally considered as rich in carotene content. Fresh Azolla was also a good source of provitamin A, especially if harvested during the linear phase of growth.

Parthasarathy *et al.* (2001b) evaluated the chemical composition of Azolla and opined that it could be used as an unconventional feed source for broilers. The content of crude protein, ether extract, crude fiber, NFE and total ash ranged from 23.91 to 24.22 per cent, 2.52 to 3.01 per cent, 13.84 to16.40 per cent, 38.85 to 44.06 per cent and 12.8 to 16.26 per cent, respectively. The ME value of Azolla was 1855 kcal/kg DM. The mineral profile of various species indicated that *Azolla microphylla* contained higher levels of calcium (2.11 %) and phosphorus (1.08 %) compared to other species of Azolla.

Parthasarathy *et al.* (2002) analysed the chemical composition of *Azolla pinnata* and indicated that it was a fairly rich source of crude protein (26.02 %) and total ash (12.3 %). The other proximate principles present were 13.6 per cent crude fibre, 2.37 per cent EE and 45.71 per cent NFE. The macro minerals like calcium and phosphorus were 1.24 per cent and 0.72 per cent, respectively and more or less in the ratio of 2:1. The apparent and true ME values of *Azolla pinnata* were 1529 and 1855 kcal/kg DM, respectively.

Basak *et al.* (2002) studied the chemical composition of *Azolla pinnata* and reported that the meal contained 25.78 per cent crude protein, 15.71 per cent crude fiber, 3.4 per cent ether extract, 15.76 per cent ash and 30.08 per cent NFE on dry matter basis.

Alalade and Iyayi (2006) reported that Azolla meal contained 21.4 per cent crude protein, 12.7 per cent crude fibre, 2.7 per cent ether extract, 16.2 per cent ash and 47.0 per cent carbohydrate on dry matter basis.

2.2.1 Nutritive Value of Other Aquatic Plants

Gutcho (1973) analysed the algal meal from *Spongicoccum exentricum* and reported 9 per cent moisture, 32 per cent protein, 4 per cent fat, 1 per cent fiber, 6 per cent ash and 250 mg/lb beta-carotene.

Muztar *et al.* (1976) reported that some aquatic plants like Hydrilla (*Hydrilla verticililata*) and water hyacinth (*Eichhornia crassiper*) were approximately equal to alfalfa in crude protein and fiber content, but high in ash and xanthophylls content than conventional forage crops.

Lipstein and Hurtwitz (1980) analysed the algae chlorella and reported 89 g/kg moisture, 574 g/kg protein, 69.4 g/kg total lipids, 22 g/kg fiber, 2 g/kg calcium, 11.7 g/kg phosphorus and 11.6 MJ/kg metabolisable energy on dry matter basis. The algal lipids contained more linolenic (18:3) and less linoleic (18:2) acids than are usually found in maize and soybean oils. It also had a high pigment concentration of xanthophylls and carotene ranged from 650 to 1100 mg/kg and from 120 to 260 mg/kg, respectively.

Lipstein *et al.* (1980) stated that the linoleic acid concentration in algae chlorella meal amounts to about 10 g/kg, compared with approximately 5 g/kg in the case of soybean meal. The importance of linoleic acid was valuable in ensuring maximal egg size.

Rusoff *et al.* (1980) reported that the crude protein of solar dried duckweed ranged from 25.2 to 36.5 per cent and that of the protein concentrate (duckweed extract) from 37.5 to 44.7 per cent. The essential amino acids of the protein concentrate compared well with the FAO reference pattern with the exception of methionine. Studies showed that duckweed had potential as an effective supplement to grains for animal and human consumption.

Bratova and Ganovski (1983) conducted chemical analysis of black sea algae *Cystozeira barbata, Ulva lactuea and Zostera nona* and reported that they contained considerable amount of carbohydrate, proteins, fats, carotene, vitamins, calcium, iron and magnesium.

Becerra *et al.* (1995a) showed that duckweed contained 4.5 per cent dry matter, 26.3 per cent protein, 3.2 per cent ether extract, 11.0 per cent crude fiber, 15.9 per cent ash, 1.1 per cent calcium, 0.5 per cent phosphorus and 535 mg/kg dry matter carotene.

Men *et al.* (1996) reported 4.7 per cent dry matter, 38.6 per cent protein, 9.82 per cent ether extract, 18.7 per cent crude fiber, 8.58 per cent nitrogen free extract, 19 per cent ash, 0.71 per cent calcium, 0.62 per cent phosphorus, 4.9 per cent potassium, 0.14 per cent sodium, 0.27 mg/kg dry matter iron, 1723 mg/kg dry matter manganese, 75 mg/kg dry matter zinc, 20 mg/kg dry matter copper and 1025 mg/kg dry matter carotene in duckweed.

Mc Neill and Elswyk (1998) reported that feeding a minimum of 2.4 per cent marine algae to laying hens resulted in the production of an egg with as much n-3 fatty acids as the serving of a lean fish. Marine algae were an enriched source of n-3 fatty acids, DHA and naturally occurring carotenoids and it contained beta-carotene from 13 to 25 mg/kg and canthaxanthin at 0.6 mg/kg.

Agwunobi (1999) analysed the chemical composition of water yam and reported a dry matter content of 36.4 per cent. The content of crude protein, ether extract, crude fiber, ash and NFE were 15.5, 0.3, 28.5, 13.5 and 32.5 per cent, respectively. The energy value of water yam was 11.18 MJ/kg dry matter.

Study of Islam (2002) showed that dried duckweed could be used in poultry diets to partially replace fish meal, soybean meal and alfalfa meal. It might be included as a protein concentrate mixture for layers and broilers also.

Khanum *et al.* (2005) revealed that the duckweed contained 7.03 per cent dry matter, 39.0 per cent protein, 7.7 per cent ether extract, 12.3 per cent crude fiber and 14.7 per cent ash.

2.3 EFFECT OF AZOLLA ON BODY WEIGHT

Subudhi and Singh (1978) studied the effect of *Azolla pinnata* in White Leghorn female chicks at levels of 16.0, 12.5 and 5.0 per cent fresh Azolla on dry weight basis along with 50, 75 and 100 per cent intake of control diet, respectively from 7 to 14 weeks of age. They reported that the growth in the treatment of 75 per cent feed with 12.5 per cent Azolla was almost comparable (518 g) to the control birds (494 g). The birds receiving normal diet with 5 per cent Azolla grew faster (614 g) than the control.

Sarria and Preston (1995) observed no significant difference in growth rate (24.6, 29.4, 34.0 g/day) in broiler chicks fed with 0, 10 and 15 per cent replacement of the protein from Soybean meal with *Azolla filliculoides*.

Ali and Leeson (1995) fed male broilers with Azolla (100 g/kg based on digestible protein) and snail meal (80 g/kg based on digestible protein) separately for 14 days. The weight gain was similar (236 and 242 g, respectively) to that found in control birds (226.3 g) fed maize-soybean meal diet.

Ardakani *et al.* (1996) observed best performance in weight gain for birds fed with 6 per cent fresh Azolla.

Parthasarathy *et al.* (2001a) indicated that broiler birds receiving 5 per cent Azolla from zero to five weeks of age had a similar weight gain as that of control (1106.00 Vs 1083.00 g), while the birds on 10, 15 and 20 per cent Azolla diets had significantly ($p<0.01$) poor weight gain. Similar results were reported when Azolla was included in diet from 0 to 8 weeks of age.

Basak *et al.* (2002) observed significant ($P<0.01$) improvement in the live weight (1637 g) of broilers when they were fed with 5 per cent Azolla meal by replacing sesame meal than control fed birds (1579 g) at 6 weeks of age.

Parthasarathy *et al.* (2002) reported that broiler birds on basal and 5 per cent Azolla diets replacing 2.6 per cent wheat bran and 2.4 per cent fish meal gained more or less similar body weights (1803 and 1816 g, respectively) at 8 weeks of age. Addition of higher levels of Azolla from 10 to 20 per cent resulted in significant ($P<0.01$) reduction in live weight gain of 1752 g (10 per cent Azolla) to 1650 g (20 per cent Azolla).

Pillai *et al.* (2004) reported that broiler chicken fed with Azolla resulted in substantial increase in bodyweight.

Alalade and Iyayi (2006) observed no significant difference in weight gain (95.43, 95.22, 98.62 and 93.44 g) of chicks fed with Azolla meal at the levels of 0, 5, 10 and 15 per cent, respectively. But the group fed diet containing 10 per cent Azolla meal performed non statistically better than the control diet fed birds.

2.3.1 Effect of Other Aquatic Plants on Body Weight

In an experiment, Muztar *et al.* (1976) included dehydrated alfalfa meal and each of the dried aquatic plant meal (cladophora, duckweed, pond weed, milfoil and vallisneria) in place of corn and soybean meal of control diet in egg strain male chicks at the levels of 2.5, 5 and 10 per cent so as to maintain all diets equinitrogenous. Diet containing any level of dehydrated alfalfa or aquatic plant were significantly superior to the control diet.

Lipstein and Hurtwitz (1980) included 150 g chlorella algae meal per kg in the starter diet and finisher diet which reduced weight gain by 5 per cent and 10 per cent, respectively compared with the control diet.

Lipstein *et al.* (1980) observed no significant effect of dietary algae meal, chlorella on body weight of layer birds.

Lizama *et al.* (1988) reported that body weight gain in chicks fed with 5 or 10 per cent Elodea by replacing yellow maize and soybean meal were similar (4.41 and 4.22 g/bird/day) to controls (4.45 g/bird/day), but 5 per cent Hydrilla significantly ($P<0.05$) depressed the feed intake and weight gain (3.6 g/bird/day).

Mc Dowell *et al.* (1990) noticed that mean gain in body weight was lower for the birds fed with aquatic plants Elodea and Hydrilla compared with control (corn-soybean meal) fed birds.

Ross and Dominy (1990) used one week old Japanese quails to study the effects of 0, 1.5, 3.0, 6.0 and 12 per cent of spirulina on growth. Body weight gains at 5 weeks of age among the quails fed different levels of spirulina showed no significant difference (115.7, 111.4, 112.3, 114.1 and 112.1 g, respectively).

Benicio *et al.* (1993) reported that weight gain of broiler chickens during the starting period was not affected by inclusion of 3 per cent water hyacinth in pelleted diets. However, performance was affected by higher level of inclusion.

Haustein *et al.* (1994) observed that weight gain of chicks fed with 15 per cent dried duckweed was similar to that of controls. Increase in duckweed above 15 per cent resulted in decrease in weight gain. Females given diets containing 5 per cent duckweed had increased final weight.

Men *et al.* (1995) reported that the rate of live weight gain was significantly higher for cross bred meat type ducks when fed with diets containing 30 and 45 per cent duckweed than control diet.

Becerra *et al.* (1995a) studied the effect of partial replacement of soybean with duckweed (0, 15, 25, 35 and 45 per cent) in sugar cane juice based diets and reported significantly ($P<0.01$) reduced weight gain (29.5, 25.5, 24.4, 21.6 and 20.8 g, respectively) in cherry valley growing ducks.

Men *et al.* (1996) included duckweed in muscovy duck diets replacing soybean meal. The basal diet was broken rice and the protein supplement came from roasted soybean to supply 100 (control), 40 (DW60), and zero (DW100) per cent protein on three treatments. They observed that live weight at 70 days and growth rate from 28 to 70 days were highest for muscovy males fed the control ration which contained broken rice balanced with protein from roasted soybeans to supply 100 per cent requirement and duckweed *ad libitum*. No difference in growth rate (ranged from 21.7 to 22.5 g for females and 27.6 to 28.3 g for males) was reported between DW60 and DW100 diets.

Islam *et al.* (1996) reported that the live weight gain was lower with starter and grower test diets containing 13.6 and 5.9 per cent leaf protein concentrate of water hyacinth on White Leghorn chicks.

Islam *et al.* (1997) measured all growth parameters, which had a linear declining trend as the proportion of duckweed increased in the diet replacing complete fish meal by duckweed and soybean meal in broilers.

Islam (2002) observed that dehydrated duckweed, when substituted for dried alfalfa meal up to 5 per cent of mixed poultry feeds, produced superior weight gain in chicks up to 3 weeks of age.

Rubio *et al.* (2003) fed broiler chickens with diets containing whole lupin seed meal (400 g/kg) and observed lower final body weight (434 g) than controls (471 g), but gain:feed ratios were not different (0.68).

Khatun *et al.* (2004) could not observe any difference in weight gain (188.51 and 189.29 g/broiler/week, respectively) among treatments when broilers were fed with duckweed fresh (6 %) and dry condition (7 %).

In a study, Khang and Ogole (2004a) found that the chicks fed with duckweed had somewhat higher weight gain (8.3 g/day) compared with chicks fed the diets without duckweed (7.8 g/day).

Khanum *et al.* (2005) fed ducks with three diets (control diet, 50 per cent control diet+*ad libitum* fresh and harvested duckweed (DWH), 50 per cent control diet+ducks were allowed to graze on duckweed in lagoon (DWG). They observed that average daily body weight gain (6.53 and 6.28 g, respectively) and the final live weight (1256 and 1189 g, respectively) were not different between duckweed diets fed ducks, but significantly (P<0.01) lower than that in the control diet (9.09 and 1345 g).

2.4 EFFECT OF AZOLLA ON FEED INTAKE

Ali and Leeson (1995) showed that feed consumption from zero to fourteen days in male broiler chicken fed with Azolla (100 g/kg on digestible protein basis) and snail meal (80 g/kg on digestible protein basis) separately were similar (318.8 g for Azolla and 331.2 g for snail meal) to control birds fed maize soybean diet (321.8 g).

Sarria and Preston (1995) fed broiler chicks with ration containing 0, 10 and 15 per cent replacement of the protein from soybean meal with *Azolla filliculoides* and observed no difference in feed intake (59.0, 58.3 and 67.0 g, respectively).

Khatun *et al.* (1999) reported that feed consumption of laying hens fed with diets containing 150 and 200 g/kg Azolla meal on a digestible protein and digestible amino acid basis was similar (108.2 and 107.3 g/bird/day, respectively) to birds fed with control diet (107.3 g/bird/day). But feed consumption significantly increased

(112.6 and 113.6 g/bird/day, respectively) with 150 and 200 g/kg Azolla meal on a total protein and total amino acid basis.

Parthasarathy *et al.* (2001a) observed that feed intake decreased as the level of Azolla was increased from 0 to 15 per cent in broiler birds, but there was a slight increase in feed intake at 20 per cent level during starter period.

Basak *et al.* (2002) found that feed consumption was almost similar (981.33, 896.67, 906.67, 913.33 g/bird) in different dietary treatments namely 0, 5, 10 and 15 per cent Azolla by replacing sesame meal from seven to forty two days of age and the differences were nonsignificant (P<0.01) at all ages of experimental period in broiler chicks.

Alalade and Iyayi (2006) observed that 10 and 15 per cent Azolla meal in the diet of chicks significantly reduced the average weekly feed intake (231.28 and 224.38 g/week, respectively). But average weekly feed intake was similar to control diet (286.95 g/week) when they were fed with 5 per cent Azolla meal (270.73 g/week).

2.4.1 Effect of Other Aquatic Plants on Feed Intake

Lipstein *et al.* (1980) observed no significant effect of dietary algae meal, chlorella on feed intake of layer birds.

Lizama *et al.* (1988) reported that chicks given 5 or 10 per cent dried ground Elodea had similar feed intake (7.28 and 7.11 g/bird/day, respectively) to that of control chicks (7.13 g/bird/day).

Haustein *et al.* (1990) found no significant difference between the control group and the hens fed 25 per cent Lemna in feed consumption.

Mc Dowell *et al.* (1990) reported increase in feed intake for diets containing aquatic plants Elodea and Hydrilla both at 7.5 per cent levels in laying hens.

Ross and Dominy (1990) used one week old Japanese quails to study the effects of 0, 1.5, 3.0, 6.0 and 12 per cent of spirulina. Feed consumed per bird per day was 24.9, 23.3, 24.0, 24.1 and 24.8 g, respectively. The group fed the diet with 1.5 per cent spirulina consumed less feed ($p<0.05$) compared with other groups.

Benicio *et al.* (1993) included 3 per cent water hyacinth in pelleted diets for broiler chickens during the starting period and observed that feed intake was not affected by inclusion. However, performance was affected by inclusion of larger amounts.

Becerra *et al.* (1995a) reported that daily intake of dry matter and crude protein reduced significantly with decreasing soybean supply in growing ducks by increasing duckweed inclusion in the diet.

Islam *et al.* (1997) found that the complete replacement of fish meal by duckweed and soybean meal depressed feed intake in broilers. They concluded that duckweed (*Lemna minor*) along with soybean meal might be used up to 9 per cent of broiler ration without any adverse effect on the performance of chicks.

Agwunobi (1999) observed no significant ($P<0.05$) difference in feed intake (110 and 120 g/day in control and all other substitution diets, respectively) in layer birds when they were fed with water yam at different levels of 0, 10, 20, 30, 40 and 50 per cent by replacing maize corresponding to 0, 20, 40, 60, 80 and 100 per cent.

Rubio *et al.* (2003) fed broiler chickens with diets containing whole lupin seed meal (400 g/kg) and observed lower feed intake in treatment birds than control fed birds.

Khatun *et al.* (2004) reported no difference among treatments on average feed consumption (2868.70 and 2806.57 g/broiler) when broilers were fed with duckweed fresh (6 %) and dry condition (7 %).

2.5 EFFECT OF AZOLLA ON FEED CONVERSION RATIO (FCR)

Ardakani *et al.* (1996) reported better FCR in broiler birds fed with 6 per cent fresh Azolla compared with control fed birds.

Khatun *et al.* (1999) concluded that feed efficiency improved in laying hen when they were fed with Azolla diets formulated on a digestible nutrient basis.

Parthasarathy *et al.* (2002) obtained feed and protein efficiency ratio which were in the same order as in basal and 5 per cent Azolla diets replacing 2.6 per cent wheat bran and 2.4 per cent fish meal, where as these were significantly decreased as the level of Azolla increased from 10 to 20 per cent.

Basak *et al.* (2002) reported that FCR was very close to standard (1.87:1) in birds fed with 0 and 5 per cent Azolla when broilers were fed with Azolla at different levels of 0, 5, 10 and 15 per cent (2.17, 2.06, 2.38 and 2.50, respectively). FCR reduced significantly at 10 and 15 per cent level of Azolla fed broiler ration.

Alalade and Iyayi (2006) observed reduction in feed conversion ratio from 3.13 on control diet of chicks to 2.54 in 10 per cent Azolla fed birds. The FCR was 2.55 on 15 per cent Azolla fed birds.

2.5.1 Effect of Other Aquatic Plants on Feed Conversion Ratio (FCR)

Muztar *et al.* (1976) observed that feed efficiency decreased as the level of dehydrated alfalfa or dried aquatic plant was increased in the diet of male egg strain chicken.

Lipstein *et al.* (1980) observed no significant effect of dietary algae meal, chlorella on feed conversion of layer birds.

Lizama *et al.* (1988) reported that 5 or 10 per cent Elodea fed chicks replacing yellow maize and soybean meal had similar FCR (1.65 and 1.69, respectively) as that of controls (1.61).

Ross and Dominy (1990) used one week old Japanese quails to study the effects of 0, 1.5, 3.0, 6.0 and 12 per cent of spirulina. There was no significant difference in feed efficiency as determined by the amount of feed consumed per gram of egg produced (3.16, 2.95, 3.33, 2.77, 3.06 g/g, respectively).

Haustein *et al.* (1990) found no significant difference between the control group and the hens fed 25 per cent Lemna in feed conversion.

Mc Dowell *et al.* (1990) reported no difference among treatments in feed conversion when they were fed with control diet (corn-soybean meal), 7.5 per cent Elodea, 7.5 per cent Hydrilla and 7.5 per cent Hydrilla and algae (Pithophora spp).

After conducting a study, Benicio *et al.* (1993) opined that FCR was not affected by inclusion of 3 per cent water hyacinth in pelleted diets for broiler chickens during the starting period. However, performance was affected by supplementation of larger amounts.

Men *et al.* (1995) studied the effect of feeding duckweed (DW) replacing the roasted soybeans in diets based on broken rice for cross bred meat ducks. The five diets were based on broken rice with 27 g/day soybean (control, DW zero), 19g/day soybean (DW 30 per cent), 15 g/day soybean (DW 45 per cent), 12g/day soybean (DW 60 per cent) and zero soybean (DW 100 per cent). They observed that FCR was best in ducks fed with control diet. However, it did not differ significantly among the diets containing duckweed.

Becerra *et al.* (1995a) studied the effect of partial replacement of soybean with duckweed (0, 15, 25, 35 and 45 %) in sugar cane juice based diets and reported that FCR was increased (4.9, 6.0, 6.1, 6.7 and 6.6, respectively) significantly ($P<0.01$) in cherry valley growing ducks.

Men *et al.* (1996) included duckweed in muscovy duck diets replacing soybean meal. The basal diet was broken rice and the protein supplement came form roasted soybean to supply 100 (control), 40 (DW 60), and zero (DW 100) per cent protein on three treatments. They reported that the feed dry matter conversion was poorer (4.06 to 4.17 for females and 4.12 to 4.23 for males) on all duckweed diets compared with control diet (3.76 and 3.24 for females and males, respectively).

Islam *et al.* (1997) reported that the complete replacement of fish meal by duckweed and soybean meal depressed FCR in broilers from 2.45 to 2.50.

Agwunobi (1999) observed no significant ($P<0.05$) difference in the feed efficiency between the control diet and the test diets containing water yam at different levels by replacing maize in layers.

Islam (2002) opined that inclusion of 15 per cent Lemna and 15 per cent wolffia in the diets of layers produced no significant difference in feed conversion when compared with those of control groups.

Rubio *et al.* (2003) reported that the gain: feed ratio of broiler chickens fed diets containing whole lupin seed meal was similar to that of control fed groups.

Khang and Ogole (2004b) got highest value for FCR, when hens were fed with fresh duckweed replacing 75 per cent of the protein from roasted soybeans in a diet based on broken rice.

Khatun *et al.* (2004) reported no difference in FCR among treatments (2.53 and 2.47) when broilers were fed with duckweed fresh (6 %) and dry condition (7 %), respectively.

2.6 EFFECT OF AZOLLA ON EGG PRODUCTION

Singh and Subudhi (1978) observed that egg laying started early in the treatment of 100 per cent feed plus 5 per cent Azolla. The number of eggs per week was also more in this treatment than control. The egg production in the treatment of 75 per cent feed plus 12.5 per cent Azolla was identical to the control.

In a study, Jayaraman *et al.* (1995) found that the average egg laying as 274 eggs/duck/year in the integrated fish-duck-Azolla farming system.

Khatun *et al.* (1999) reported that hen day egg production improved in birds fed with 50, 100, 150 and 200 g Azolla meal/kg feed using digestible protein and digestible amino acid over control diet and the diet with 50, 100, 150 and 200 g Azolla meal/kg feed using total protein and total amino acid.

2.6.1 Effect of Other Aquatic Plants on Egg Production

Lipstein *et al.* (1980) reported no significant effect of dietary algae meal, chlorella on egg out put of layer birds.

Bratova and Ganovski (1983) supplemented algal meal in the ration mixtures of laying hens and observed increased egg laying capacity of birds.

Haustein *et al.* (1990) found no significant difference between the control group and the hens fed 25 per cent Lemna in egg production.

One week old Japanese quails were used to study the effects of 0, 1.5, 3.0, 6.0 and 12 per cent of spirulina on egg production. There was no significant difference in hen day (81.2, 83.9, 76.0, 88.6 and 75.9) or hen housed egg production (72.1, 72.1, 62.6, 76.4 and 67.7, respectively) for quails fed any of the dietary treatments (Ross and Dominy, 1990).

Agwunobi (1999) reported that the birds fed with diets containing substitution of maize with water yam (*Dioscorea alata*) up to 80 per cent, laid significantly ($p<0.05$) more eggs than those on the 100 per cent substitution rate (48.4 and 38.4 per cent average hen day production), respectively.

Islam (2002) opined that inclusion of 15 per cent Lemna and 15 per cent wolffia in the diets of layers produced no significant difference in egg production when compared with those of control groups.

Khang and Ogole (2004b) observed highest production and better fertility and hatchability of eggs obtained from hens fed with fresh duckweed replacing 75 per cent of the protein from roasted soybeans in a diet based on broken rice.

Egg production at 31 weeks of age was lower with 25 per cent lupin diet without and with foraging material (76.07 per cent) compared with control (0 % lupin) and 15 per cent lupin (89.0 % and 90.88 %, respectively) diets in hens (Hammershoj and Steenfeldt, 2005).

2.7 EFFECT OF AZOLLA ON EGG WEIGHT

Khatun *et al.* (1999) observed significant improvement on egg mass out put in the birds fed with 150 and 200 g Azolla/kg on a digestible protein and digestible amino acid basis over the control diet and 150 and 200 g Azolla /kg on total protein and total amino acid basis.

2.7.1 Effect of Other Aquatic Plants on Egg Weight

Lipstein *et al.* (1980) observed no significant effect of dietary algae meal, chlorella on egg weight of layer birds.

When the birds were fed with black sea algae, Bratova and Ganovski (1983) observed higher egg weight and more calcium in the shells.

Ross and Dominy (1990) used one week old Japanese quails to study the effects of 0, 1.5, 3.0, 6.0 and 12 per cent of spirulina. The effect of spirulina on egg weight was variable; only the 6 per cent content of spirulina produced eggs significantly heavier ($p<0.05$) than those of the control birds or those fed all other spirulina diets (10.95, 10.89, 10.96, 11.23 and 11.03 g, respectively).

Haustein *et al.* (1990) reported no significant difference between the control group and the hens fed 25 per cent Lemna in mean egg weight.

Mc Dowell *et al.* (1990) reported no difference among treatments in egg weight when they were fed with control diet (corn-soybean meal), 7.5 per cent Elodea, 7.5 per cent Hydrilla and 7.5 per cent Hydrilla and algae (Pithophora spp).

No significant difference in egg weight was observed when layer birds were fed with water yam by replacing maize (Agwunobi, 1999).

Islam (2002) reported that inclusion of 15 per cent Lemna and 15 per cent wolffia in the diets of layers produced no significant difference in mean egg weight when compared with those of control groups.

Khang and Ogole (2004b) observed an average egg weight when birds were fed with 20 per cent duckweed, replacing roasted soybeans in a diet based on broken rice.

Hammershoj and Steenfeldt (2005) reported that egg weight was highest (64 g) with the control (zero per cent lupin diet), and median with fifteen per cent lupin diet (60 g), whereas the twenty five per cent lupin diet with and without foraging material resulted in egg weights of 58 and 56 g, respectively.

2.8 EFFECT OF OTHER AQUATIC PLANTS ON EGG QUALITY

Haustein *et al.* (1990) opined that the optimal level of Lemna in the diets of chickens were 15 per cent, but even 40 per cent Lemna did not affect egg quality.

Mc Dowell *et al.* (1990) reported no difference among treatments in egg Haugh unit when they were fed with control diet (corn-soybean meal), 7.5 per cent Elodea, 7.5 per cent Hydrilla and 7.5 per cent Hydrilla and algae (Pithophora spp).

Egg quality was highest when hens were fed with fresh duckweed replacing 75 per cent of the protein from roasted soybeans in a diet based on broken rice (Khang and Ogole, 2004b).

2.8.1 Shell Quality

Mc Dowell *et al.* (1990) noticed that egg shell quality was higher for the two diets containing 7.5 per cent Hydrilla and 7.5 per cent Hydrilla and algae in layers.

Ross and Dominy (1990) used one week old Japanese quails to study the effects of 0, 1.5, 3.0, 6.0 and 12 per cent of spirulina. No statistical differences were reported for egg shell thickness among difference dietary groups (0.211, 0.224, 0.218, 0.218, 0.218 mm, respectively).

Rao (2005) reported that supplementation of *Cissus quandrangularis* plant meal to aged layers increased egg shell quality and decreased incidence of shell breakage.

2.9 EFFECT OF AZOLLA ON PIGMENTATION

The yolk portion of egg of Azolla fed birds was more yellowish than the control birds in the study of Singh and Subudhi (1978).

Becerra *et al.* (1995b) observed deeper yellow colour of legs, beaks and skin of ducks fed with Azolla compared to control group.

Khatun *et al.* (1999) reported that yolk colour significantly improved with increasing levels of Azolla meal and period of feeding whether fed on a total or on a digestible protein and amino acid basis in laying hen.

2.9.1 Effect of Other Aquatic Plants on Pigmentation

Williams *et al.* (1963) reported that the dietary carotenoids were preferentially deposited in the egg yolk of laying hens. The serum carotenoids reflected changes in dietary carotenoid consumption more quickly than egg yolk carotenoids. Hens which laid at high rate of production deposited fewer carotenoids in the egg yolk than hens which laid at a low rate.

Creger (1963) concluded that the naturally occurring xanthophylls found in a dehydrated blend of three species of flowering aquatic plants were biologically available and produced egg yolks of NEPA (National Egg and Poultry Association) numbers which express colour in terms of dichromate per cent, similar to those which resulted from the feeding of approximately equivalent levels of xanthophylls from dehydrated alfalfa meal.

Madiedo and Sunde (1964) reported that algae containing 768 mg of xanthophylls per kg supplied at a 1 per cent level increased pigmentation to a beta carotene equivalent value of 98 in layers. The increase in beta-carotene equivalent produced by 1 per cent algae was higher than that produced by 10 per cent alfalfa.

Gutcho (1973) reported that yolk color of hens fed with algae *Spongicoccum exentricum* increased by increasing its inclusion in the diet and reported carotene content of 76 micro grams per gram of yolk in hens fed with 2 per cent algae.

Lipstein ad Hurtwitz (1980) noticed marked increase in the intensity of pigmentation of the skin and shank of broilers fed with chlorella algae meal.

Lipstein *et al.* (1980) found that high concentration of dietary chlorella algae meal caused a deep yellow yolk color of acceptable appearance.

Bratova and Ganovski (1983) observed higher amounts of carotene and vitamins (A and E) in egg yolk when laying hens were fed with black sea algae.

No significant difference was found between the control group and the hens fed 25 per cent Lemna in yolk pigmentation. When eggs from hens fed 25 per cent Lemna spp were compared with eggs from 40 per cent supplemented groups it was observed that higher levels of Lemna spp produced smaller, but still significant ($P<0.05$), incremental changes in yolk pigmentation. Pigmentation increased significantly ($P<0.01$) when 15 per cent *Wolffia arrhiza* were included in the diets of layers (Haustein *et al.*, 1990).

Mc Dowell *et al.* (1990) observed increased yolk pigmentation when birds were fed with 7.5 per cent Elodea, 7.5 per cent Hydrilla and 7.5 per cent Hydrilla and algae

(Pithophora spp) than control diet (corn-soybean meal) fed groups. They also reported that total pigmenting units present in corn would be lower than aquatic plants.

Ross and Dominy (1990) used one week old Japanese quails to study the effects of 0, 1.5, 3.0, 6.0 and 12 per cent of spirulina. Yolk colour increased significantly with each additional increase of the spirulina content in the diet (Roche scale of 4.9, 8.2, 9.9, 11.5 and 12.2, respectively).

Anderson *et al.* (1991) studied the effect of xanthophylls of spirulina on egg yolk pigmentation. Optimum pigmentation was obtained with 1 per cent spirulina in a diet otherwise free of xanthophylls.

Haustein *et al.* (1994) reported significant increase in the pigmentation of all chicks fed with dried duckweed.

Ross *et al.* (1994) compared freeze dried and extruded *Spirulina platensis* as yolk pigmenting agents. In eight weeks long study Japanese quails were given 0, 0.5, 1.0, 2.0 and 4.0 per cent of freeze dried spirulina or the dry equivalent of fresh spirulina extruded with maize. Another experiment of similar kind was also conducted, but for an extended period of 16 weeks. Yolk colour increased with increasing dietary spirulina in both the experiments and there was a consistent increase with freeze dried over the extruded spirulina.

Sarria and Preston (1995) found that dietary supplements of xanthophylls, carotenoids and zeaxanthin effectively increased zeaxanthin concentrations in serum, retina, liver and fat of supplemented quails. The egg yolks from such quails provided the retina of the developing quail chicks with a rich source of lutein and zeaxanthin.

Haq and Bailey (1996) reported that domestic hens characteristically transfer certain carotenoids from maternal diet into eggs more efficiently than others and can metabolically transform certain carotenoids before deposition into egg yolk.

Mc Neill and Elswyk (1998) reported that Single Comb White Leghorn layers fed with marine algae at 2.4 per cent and 4.8 per cent for 4 week period showed an increase in egg yolk a* (represent red- green colour axis (redness) in L*a*b* color notation system) values (0.99 and 2.67, respectively) as compared to controls (-0.10). The carotenoids present in the marine algae were contributing to its characteristic red-range colour and were more effective in pigmenting egg yolk. In second experiment, the yolk colour was analysed in every week for four weeks and showed that after only one week of feeding, yolk a* values in all marine algae treatments were significantly ($p<0.05$) enhanced (1.4 and 1.9 in 2.4 per cent and 4.8 per cent marine algae, respectively) as compared to control (-0.4). Yolk colour had reached a plateau after 14 days, which was sustained throughout the experiment.

Surai *et al.* (1998) supplemented the maternal diet with vitamin A and observed an associated increase in the accumulation of vitamin A, vitamin E, ascorbic acid and carotenoids in the egg yolk and in the embryonic liver of hen. The concentration of both vitamin E and carotenoids in the yolk were significantly reduced by high dietary contents of vitamin A. Only 10 per cent of the stored vitamin A in the liver was transferred to the egg yolk and more than 90 per cent was used for other metabolic purposes.

There was an increase in the yolk concentrations of seven carotenoids, and also unidentified carotenoid in eggs produced by carotenoid supplemented females of wild Lesser Black-backed Gulls (*Larus fuscus* L.) in comparison with controls, indicating differential transfer of carotenoids from maternal diet to yolk (Blount *et al.*, 2002).

Surai *et al.* (2003) reported that carotenoid supplementation of the chicken diet were associated with increased lutein, citranaxanthine, canthaxanthine and carotenoic acid accumulation in the egg yolk.

Chang *et al.* (2004) stated that the lutein bioavailability from lutein enriched egg is higher than that from other sources such as lutein, lutein ester supplements and spinach.

Khang and Ogole (2004b) observed that the yolk pigmentation of the eggs increased in response to protein derived from duckweed.

Karadas *et al.* (2005) found that retinyl oleate and retinyl palmitate concentrations in egg yolk and the liver of day old quail chicks significantly increased as a result of carotenoid supplementation of maternal diet with alfalfa nutrient concentrate, tomato powder or marigold extract.

Hammershoj and Steenfeldt (2005) observed that yolk color became significantly more yellow with lupin content in the diet of layer chicken.

2.10 EFFECT OF AZOLLA ON CARCASS CHARACTERISTICS

Becerra *et al.* (1995a) observed no significant difference in carcass, heart, liver and gizzard weights compared with control when broilers derived 15, 30, 45 and 60 per cent of daily crude protein from Azolla.

Basak *et al.* (2002) reported that dressing per cent significantly increased on diet with 5 per cent Azolla meal (72.16 %), compared with control (69.38 %), 10 per cent Azolla meal (68.24 %) and 15 per cent Azolla meal (68.78 %) replacing sesame meal in broiler diets. Giblet per cent significantly increased in 15 per cent Azolla meal fed groups.

2.10.1 Effect of Other Aquatic Plants on Carcass Characteristics

Islam *et al.* (1997) studied the effect of complete replacement of fish meal (FM) by different combinations of duckweed and soybean meal (SBM) in broiler chicks and reported 72.8 per cent (control with 12 % FM), 71.3 per cent (3 % DW+13.5 % SBM), 69.3 per cent (6 % DW+11.5 % SBM) and 69.9 per cent dressing yield (9 % DW+10 % SBM). They could not observe any significant difference in dressed yield.

Zhengwei *et al.* (2000) investigated the effect of retinoic acid on the development of reproductive organs and egg production in female Japanese quails. The oviduct and ovary grew more rapidly ($P<0.05$) in retinoic acid treated (4 mg/kg) quail than in vitamin A treated quail at 5 weeks of age.

Khanum *et al.* (2005) fed ducks with three diets (control diet, 50 per cent control diet+*ad libitum* fresh and harvested duckweed (DWH), 50 per cent control diet+ducks were allowed to graze on duckweed in lagoon (DWG). The treatment effect on carcass characteristics did not vary significantly except for a significant lower live weight (1310g) prior to slaughter in DWH. Carcass yield was 70.7, 70.2 and 64.7 per cent, respectively.

2.11 EFFECT ON SERUM PROFILES

2.11.1 Serum cholesterol

Kaya *et al.* (2003) supplemented the diet of laying quails with Yucca (from the family of lily plant) powder (0,100 and 200 ppm) for a period of 14 weeks starting from 9 weeks. Yucca powder supplementation reduced serum cholesterol (163.55, 109.40 and 132.14 mg/dl, respectively) and triglyceride level (586.12, 164.00 and 178.00 mg/dl, respectively).

Rubio *et al.* (2003) studied the effect of feeding growing broiler chicken with diets containg sweeet lupin (*Lupinus angustifolius*) for 21 days and reported that cholesterol and triglycerides were significantly ($P<0.05$) lower than control (4.2 and 1.2 mM/l, respectively) in lupin fed groups (3.2 and 0.6 mM/l, respectively).

Sahin *et al.* (2006) supplemented lycopene, a predominant carotenoid present in tomatoes at different levels of 0, 50, 100 and 200 mg/kg diet of Japanese quails under heat stress (34^0C). They reported that lycopene supplementation linearly reduced serum cholesterol (5.3, 5.0, 4.7 and 4.3 mmol/l, respectively).

2.11.2 Serum protein

Yucca powder supplementation by Kaya *et al.* (2003) in the diet of laying quails (0,100 and 200 ppm) reported that serum total protein concentration was not changed by dietary treatments (4.52, 4.25 and 4.01 g/dl, respectively). But albumen concentration level was reduced in quails fed 100 ppm Yucca powder.

Rubio *et al.* (2003) reported that plasma amino acid concentrations were not different from control birds and lupin fed birds.

2.11.3 Serum uric acid

Buckingham *et al.* (1978) opined that a total of 5.5 per cent of the Azolla nitrogen was present as purine, resulting in a purine concentration of 492 mg/100g of Azolla, equally distributed between adenine and guanine.

Rubio *et al.* (2003) reported significantly ($P<0.05$) higher plasma uric acid concentration in lupin fed birds (7.7µm/l) than control birds (4.4µm/l).

2.12 LIVABILITY

Basak *et al.* (2002) observed cent per cent survivability in broiler chicks when they were fed with Azolla at different levels.

Parthasarathy *et al.* (2002) reported that feeding of Azolla at a level of 20 per cent did not have any adverse effect on the livability of broilers.

Parthasarathy *et al.* (2001) the broiler birds receiving 10, 15 and 20 per cent Azolla diets for five weeks of age suffered nearly 24 to 31 per cent less returns as compared to 5 per cent Azolla supplemented group, which was attributed to poor feed efficiency in the above three groups. Same result reported when Azolla was included in diet from 0 to 8 weeks.

2.13 ECONOMICS

Singh and Subudhi (1978) suggested that about 20 to 25 per cent of commercial feed could be replaced by fresh Azolla in poultry feed.

Lipstein *et al.* (1980) reported that algae meal could be included in the layer hen's diet up to 12 per cent level substituting soybean meal. For practical layer diets, algae meal can serve as almost the only protein supplement economically.

Jayaraman *et al.* (1995) observed 24 per cent reduction in feed cost in the integrated fish-duck-Azolla farming system.

Ardakani *et al.* (1996) included Azolla in poultry diets and studied the economics and showed that the cost of live weight gain production in the treatments containing 6 and 8 per cent fresh Azolla were lower than control groups.

Parthasarathy *et al.* (2001a) studied the economics of utilizing Azolla in broiler ration at different levels of 0, 5, 10, 15 and 20 per cent by replacing a protein mix containing wheat bran and groundnut cake (53:47) in first trial and wheat bran and fish meal (52:48) in second trial. The findings of this study indicated that incorporation of Azolla as a feed ingredient at 5 per cent level in broiler rations could provide promising economic returns.

The use of *Lemna trisulcca* meal as a partial replacement of the costly animal protein in the layer diets of Leghorn breed by reducing the proportion of fish meal to 2 per cent compared with 7 per cent in the control diet, found good result (Islam, 2002).

Men *et al.* (2001) stated that if the duckweed was grown on farm and managed and harvested by household labour, the saving over purchased protein supplements was up to 48 per cent.

Men *et al.* (2002) opined that replacement of 100 per cent of the protein supplement by fresh duckweed in the diets of the local laying ducks decreased the feed costs by 25 per cent compared to controls.

Khatun *et al.* (2004) reported that inclusion of duckweed (either fresh or dry condition) at 6 per cent levels (DM basis) significantly reduced the feed cost of individual broilers.

Khang and Ogole (2004b) reported that even at 100 per cent of roasted soybeans replacement by duckweed, the egg production and margin of income over feed cost were better than on the control diet in which the supplementary protein came only from roasted soybeans.

Materials and Methods

3. MATERIALS AND METHODS

An experiment was carried out at the Department of Poultry Science, College of Veterinary and Animal Sciences, Kerala Agricultural University, Mannuthy, to study the effect of dietary supplementation of dried Azolla on production performance of Japanese quail and to evaluate the economics of feeding Azolla. The experiment was carried out during the period from January through June 2006.

3.1 EXPERIMENTAL MATERIALS

3.1.1 Birds

One hundred and ninety two Japanese quail pullets with an average weight of 185 g received from the Revolving Fund Hatchery of the Centre for Advanced Studies in Poultry Science, Mannuthy were utilized for the study. The parent stocks of these quails were maintained at the University Poultry Farm, Mannuthy. The birds were housed at six weeks of age.

3.1.2 Rations

Quail layer rations with crude protein 22 per cent and metabolisable energy 2650 kcal per kg feed formed the experimental rations. The details of treatment groups and experimental diets are given below.

T_1 = Control ration (quail layer ration) containing 22 per cent crude protein, 2650 kcal metabolisable energy per kg feed, 3 per cent calcium and 0 .45 per cent phosphorus.

T_2 = Control ration (quail layer ration) containing 1.5 per cent Azolla (dry matter basis).

T_3 = Control ration (quail layer ration) containing 3.0 per cent Azolla (dry matter basis).

T4 = Control ration (quail layer ration) containing 4.5 per cent Azolla (dry matter basis).

All the rations were made isocaloric and isonitrogenous. The experimental rations were formulated as outlined in Table 1. Chemical composition of formulated rations were determined and are presented in Table 2.

3.1.3 Production and Preparation of Azolla

An artificial water body was made with the help of a silpauline sheet of size 2.8×1.8 m. A pit of the size 2 m length, 1 m width and 20 cm depth was dug as the first step. This pit was then covered with second hand plastic gunnies to prevent the growth of roots of the nearby trees. The silpauline sheet was spread over the gunnies without any fold. About 10 to 15 kg sieved fertile soil was uniformly spread over the silpauline sheet. Slurry was prepared with 2 kg cow dung and 20 to 25 g super phosphate in 10 litre water and was poured into the sheet. More water was poured to make the water level at about 10 cm. Seed material of about 500 g to 1 kg of fresh and pure culture of Azolla was inoculated in the pit. The species used was *Azolla pinnata*. Once the Azolla was established, it was harvested every seven days, taking an average of seventy five per cent of the biomass from the ponds, the remaining twenty five per cent served as the seed material for the next crop. Water was continuously added to compensate for evaporation. About 20 g of super phosphate and 1 kg of cow dung was added once in 5 days to keep the Azolla in rapid multiplication phase. The Azolla were dried in sunlight after harvesting

3.2 EXPERIMENTAL DESIGN

The experiment was conducted during the laying phase of Japanese quails from six to twenty six weeks of age. One hundred and ninety two Japanese quail pullets were weighed individually and distributed randomly to four treatment groups with four replicates of twelve birds in each. The quails were housed in cages at five weeks of age for cage adaptation.

Each replicate was housed in separate cage, of dimension 50x40x20cm, maintaining uniform standard management conditions. The birds were fed experimental feed *ad libitum* and clean drinking water was provided throughout the experimental period. Data collection was done for five periods of twenty eight days each from seven to twenty six weeks of age.

The following parameters were studied during the course of the experiment.

3.2.1 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 and afternoon, throughout the experimental period.

3.2.2 Body Weight

Body weight of all birds at sixth and twenty sixth week of age was recorded (BW_6 and BW_{26}).

3.2.3 Age at Sexual Maturity

The age at first egg, 10 and 50 per cent production (days) were recorded in each replicate and from this data mean age at sexual maturity was arrived at.

3.2.4 Egg Production

Egg production was recorded daily from seven to twenty six weeks of age, replicate wise and expressed as hen housed and hen day egg production.

3.2.5 Egg Weight

At the end of each twenty eighth day laying period all the eggs laid by the birds among the treatment groups were collected for three consecutive days, weighed individually with 0.01g accuracy. Based on these data mean egg weight was worked out replicate wise.

3.2.6 Feed Consumption

The weight of feed issued was recorded replicate wise in every week and the balance feed available in the feeders at the end of every week was measured. The mean daily feed consumption per bird was calculated from this data.

3.2.6 Feed Conversion Ratio (FCR)

Feed Conversion Ratios (FCR) were calculated based on egg number as well as egg mass and represented as FCR per dozen eggs and per kilogram egg mass.

3.2.8 Egg Quality

At the end of each twenty eight day period five eggs were randomly collected from each replicate for egg quality study. Shape, albumen and yolk indices, internal quality unit and shell thickness were measured. The heights of albumen and yolks were measured using Ame's tripod stand micrometer. The widths of yolk and albumen were measured by using hand slide callipers. The shell thickness was measured using Mitutoyo Digimatic Micrometer.

The formulae applied for calculating shape, albumen and yolk indices were

$$\text{Shape index} = \frac{\text{Greatest width of the egg (mm)} \times 100}{\text{Greatest length of the egg (mm)}}$$

$$\text{Albumen index} = \frac{\text{Maximum height of thick albumen (mm)}}{\text{Maximum width of thick albumen (mm)}}$$

$$\text{Yolk index} = \frac{\text{Maximum height of yolk (mm)}}{\text{Maximum diameter of yolk (mm)}}$$

The internal quality unit of quail egg was calculated using the formula.

$$\text{Internal quality unit (IQU)} = 100 \log (H+4.18-0.8989W^{0.6674})$$

Where, H stands for height of the albumen in millimeters and W for weight of egg in gram.

3.2.9 Livability

The period wise per cent livability was recorded based on the number of birds alive for each period after recording the mortality of birds from different treatment groups. Post mortem examination was conducted in each case to find out cause of death.

3.2.10 Chemical Analysis

The chemical composition of experimental rations and Azolla were determined as per the procedure described by AOAC (1990).

3.2.11 Serum Analysis

At the end of 26th week of age, blood samples were collected from two birds in each replicate by severing the jugular vein for the estimation of serum protein, cholesterol, creatinine and uric acid. The method used for estimation were modified Biuret method, Wybenga and Pileggi's method, modified Jaffe's method and Uricase-PAP method, respectively.

3.3 YOLK COLOUR COMPARISON

3.3.1 Sampling Methods and Analysis

At the end of each twenty eight day period two eggs were randomly collected from each replicate for carotenoid estimation. Egg yolk was extracted with acetone, filtered and determined the absorbance or transmittance at 450 nm using spectrophotometer (AOAC, 1990). The oxycarotenoid content of egg yolk was estimated using a beta-carotene standard curve and recorded the yolk colour equivalent to micro gram beta-carotene per gram of sample.

3.3 ECONOMICS

Economics of egg production by incorporating dried Azolla in layer diet of Japanese quail was calculated taking into account of prevailing cost of the feed ingredients and quail eggs during the study period.

3.5 STATISTICAL ANALYSIS

Data collected on various parameters were statistically analysed by Completely Randomised Design (CRD) as described by Snedecor and Cochran (1985). Means were compared by Least Significant Difference (LSD) test using MSTAT-C.

Table 1. Ingredient composition of experimental rations, per cent

Ingredients	T1	T2	T3	T4
Maize	45.00	45.00	45.00	46.00
Wheat bran	3.50	2.00	0.50	-
Soybean meal	24.00	24.00	24.00	23.00
Unsalted dried fish	10.00	10.00	10.00	10.00
Gingelly oil cake	5.00	5.00	5.00	5.00
Rice polish	5.00	5.00	5.00	4.50
Dried Azolla	-	1.50	3.00	4.50
Shell grit	5.50	5.50	5.50	5.00
Mineral mixture*	1.75	1.75	1.75	1.75
Salt	0.25	0.25	0.25	0.25
TOTAL	100	100	100	100
Nicomix A+B2+D3+K** (g)	15	15	15	15
Alusil Premix*** (g)	200	200	200	200
L-Lysine (g)	50	50	50	50
DL-Methionine (g)	25	25	25	25
Choline (g)	50	50	50	50

Mineral mixture*: Supermin P mineral mixture without salt (Kwality Agrovet industries, Salem) Composition: Calcium: 30.0 per cent, Phosphorus: 9.0 per cent, Iron: 0.2 per cent, Iodine: 0.01 per cent, Zinc: 0.05 per cent, Manganese: 0.4 per cent, Copper: 0.4 per cent, Flourine (max): 0.05 per cent, Acid Insoluble Ash (max): 2.5 per cent and Moisture: 3 per cent.

Nicomix A+B2+D3+K** (Nicholas Primal India Ltd., Mumbai)

Composition per gram: Vitamin A: 82,000 IU, Vitamin D3: 12,000 IU,

Vitamin B2: 50 mg, Vitamin K: 10 mg

Alusil Premix*** (Stallen South Asia Pvt. Ltd) containing SIO_2 400-500 g, Al_2O_3 320-400 g, Fe_2O_3 3-10 g, MgO 5-20 g, CaO 30-50 g, Na_2O 25-45 g, K_2O 5-10 g and inert ingredients made up to 1000 g.

Table 2. Chemical composition of experimental rations, per cent
(on dry matter basis)

Components	T1	T2	T3	T4
Dry matter	90.01	90.05	90.39	90.78
Crude protein	22.20	22.33	22.45	22.29
Ether extract	3.06	3.10	3.13	3.13
Crude fibre	4.95	4.60	4.01	3.98
NFE	59.61	59.53	59.71	59.63
Total ash	10.18	10.44	10.70	10.97
Acid insoluble ash	2.10	2.19	2.28	2.37
Calcium	3.25	3.28	3.31	3.18
Phosphorus	0.84	0.83	0.82	0.81
ME (kcal/ kg)*	2651.97	2652.24	2652.50	2656.51

* Calculated values

Results

4. RESULTS

The results of an experiment carried out to study the effect of dietary inclusion of dried Azolla on production performance of Japanese quails 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. from January to June 2006 are presented in Table 3. 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 was significantly ($P<0.05$) higher during period III compared to that in periods I, IV and V and was comparable in period II. The maximum temperature in periods I and V were almost same and was significantly ($P<0.05$) lower compared to all other periods. The minimum temperature was significantly ($P<0.05$) higher during period IV compared to periods I, II and V and was comparable in period III. The minimum temperature was significantly ($P<0.05$) lower during periods I and II compared to all other periods.

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

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

Period	Age in weeks	Temperature (^{0}C)		Relative Humidity (%)	
		Maximum	Minimum	F.N.	A.N.
I (Jan 20 – Feb 16)	7-10	34.73^{c} ±0.19	22.91^{c} ±0.41	70.79^{d} ±2.20	53.25^{d} ±1.98
II (Feb 17 –Mar 16)	11-14	36.68^{ab} ±0.32	23.59^{c} ±0.34	77.89^{c} ±1.90	63.54^{c} ±2.23
III (Mar 17 –Apr 13)	15-18	37.07^{a} ±0.25	25.66^{ab} ±0.25	85.36^{b} ±0.96	71.07^{b} ±2.04
IV (Apr14 –May 11)	19-22	35.82^{b} ±0.19	26.09^{a} ±0.22	84.72^{b} ±1.48	85.07^{a} ±1.27
V (May 12 – Jun 8)	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

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

were significantly ($P \leq 0.05$) different from that of other periods. 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 NUTRITIVE VALUE OF AZOLLA

Proximate analysis of Azolla presented in Table 4 showed that it contained 5.25 per cent dry matter, 23.14 per cent crude protein, 3.50 per cent ether extract, 12.20 per cent crude fiber, 43.66 per cent nitrogen free extract, 17.5 per cent ash, 2.29 per cent calcium and 0.39 per cent phosphorus. A metabolisable energy value of 1807 kcal/kg was also calculated. Chemical composition is graphically represented in Fig.1.

4.3 BODY WEIGHT

Data on mean body weight at six and twenty six weeks of age and body weight gain as influenced by different dietary treatments viz., control ration (T1), quail layer ration containing 1.5 per cent Azolla (T2), quail layer ration containing 3 per cent Azolla (T3) and quail layer ration containing 4.5 per cent Azolla are presented in Table 5.

The mean body weight of birds belonging to the treatments T1, T2, T3 and T4 at six weeks of age was 185.23, 186.04, 185.01 and 186.56 g, respectively. The corresponding values at twenty six weeks of age were 222.27, 223.31, 220.52 and 223.30 g, respectively. The mean body weight gain during the experimental period among the different treatment groups viz., T1, T2, T3 and T4 were 37.74, 37.27, 35.51 and 36.74 g, respectively.

The body weight of quails in different treatments was comparatively uniform at the beginning and at the end of the experiment and means did not vary significantly ($P<0.05$) at both ages. The birds maintained on T2, recorded numerically higher body.

Table 4. Chemical composition of Azolla, per cent (on dry matter basis)

Components	Composition
Dry matter	5.25
Crude protein	23.14
Ether extract	3.50
Crude fibre	12.20
NFE	43.66
Total ash	17.50
Calcium	2.29
Phosphorus	0.39
ME (kcal/ kg)*	1807

* Calculated value

Fig.1 Per cent chemical composition of Azolla (on dry matter basis)

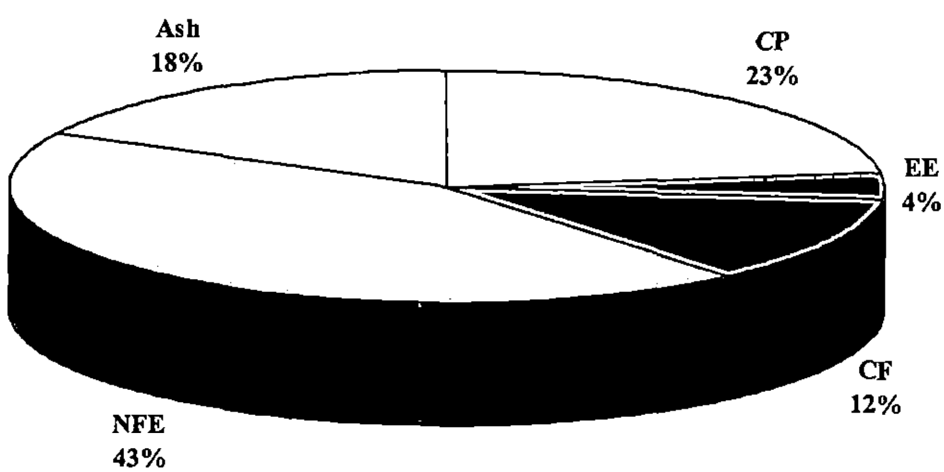

Table 5. Mean (± S.E.) body weight (g) at 6 and 26 weeks of age and body weight gain (g) in layer Quails as influenced by dietary inclusion of dried Azolla

Age in weeks	Body weight (g)				Overall mean
	T_1 Azolla (0 %)	T_2 Azolla (1.5 %)	T_3 Azolla (3.0 %)	T_4 Azolla (4.5 %)	
6	185.23±4.00	186.04±1.50	185.01±1.11	186.56±1.51	185.71±1.88
26	222.27±3.89	223.31±3.78	220.52±4.89	223.30±3.56	222.35±3.68
Gain in BW (g)	37.74±7.75	37.27±5.12	35.51±6.63	36.74±6.05	36.64±2.89

Non significant

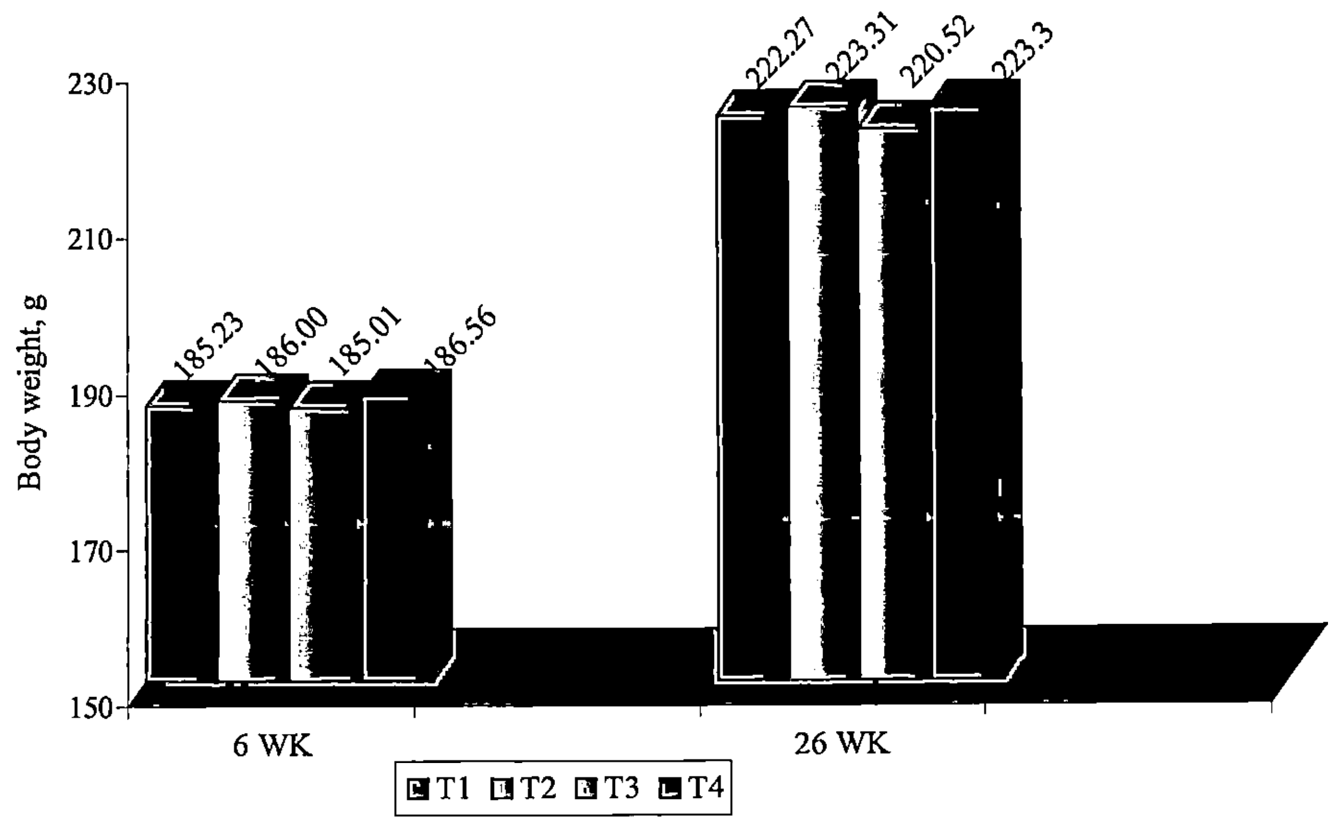

Fig.2 Mean body weight (g) at six and twenty six weeks of age of Japanese quails as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age

weight followed by T4, T1 and T3 at the end of twenty-six weeks. Birds fed Azolla diets recorded numerically lower weight gain than those fed control diet.

The data on mean body weight of birds at sixth and twenty-sixth week of age as influenced by dietary inclusion of dried Azolla is graphically represented in Fig. 2.

4.4 AGE AT FIRST EGG, 10 AND 50 PER CENT PRODUCTION

The data pertaining to age at first egg, mean ages at 10 and 50 per cent production as influenced by the dietary inclusion of dried Azolla are presented in Table 6.

All the treatments viz., T1, T2, T3 and T4 attained sexual maturity at the same age of 42 days. The mean age at 10 per cent production for the different treatment groups viz. T1, T2, T3 and T4 were 43, 44, 44 and 43 days, respectively. Birds fed with Azolla, attained 50 per cent production at one day later (48 days) than the control diet fed birds.

4.5 FEED CONSUMPTION

The mean daily feed intake per bird during each 28 day period among the different treatment groups is given in Table 7.

The mean daily feed consumption per bird among different dietary treatments T1, T2, T3, and T4 were 17.59, 22.40, 22.38 and 22.64 g, respectively from seven to ten weeks of age. The corresponding values during the period from eleven to fourteen weeks were 28.63, 28.54, 28.94 and 29.21 g, respectively. The mean daily feed intake for the periods from fifteen to eighteen weeks, nineteen to twenty two weeks and twenty three to twenty six weeks were 31.94, 32.65, 31.06 and 31.68 g; 31.72, 33.70, 34.84 and 32.07 g and 31.90, 32.51, 33.01 and 32.90 g, respectively.

The quails fed standard layer ration (T1) and those fed with diets containing different levels of Azolla (T2, T3 and T4) were comparatively similar in mean daily feed consumption during all the periods with the exception of first period of seven to ten

Table 6.Age at first egg (AFE), 10 and 50 per cent production (days) of Japanese Quails as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age.

Parameter	Treatments			
	T_1 Azolla (0 %)	T_2 Azolla (1.5 %)	T_3 Azolla (3.0 %)	T_4 Azolla (4.5 %)
Age at first egg (days)	42	42	42	42
Age at 10 per cent production (days)	43	44	44	43
Age at 50 per cent production (days)	47	48	48	48

Non significant

Table 7. Mean (± S.E.) feed consumption per bird per day (g) of Japanese Quails as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age

Period	Age in weeks	Feed consumption per bird per day (g)				Overall mean
		T_1 Azolla (0 %)	T_2 Azolla (1.5 %)	T_3 Azolla (3.0 %)	T_4 Azolla (4.5 %)	
I	7-10	17.59±0.25^{b}	22.40±0.41^{a}	22.38±0.36^{a}	22.64±0.28^{a}	21.25±1.13
II	11-14	28.63±0.59	28.54±0.51	28.94±0.35	29.21±0.47	28.83±0.46
III	15-18	31.94±0.80	32.65±0.37	31.06±0.74	31.68±0.85	31.83±0.71
IV	19-22	31.72±0.84	33.70±0.51	34.84±3.2	32.07±0.30	33.08±1.64
V	23-26	31.90±1.15	32.51±0.30	33.01±0.40	32.90±1.16	32.58±0.75
Cumulative mean	7-26	28.35±0.54	29.96±0.10	30.05±0.85	29.70±0.52	29.51±0.62

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

weeks of age. The statistical analysis of data on mean daily feed intake showed that this trait was not different between treatments with the exception of first period. During the first period, Azolla supplemented birds consumed significantly ($P<0.05$) higher amount feed than control birds (T1). It was statistically comparable among groups T2, T3, and T4.

The cumulative mean daily feed intake of Japanese quails from seven to twenty six weeks of age as influenced by the dietary inclusion of Azolla were 28.35, 29.96, 30.05 and 29.70 g for the groups T1, T2, T3 and T4, respectively. The mean daily feed intake was numerically higher in T2, T3 and T4 compared with control group T1. But the differences were statistically non significant.

4.6 FEED CONVERSION RATIO (FCR)

4.6.1 FCR (kg feed/dozen eggs)

The mean feed efficiency values expressed as feed per dozen eggs as influenced by incorporation of dried Azolla in the diet of Japanese quails from seven to twenty six weeks of age are presented in Table 8.

Statistical analysis of the data indicated that the feed efficiency of the group T1 (0.34) was significantly superior ($P<0.05$) as compared to treatment groups T2 (0.42), T3 (0.51) and T4 (0.44) during the first period of seven to ten weeks of age. The mean feed efficiency of all the treatments was stastically comparable during the other periods of the experiment as well as cumulative FCR from seven to twenty six weeks of age.

The mean cumulative feed conversion efficiency for the groups T1, T2, T3 and T4 were 0.41, 0.42, 0.45 and 0.43, respectively. All the treatments fed with Azolla showed numerically higher value for FCR per dozen eggs than the control (T1) fed group during seven to twenty six weeks of age.

Table 8. Mean (± S.E.) feed efficiency (kg feed/ dozen eggs) of Japanese Quails as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age

Period	Age in weeks	Feed efficiency (kg feed/ dozen eggs)				Overall mean
		T_1 Azolla (0 %)	T_2 Azolla (1.5 %)	T_3 Azolla (3.0 %)	T_4 Azolla (4.5 %)	
I	7-10	0.34±0.03[b]	0.42±0.03[ab]	0.51±0.04[a]	0.44±0.03[a]	0.43±0.04
II	11-14	0.40±0.02	0.39±0.03	0.42±0.01	0.39±0.02	0.40±0.02
III	15-18	0.41±0.01	0.41±0.01	0.40±0.02	0.39±0.01	0.40±0.01
IV	19-22	0.43±0.01	0.44±0.02	0.44±0.02	0.42±0.01	0.43±0.01
V	23-26	0.45±0.02	0.45±0.02	0.47±0.02	0.47±0.03	0.46±0.02
Cumulative FCR	7-26	0.41±0.01	0.42±0.02	0.45±0.02	0.43±0.01	0.42±0.02

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

4.6.2 FCR (kg feed/kg egg mass)

The data on mean feed efficiency calculated based on per kilogram of egg mass among the treatment groups during the five periods is presented in Table 9. Statistical analysis revealed significant ($P<0.05$) differences in feed efficiency during seven to ten weeks of age only. The group T1 had a value of 2.66, which was significantly different from T3 (3.79) and T4 (3.43). But it was statistically comparable with T2 (3.30).

The mean cumulative feed conversion efficiency for the groups T1, T2, T3 and T4 were 3.02, 3.11, 3.23 and 3.12, respectively. The cumulative mean feed efficiency from six to twenty six weeks of age was numerically inferior for the group T3 followed by T4, T2 and T1. Statistical analysis revealed that this trait was not influenced by dietary inclusion of Azolla at the levels used in this experiment.

4.7 EGG PRODUCTION

The data on mean quail housed number (eggs per bird) and quail housed per cent and quail day number and quail day per cent from seven to twenty six weeks of age among the treatment groups T1, T2, T3, and T4 are presented in Tables 10, 11, 12 and 13, respectively.

4.7.1 Quail Housed Egg Production

Statistical analysis of the mean quail housed egg number did not reveal any significant difference between treatments. In general, quail housed egg number was less with both control and Azolla supplemented groups during 7 to 10 weeks of age (first period). The data on mean quail housed egg number indicated that it was highest for the group T2 in all the periods except during 15 to 18 weeks of age where T4 ranked top. The cumulative quail housed egg number was numerically highest with the group T2 (120.00) followed by birds in group T4 (119.24), T1 (117.32) and T3 (112.18).

Table 9. Mean (± S.E.) feed efficiency (kg feed/kg egg mass) of Japanese Quails as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age

Period	Age in weeks	Feed efficiency (kg feed/kg egg mass)				Overall mean
		T_1 Azolla (0 %)	T_2 Azolla (1.5 %)	T_3 Azolla (3.0 %)	T_4 Azolla (4.5 %)	
I	7-10	2.66±0.19[b]	3.30±0.16[ab]	3.79±0.21[a]	3.43±0.28[a]	3.30±0.29
II	11-14	3.04±0.26	3.98±0.31	3.04±0.17	2.83±0.07	2.97±0.20
III	15-18	3.05±0.18	2.99±0.14	2.93±0.07	2.89±0.11	2.96±0.12
IV	19-22	3.19±0.05	3.15±0.12	3.16±0.11	3.10±0.04	3.15±0.08
V	23-26	3.17±0.11	3.12±0.15	3.25±0.09	3.34±0.14	3.23±0.14
Cumulative FCR	7-26	3.02±0.11	3.11±0.08	3.23±0.09	3.12±0.03	3.12±0.08

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

Table 10. Mean (± S.E.) Quail Housed Number (QHN) (eggs/bird) of Japanese Quails as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age

Period	Age in weeks	Quails Housed Number (eggs/bird)				Overall mean
		T_1 Azolla (0 %)	T_2 Azolla (1.5 %)	T_3 Azolla (3.0 %)	T_4 Azolla (4.5 %)	
I	7-10	17.65±1.30	18.02±1.19	15.04±1.01	17.42±1.31	17.03±1.24
II	11-14	24.36±1.32	24.81±1.65	23.19±0.44	25.33±0.58	24.42±1.08
III	15-18	26.04±0.66	26.94±0.56	26.28±0.55	27.25±0.21	26.63±0.53
IV	19-22	24.60±0.87	25.46±0.76	23.75±0.78	25.46±0.38	24.82±0.74
V	23-26	24.68±1.71	24.76±0.97	23.92±0.78	23.77±0.92	24.28±1.05
Cumulative QHN	7-26	117.32±4.50	120.00±3.58	112.18±2.98	119.24±1.58	117.20±5.67

Non significant

Table 11. Mean (± S.E.) Quail Housed Per cent (QHP) egg production of Japanese Quails as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age

Period	Age in weeks	Quails Housed Per cent (QHP)				Overall mean
		T_1 Azolla (0 %)	T_2 Azolla (1.5 %)	T_3 Azolla (3.0 %)	T_4 Azolla (4.5 %)	
I	7-10	63.02±4.63	64.36±4.23	53.72±3.61	62.21±4.67	60.83±4.41
II	11-14	86.98±4.71	88.62±5.89	82.82±1.56	90.48±2.08	87.22±3.86
III	15-18	93.01±2.33	96.18±2.03	93.89±1.95	97.32±0.74	95.09±1.89
IV	19-22	87.84±3.08	90.94±2.71	84.81±2.79	90.92±1.36	88.63±2.65
V	23-26	85.71±4.67	88.44±3.44	85.44±2.78	84.88±3.28	86.12±3.31
Cumulative QHP	7-26	83.31±11.60	85.71±12.5	80.13±10.60	85.16±5.60	83.58±11.60

Non significant

Table 12. Mean (± S.E.) Quail Day Number (QDN) (eggs/bird) of Japanese Quails as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age

Period	Age in weeks	Quails Day Number (QDN) (eggs/bird)				Overall mean
		T_1 Azolla (0 %)	T_2 Azolla (1.5 %)	T_3 Azolla (3.0 %)	T_4 Azolla (4.5 %)	
I	7-10	17.65±1.30	18.02±1.19	15.04±1.01	17.42±1.31	17.03±1.23
II	11-14	24.36±1.32	24.81±1.65	23.47±0.68	25.33±0.59	24.49±1.09
III	15-18	26.30±0.56	26.79±0.61	26.00±0.39	27.25±0.21	26.58±0.48
IV	19-22	24.93±1.03	26.00±0.68	26.88±2.83	25.55±0.38	25.84±1.44
V	23-26	25.39±1.59	24.76±0.97	23.92±0.78	23.77±0.92	24.46±1.05
Cumulative QDN	7-26	118.61±4.33	120.38±3.85	115.32±2.85	119.34±1.53	118.41±3.13

Non significant

Table 13. Mean (± S.E.) Quail Day Per cent (QDP) egg production of Japanese Quails as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age

Period	Age in weeks	Quails Day Per cent (QDP)				Overall mean
		T_1 Azolla (0 %)	T_2 Azolla (1.5 %)	T_3 Azolla (3.0 %)	T_4 Azolla (4.5 %)	
I	7-10	63.02±4.63	64.36±4.23	53.72±3.11	62.21±4.42	60.83±4.42
II	11-14	86.98±4.71	88.62±5.89	83.83±2.45	90.48±2.08	87.48±3.88
III	15-18	93.91±2.01	95.65±2.15	92.87±1.42	97.32±0.74	94.94±1.79
IV	19-22	89.04±3.66	92.84±2.42	86.79±2.49	91.26±1.34	89.98±2.62
V	23-26	85.71±4.68	88.44±3.44	85.44±2.78	84.88±3.28	86.12±3.31
Cumulative QDP	7-26	83.73±2.94	85.98±2.74	80.83±1.92	85.23±1.09	83.87±2.32

Non significant

The mean per cent quail housed egg production as influenced by varying dietary treatments showed similar trends to that of quail housed egg number. The period wise mean per cent egg production, irrespective of treatment effects showed that the quail layers performed well in all periods except period one. The cumulative mean per cent quail housed egg production were 83.31, 85.71, 80.13 and 85.16 for the treatment groups T1, T2, T3 and T4, respectively. The statistical analysis of the data on mean per cent quail housed egg production for the period from seven to twenty six weeks of age failed to show any significant difference between treatment groups.

4.7.2 Quail Day Egg Production

Overall mean quail day egg numbers were 118.61, 120.38, 115.32 and 119.34 and overall mean per cent quail day egg production were 83.73, 85.98, 80.83 and 85.23, respectively for T1, T2, T3 and T4. The birds fed with 1.5 per cent Azolla (T2) showed numerically highest quail day number during the first period only, that is from seven to ten weeks of age, whereas quail day per cent was higher during seven to ten, nineteen to twenty two and twenty three to twenty six weeks of age. The birds in the treatment T3 with 3 per cent Azolla were lowest in quail day egg production and per cent during the entire experimental period except nineteen to twenty two weeks of age, in which period quail day number was highest with this group. But the birds fed 4.5 per cent Azolla (T4) reached top in quail day egg number and per cent during 11 to 14 weeks of age (25.33 and 90.48, respectively), and 15 to 18 weeks of age (27.25 and 97.32, respectively). Also, T4 recorded quail day per cent production above ninety in three consecutive periods starting from second to fourth (90.48, 97.32 and 91.26, respectively). The birds fed with standard quail layer ration without Azolla (T1) showed numerically higher quail day egg number during the last period of the experiment that is from 23 to 26 weeks of age. Quail day egg production of the treatment groups during the five periods was statistically similar.

4.8 EGG WEIGHT

The mean egg weight (g) of layer quails as influenced by dietary supplementation of dried Azolla from seven to twenty six weeks of age are given in Table 14 and is represented graphically in Fig. 3.

In the control group T1, the mean egg weight ranged from 10.72 to 11.92 g during the entire experimental period. In T2 birds, the range in egg weight was from 10.64 to 12.28 g, while it was in the range of 11.18 to 12.34 g for T3. In birds fed with 4.5 per cent Azolla, the mean egg weight range was from 10.98 to 12.10 g. Birds in the three treatments fed with Azolla recorded highest egg weight in all the five periods of experiment than the control (T1) group with slight variation in second and fourth periods. In all the periods, the egg weight of quail layers fed with 3 per cent Azolla (T3) was numerically heavier (11.71, 11.18, 11.37, 11.58 and 12.34 g for the periods 1 to 5, respectively) than the eggs laid by control birds (T1) and those supplemented with 1.5 (T2) and 4.5 per cent Azolla (T4) in their diets. During the fifth period, treatments T2, T3 and T4 recorded egg weight above 12 g (12.28, 12.34 and 12.10 g, respectively) compared with control birds where it was 11.92 g. The cumulative mean egg weight from 7 to 26 weeks of age was highest ($P<0.05$) for T3 (11.64 g) followed by T2 (11.41 g), T4 (11.39 g) and T1 (11.27 g). The statistical analysis of the data pertaining to the mean egg weight revealed significant differences ($P<0.05$) during the periods 2, 3, 4 and in the cumulative egg weight. The mean egg weight was not influenced during the first and last periods. All Azolla supplemented birds laid significantly ($P<0.05$) heavier eggs than the control birds fed quail layer ration. The birds fed a diet supplemented with 3 per cent dried Azolla laid significantly ($P<0.05$) heavier eggs. The egg weight of T2 and T4 birds were intermediary. The egg weight of Azolla supplemented groups (T2, T3 and T4) was statistically comparable.

Table 14. Mean (± S.E.) egg weight (g) of Japanese Quails as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age

Period	Age in weeks	Egg weight (g)				Overall mean
		T_1 Azolla (0 %)	T_2 Azolla (1.5 %)	T_3 Azolla (3.0 %)	T_4 Azolla (4.5 %)	
I	7-10	11.48±0.19	11.49±0.13	11.71±0.21	11.64±0.19	11.58±0.17
II	11-14	$10.72±0.25^{b}$	$10.64±0.27^{b}$	$11.18±0.16^{a}$	$10.98±0.16^{ab}$	10.88±0.22
III	15-18	$10.97±0.18^{b}$	$11.35±0.20^{a}$	$11.37±0.24^{a}$	$11.10±0.15^{ab}$	11.20±0.19
IV	19-22	$11.27±0.18^{b}$	$11.28±0.23^{b}$	$11.58±0.21^{a}$	$11.14±0.09^{b}$	11.32±0.19
V	23-26	11.92±0.21	12.28±0.17	12.34±0.37	12.10±0.22	12.17±0.25
Cumulative EW (g)	7-26	$11.27±0.17^{b}$	$11.41±0.18^{ab}$	$11.64±0.22^{a}$	$11.39±0.13^{ab}$	11.43±0.17

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

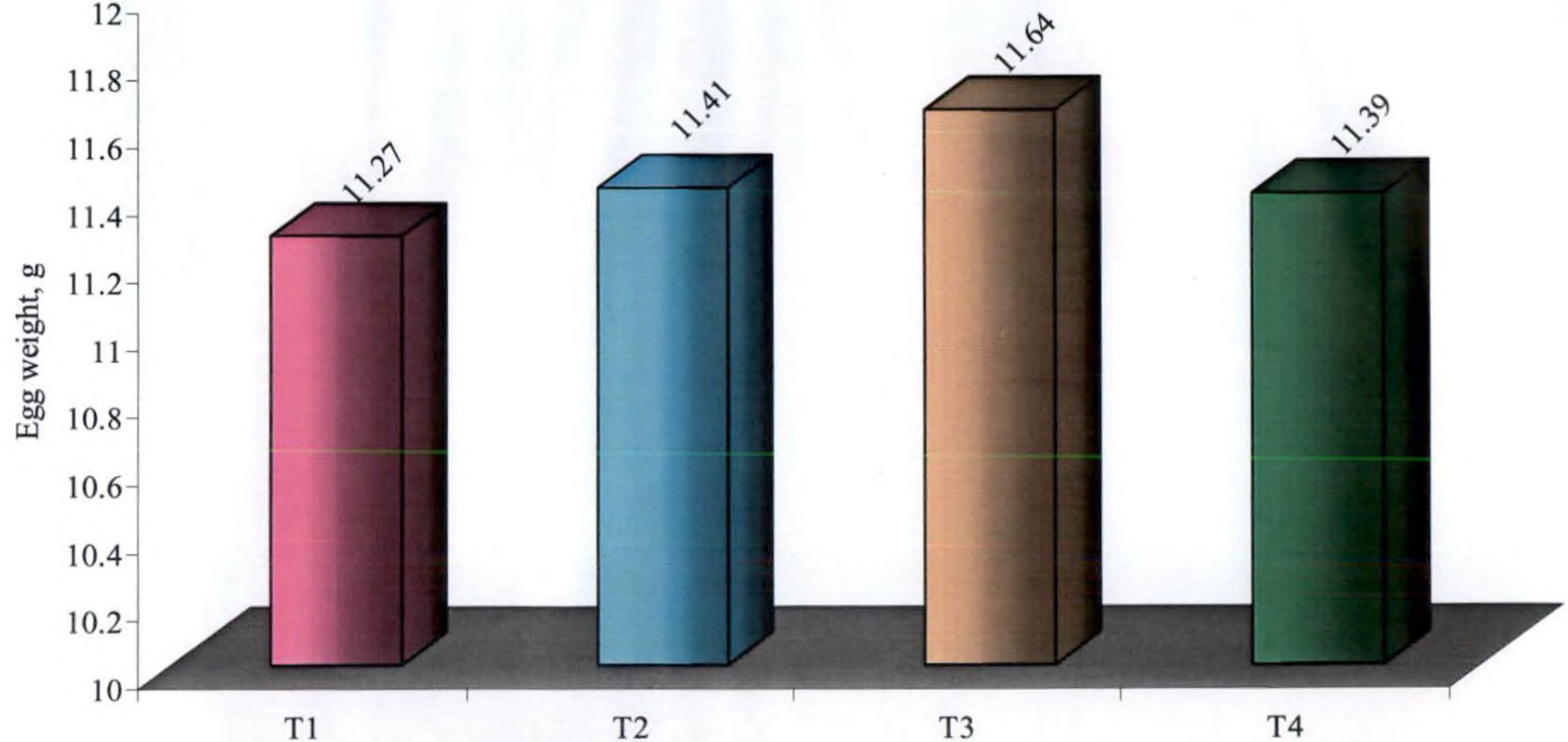

Fig. 3 Mean egg weight (g) of Japanese quails as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age

4.9 EGG QUALITY CHARACTERISTICS

The data on egg quality traits viz., shape index, albumen index, yolk index, shell thickness and IQU as influenced by inclusion of dried Azolla are presented in Tables 15,16, 17, 18 and 19, respectively.

4.9.1 Shape Index

The overall mean values for shape index of the eggs for the treatment groups T1, T2, T3 and T4 were 77.69, 76.45, 76.58 and 77.43, respectively. The mean shape index values of eggs obtained from quail layers fed with Azolla were numerically lower in all periods of experiment except the first period. The highest mean shape index value of 79.97 was noted with group T3 during the first period. The mean shape index values of the four treatment groups during the entire experimental period were statistically similar.

4.9.2 Albumen Index

The overall mean albumen index of the eggs belonging to T1, T2, T3 and T4 were 0.11, 0.13, 0.11 and 0.12, respectively. The mean albumen index for the treatment groups were statistically ($p<0.01$) different only in the third period of experiment, with highest value for T4 (0.12), lowest for T2 and T3 (0.10) and an intermediary value (0.11) with T1, which was comparable to other three treatments. The overall mean albumen index of the eggs of four treatments during the entire experimental period did not differ statistically ($P>0.05$).

4.9.3 Yolk Index.

The highest mean yolk index value of 0.50 was noted with the control group T1, on 10^{th} and 26^{th} week of age. The cumulative mean yolk index calculated for the treatments T1, T2, T3 and T4 were 0.48, 0.45, 0.45 and 0.44 respectively.

Statistical analysis of the mean yolk index values revealed that this trait was influenced in all the periods except third period and the cumulative mean from 10 to 26 weeks of age. The magnitude of difference between mean yolk index values showed that

Table 15. Mean (± S.E.) shape index of Japanese Quail eggs as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age

Period	Age in weeks	Shape index				Overall mean
		T_1 Azolla (0 %)	T_2 Azolla (1.5 %)	T_3 Azolla (3.0 %)	T_4 Azolla (4.5 %)	
I	10	78.03±0.20	78.24±0.39	79.97±0.42	78.20±0.87	77.86±0.14
II	14	78.45±0.12	76.36±0.98	77.54±0.67	77.85±0.41	77.55±0.69
III	18	78.68±0.12	76.57±0.95	77.53±0.71	78.04±0.31	77.70±0.68
IV	22	77.53±0.59	76.66±0.72	75.87±0.84	77.37±1.23	76.89±0.86
V	26	75.73±0.23	74.43±0.68	75.00±0.97	75.70±0.40	75.21±0.63
Cumulative mean	7-26	77.69±0.24	76.45±0.63	76.58±0.57	77.43±0.56	77.04±0.54

Non significant

Table 16. Mean (± S.E.) albumen index in Japanese Quail eggs as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age

Period	Age in weeks	Albumen index				Overall mean
		T_1 Azolla (0 %)	T_2 Azolla (1.5 %)	T_3 Azolla (3.0 %)	T_4 Azolla (4.5 %)	
I	10	0.11±0.05	0.13±0.05	0.12±0.01	0.13±0.05	0.12±0.01
II	14	0.11±0.05	0.10±0.05	0.10±0.05	0.11±0.05	0.10±0.05
III	18	0.11±0.05^{AB}	0.10±0.05^{B}	0.10±0.05^{B}	0.12±0.01^{A}	0.11±0.05
IV	22	0.11±0.01	0.10±0.05	0.10±0.05	0.11±0.05	0.10±0.05
V	26	0.10±0.05	0.10±0.05	0.10±0.05	0.10±0.05	0.10±0.05
Cumulative mean	7-26	0.11±0.05	0.13±0.04	0.11±0.05	0.12±0.04	0.11±0.05

Mean values bearing the same superscript within a row did not differ significantly ($P \leq 0.01$)

Table 17. Mean (± S.E.) yolk index in Japanese Quail eggs as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age

Period	Age in weeks	Yolk index				Overall mean
		T_1 Azolla (0 %)	T_2 Azolla (1.5 %)	T_3 Azolla (3.0 %)	T_4 Azolla (4.5 %)	
I	10	0.50 ± 0.01^{A}	0.46 ± 0.01^{AB}	0.43 ± 0.01^{B}	0.43 ± 0.01^{B}	0.46±0.01
II	14	0.46 ± 0.00^{ab}	0.43 ± 0.00^{b}	0.47 ± 0.01^{a}	0.44 ± 0.01^{ab}	0.45±0.01
III	18	0.46±0.00	0.44±0.00	0.44±0.01	0.46±0.01	0.45±0.01
IV	22	0.49 ± 0.01^{A}	0.49 ± 0.01^{A}	0.48 ± 0.01^{A}	0.43 ± 0.01^{B}	0.47±0.01
V	26	0.50 ± 0.01^{A}	0.45 ± 0.01^{AB}	0.43 ± 0.01^{B}	0.45 ± 0.11^{AB}	0.46±0.01
Cumulative mean	7-26	0.48 ± 0.08^{A}	0.45 ± 0.09^{B}	0.45 ± 0.06^{B}	0.44 ± 0.04^{B}	0.46±0.07

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

Mean values bearing the same superscript (A, B) within a row did not differ significantly ($P \leq 0.01$)

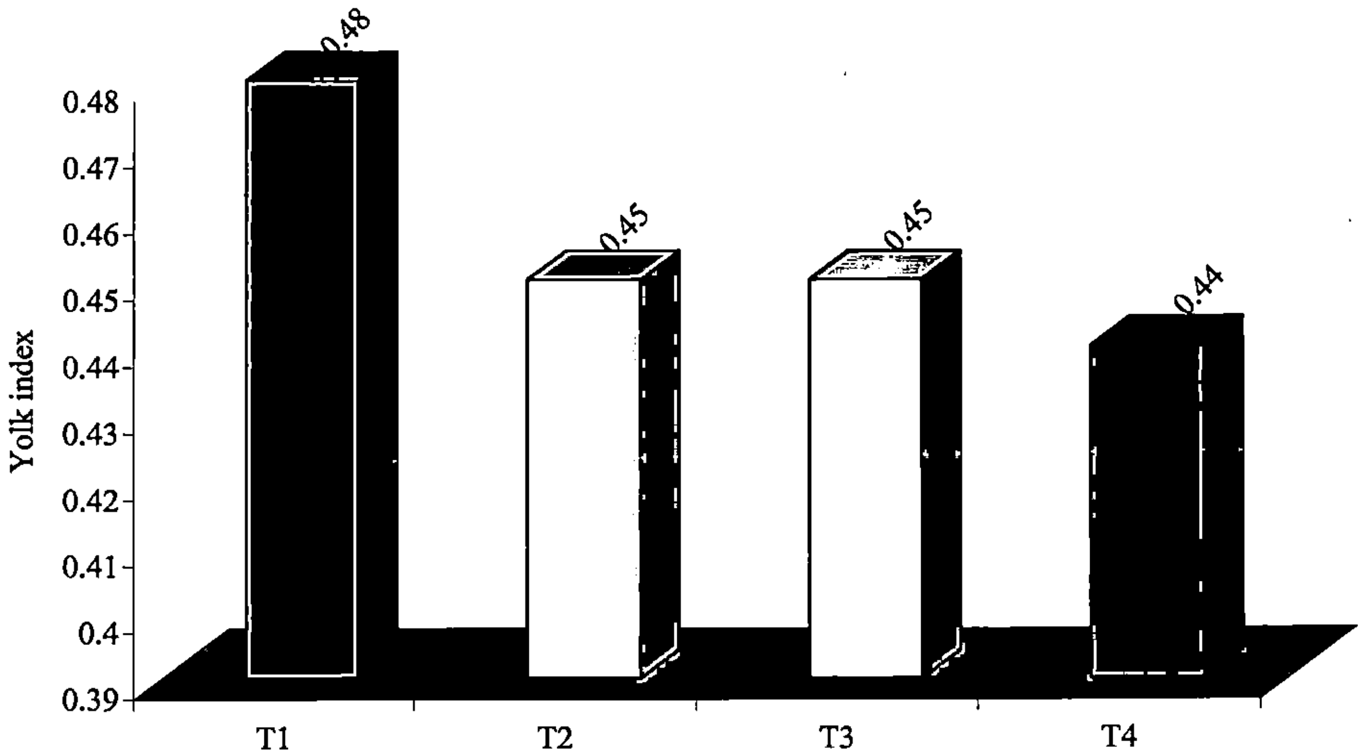

Fig.4 Mean yolk index of Japanese quail eggs as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age

Table 18. Mean (± S.E.) shell thickness (mm) in Japanese Quail eggs as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age

Period	Age in weeks	Shell thickness (mm)				Overall mean
		T_1 Azolla (0 %)	T_2 Azolla (1.5 %)	T_3 Azolla (3.0 %)	T_4 Azolla (4.5 %)	
I	10	0.16±0.05	0.16±0.05	0.16±0.01	0.17±0.01	0.16±0.05
II	14	0.19±0.05	0.19±0.04	0.19±0.04	0.19±0.04	0.19±0.05
III	18	0.19±0.05	0.19±0.05	0.19±0.05	0.19±0.05	0.19±0.05
IV	22	0.20±0.05	0.24±0.01	0.23±0.01	0.21±0.01	0.22±0.01
V	26	0.23±0.01	0.23±0.05	0.23±0.01	0.23±0.01	0.23±0.05
Cumulative mean	7-26	0.19±0.05	0.20±0.05	0.20±0.05	0.20±0.05	0.20±0.05

Non significant

Table 19. Mean (± S.E.) internal quality unit (IQU) in Japanese Quail eggs as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age

Period	Age in weeks	Internal Quality Unit (IQU)				Overall mean
		T_1 Azolla (0 %)	T_2 Azolla (1.5 %)	T_3 Azolla (3.0 %)	T_4 Azolla (4.5 %)	
I	10	60.92 ± 3.45^{A}	54.52 ± 2.85^{AB}	52.87 ± 1.74^{AB}	49.45 ± 1.04^{B}	54.44±3.07
II	14	78.68±0.12	76.57±0.95	77.53±0.71	78.04±0.31	77.70±0.68
III	18	60.11±1.07	54.83±2.50	55.55±2.24	58.48±2.61	57.24±2.05
IV	22	59.69 ± 3.49^{a}	57.18 ± 1.72^{a}	47.05 ± 3.08^{b}	59.86 ± 1.65^{a}	55.95±3.53
V	26	51.73±1.57	49.80±1.78	48.57±1.79	49.87±4.30	50.00±2.41
Cumulative mean	7-26	58.52±1.87	54.26±1.80	51.92±1.17	55.55±1.37	55.06±1.87

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

Mean values bearing the same superscript (A, B) within a row did not differ significantly ($P \leq 0.01$)

during periods 1, 4 and 5 and for the whole period taken together, the significance was at one per cent level, whereas during second period it was at five per cent level.

The cumulative mean yolk index was significantly ($P<0.01$) higher with the control birds fed standard quail layer diet and it was significantly different from other treatments. Both T2 and T3 noted with a middle value of 0.45 and T4 with a lower value of 0.44. As the level of Azolla increased, there was a linear decrease in the mean yolk index. But the values were comparable among Azolla treated groups.

The mean yolk index in eggs of Japanese quails as influenced by the dietary inclusion of dried Azolla from seven to twenty six weeks of age is graphically represented in Fig.4.

4.9.4 Shell Thickness

The mean egg shell thickness for the treatment groups T2, T3 and T4 was numerically higher (0.20 mm) compared to T1 (0.19). On statistical analysis, shell thickness did not differ significantly among different dietary treatments in the various periods as well as for the whole period. As the age advances there was a proportionate increase in mean egg shell thickness.

4.9.5 Internal Quality Unit (IQU)

In the control group, the IQU ranged from a minimum of 51.73 calculated on 26th week to a maximum of 78.68 observed on 14th week. In the group T2, the minimum IQU of 49.80 was found on 26th week while the maximum of 76.57 was observed on 14th week. In T3 and T4 groups, the lowest IQU were found on 22nd and 10th week of age, respectively, while the highest values were noted on 14th week in both the groups.

When the cumulative mean IQU was considered, the numerically highest value of 58.52 was noted with T1 followed by 55.55 for T4, 54.26 for T2 and 51.92 for T3 in that order.

Statistical analysis of the mean IQU of quail eggs revealed that this trait was not influenced by varying levels of dietary inclusion of Azolla except during 10th and 22nd weeks of age. The mean IQU of eggs laid by quails belonging to control group was significantly more ($P<0.01$), whereas it was low with T4 group at 10th week of age. T2 and T3 groups were statistically comparable with T1 and T4. At 22nd week of age IQU of eggs belonging to T1, T2, and T4 were significantly more ($P<0.05$) and comparable among themselves. It was significantly low with T3 group.

4.10 YOLK CAROTENOIDS

The mean yolk carotenoids of Japanese quail eggs as influenced by the dietary inclusion of dried Azolla is given in Table 20 and is graphically depicted in Fig.5.

Dietary inclusion of varying levels of dried Azolla resulted in an increase of yolk carotenoids. This increase was directly proportional to the level of Azolla added in the diet. An upward trend in yolk carotenoids level was noticed with the advancement of age in all the Azolla included diets. However in the control diet this increase was observed till the birds attained 18 weeks of age and thereafter a lower constant value was obtained.

The mean yolk carotenoids for all the periods taken together were 25.10, 35.68, 40.71 and 50.81µg/g of yolk, for the treatment groups T1, T2, T3 and T4, respectively. Statistical analysis of the data showed highly significant ($P<0.01$) differences among treatments with respect to yolk carotenoids during the entire experimental period.

The mean yolk carotenoids level was significantly higher ($P<0.01$) with the Azolla fed groups compared to control in all individual periods and for the whole experimental period taken together. Each incremental increase of Azolla in the rations resulted significant increase ($P<0.01$) in mean yolk carotenoids level. Therefore, the group T4, fed with 4.5 per cent Azolla in their diet had significantly maximum egg yolk carotenoids

Table 20. Mean (± S.E.) yolk carotenoids (µg/g) of Japanese Quails eggs as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age

Period	Age in weeks	Yolk carotenoids (µg/g)				Overall mean
		T_1 Azolla (0 %)	T_2 Azolla (1.5 %)	T_3 Azolla (3.0 %)	T_4 Azolla (4.5 %)	
I	10	23.43 ± 0.64^{D}	31.44 ± 0.78^{C}	35.25 ± 0.44^{B}	45.71 ± 0.66^{A}	33.95±8.17
II	14	25.76 ± 0.49^{D}	34.94 ± 0.50^{C}	39.18 ± 0.48^{B}	48.71 ± 0.62^{A}	37.15±8.40
III	18	26.00 ± 0.46^{D}	34.95 ± 0.31^{C}	41.53 ± 1.23^{B}	50.71 ± 0.39^{A}	38.30±9.01
IV	22	25.14 ± 0.42^{D}	37.37 ± 0.42^{C}	42.35 ± 0.43^{B}	52.43 ± 0.44^{A}	39.31±9.9
V	26	25.15 ± 0.67^{D}	39.75 ± 0.63^{C}	45.26 ± 0.88^{B}	57.41 ± 1.61^{A}	41.89±11.8
Mean	10-26	25.10 ± 0.09^{D}	35.68 ± 0.07^{C}	40.71 ± 0.14^{B}	50.81 ± 0.09^{A}	38.08±1.66

Mean values bearing the same superscript (A, B, C, D) within a row did not differ significantly ($P \leq 0.01$)

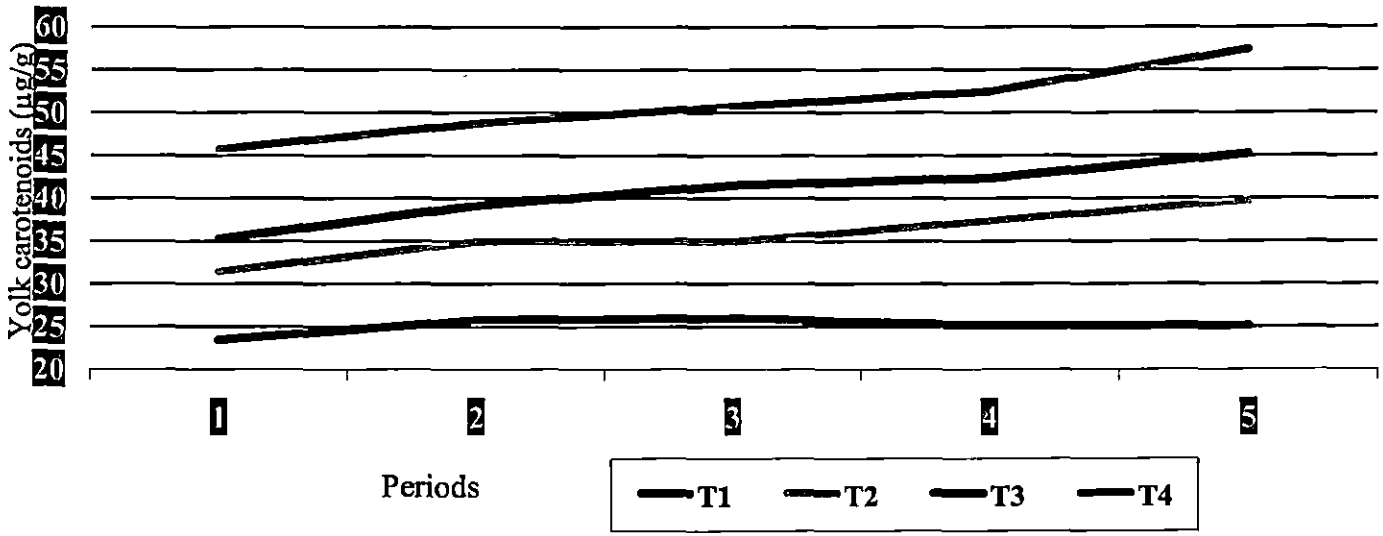

Fig.5 Mean yolk carotenoids (µg/g of yolk) of Japanese quail eggs as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age

level. The groups T2 and T3 had intermediary values and which were significantly different from each other.

4.11 PROCESSING YIELDS

The mean per cent weight of giblet, ovary and oviduct, dressed yield and ready-to-cook yield of Japanese quails as influenced by the dietary inclusion of dried Azolla are given in Table 21.

Mean giblet and ovary and oviduct weight were numerically higher for Azolla supplemented groups (T2, T3, and T4) compared to control birds fed standard quail layer diet (T1). The group fed with 1.5 per cent Azolla (T2) recorded numerically highest dressed yield (83.73 %) and the group fed with 4.5 per cent Azolla T4 recorded numerically highest ready- to- cook- yield (60.07 %). When the mean values of these traits were subjected to statistical analysis no significance could be observed.

4.12 SERUM PROFILES

The mean serum total cholesterol, creatinine, total protein and uric acid values of different dietary treatments are set out in Table 22 and serum total cholesterol is graphically represented in Fig 6.

The mean serum total cholesterol values showed a linear decrease with level dependent increase in Azolla supplementation in quail layer diet. Statistical interpretation also confirmed this trend. Mean serum total cholesterol was significantly ($P<0.01$) higher with the group T1 (167.92 mg %) and was statistically comparable with T2 (147.79 mg %). Even though, the total serum cholesterol was significantly lower in group T3 (140.35 mg %), there was no significant difference between T2 and T3. The group T4, in which 4.5 per cent Azolla was included in the diet, exhibited the lowest ($P<0.01$) serum total cholesterol value (113.99 mg %), which was statistically different from other treatments.

Table 21. Mean (± S.E.) per cent weight of giblet, ovary and oviduct, dressed yield, and R-to-C yield of Japanese Quails as influenced by dietary inclusion of dried Azolla from 7to 26 weeks of age

Parameters (%)	Treatments				Overall mean
	T_1 Azolla (0 %)	T_2 Azolla (1.5 %)	T_3 Azolla (3.0 %)	T_4 Azolla (4.5 %)	
Giblet	4.60±0.18	4.65±0.14	4.80±0.18	4.75±0.24	4.70±0.09
Ovary and oviduct	5.08±0.39	5.10±0.22	5.25±0.37	5.91±0.83	5.32±0.25
Dressed yield (without skin)	83.09±0.65	83.73±0.80	81.57±0.88	83.63±0.91	83.00±0.42
R-to-C yield (without skin)	58.07±0.80	59.71±0.99	57.99±0.46	60.07±0.88	59.11±0.46

Non significant

Table 22. Mean (± S.E.) serum total cholesterol (mg %), serum creatinine (mg/dl), serum total protein (g/dl) and serum uric acid (mg/dl) of Japanese Quails as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age

Serum parameters	Treatments				Overall mean
	T_1 Azolla (0 %)	T_2 Azolla (1.5 %)	T_3 Azolla (3.0 %)	T_4 Azolla (4.5 %)	
Total cholesterol (mg%)	167.92±5.95^{A}	147.79±1.23^{AB}	140.35±9.25^{B}	113.99±1.15^{C}	142.51±4.36
Creatinine (mg/dl)	0.37±0.05	0.28±0.14	0.38±0.23	0.43±0.04	0.36±0.14
Total protein (g/dl)	3.29±0.37	2.97±0.18	3.37±0.28	3.02±0.20	3.17±0.13
Uric acid (mg/dl)	3.10±0.11	3.27±0.06	3.31±0.04	3.27±0.04	3.24±0.04

Mean values bearing the same superscript (A, B, C) within a row did not differ significantly ($P \leq 0.01$)

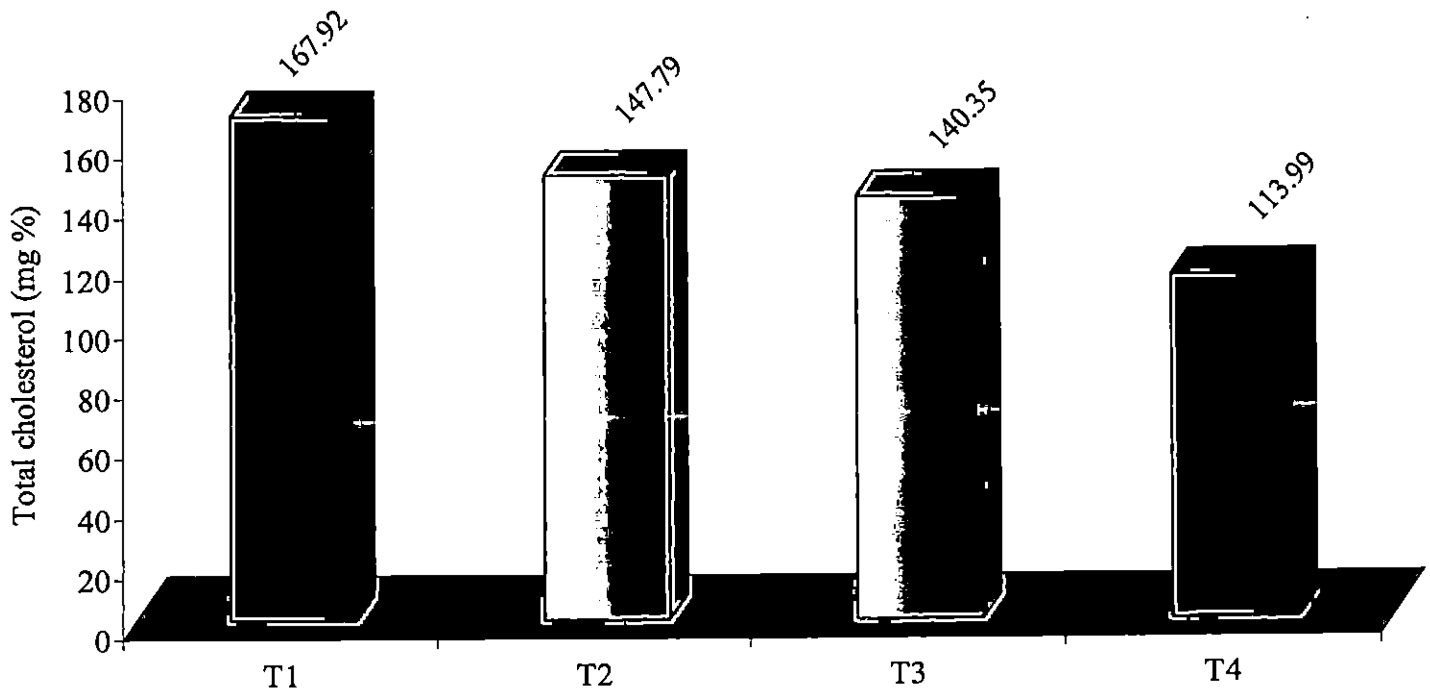

Fig. 6 Mean serum total cholesterol level in Japanese quails as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age

On the other hand, no definite trend could be drawn in the serum creatinine and total protein values due to dietary inclusion of dried Azolla in quail layer diet. However, Azolla supplementation resulted in numerical increase of serum uric acid. Statistical analysis indicated that serum creatinine, total protein and uric acid were not influenced due to Azolla inclusion in quail layer diet.

4.13 LIVABILITY

The mean livability percentage of Japanese quails from seven to twenty six weeks of age, as influenced by dietary inclusion of Azolla are presented in Table 23.

Livability was comparatively better in Azolla fed groups compared with control group fed standard layer diet (T1). Only a total of 10 birds died within the twenty weeks experimental period.

4.14 ECONOMICS

The economics of egg production (margin over feed cost) in Japanese quails as influenced by inclusion of dried Azolla are presented in Table 24.

The economics worked out for different dietary treatments indicated that feed cost for the production of one egg accounts to 31.54, 32.14, 33.17 and 31.19 paise for the treatments viz., T1, T2, T3 and T4, respectively. This revealed that the cost of feed per egg was lowest in the treatment group fed with 4.5 per cent Azolla followed by T1 (control), T2 (1.5 % Azolla) and T3 (3 % Azolla). The margin of return over feed cost per egg was found to be 38.46, 37.86, 36.84 and 38.61 paise for the treatments viz., T1, T2, T3 and T4, respectively. The corresponding values for returns over feed cost per quail housed were found to be 43.91, 44.95, 40.35 and 45.54 rupees, respectively. This indicated that inclusion of dried Azolla in quail layer diet, up to 4.5 per cent is beneficial from the economic point of view.

Table 23. Period wise mean livability per cent as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age

Periods	Age in weeks	Livability (%)				Overall mean
		T_1 Azolla (0 %)	T_2 Azolla (1.5 %)	T_3 Azolla (3.0 %)	T_4 Azolla (4.5 %)	
I	7-10	100.00	100.00	100.00	100.00	100.00
II	11-14	100.00	97.92	97.92	100.00	98.96
III	15-18	95.83	100.00	100.00	100.00	98.96
IV	19-22	95.84	97.92	95.83	97.92	96.88
V	23-26	100.00	100.00	100.00	100.00	100.00
Cumulative mean	7-26	91.67	95.83	93.75	97.92	94.79

Non significant

Table 24. Economics of egg production over feed cost of Japanese Quails as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age

Sl. No:	Particulars	Dietary inclusion of dried Azolla in experimental diets (%)			
		T_1 0	T_2 1.5	T_3 3.0	T_4 4.5
1	Total feed intake (kg)	185.46	198.60	191.00	198.16
2	Total number of eggs	5480	5698	5258	5662
3	Feed cost / kg *(Rs.)	9.32	9.22	9.13	8.97
4	Margin of return over feed cost** (Rs.)	2107.51	2157.51	1936.77	2185.91
5	Feed cost / egg (paise)	31.54	32.14	33.17	31.39
6	Margin of return over feed cost / egg (paise)	38.46	37.86	36.84	38.61
7	Margin of returns over feed cost / Quails housed (Rs.)	43.91	44.95	40.35	45.54

*cost of Azolla excluded

* * Egg cost – 70 paise per egg

Discussion

5. DISCUSSION

The results obtained from the study to find out the effect of inclusion of dried Azolla in Japanese quail layer ration on the production performance are discussed in this chapter.

5.1 METEOROLOGICAL OBSERVATIONS

Mean maximum and minimum temperature and per cent R.H. inside the experimental house during the period from January to June 2006 presented in Table 3 revealed that the maximum temperature inside the experimental house increased significantly ($P \leq 0.05$) during the second period and continued high during the third period indicating that the experimental quails were subjected to a high ambient temperature during the period from 11 to 22 weeks of age. 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 those reported by Somanathan *et al.* (1980). He got a maximum temperature ranging from 31.14 to 35.14°C at Mannuthy region during the period from January to June.

Minimum temperature of 22.91 in period I and 23.59°C in period II were significantly ($P \leq 0.05$) lower than that in all other periods and was almost in the comfortable zone for poultry. It was significantly ($P \leq 0.05$) higher in IVth period and was intermediate in period III.

The forenoon relative humidity (R.H.) of period I (70.79 %) showed significant ($P \leq 0.05$) increase of 7.1 per cent in period II and 7.47 per cent in period III. The R.H. (F.N.) continued high in the IVth period and was significantly ($P \leq 0.05$)

increased by 6.71 per cent during the V^{th} period and thereby the humid environment existed throughout the experimental period. The R.H. in the afternoon also showed *significant* ($P \leq 0.05$) *increase until period IV and continued high during period V.* It was 53.25 per cent in period I and showed 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. So the entire experiment was carried out during hot and humid environment.

5.2 NUTRITIVE VALUE OF AZOLLA

Chemical analysis of Azolla presented in Table 4 indicated that it contained 23.14 per cent CP, 3.50 per cent EE, 12.20 per cent CF, 43.66 per cent NFE, 17.50 per cent ash, 2.29 per cent calcium and 0.39 per cent phosphorus on dry matter basis. The metabolisable energy content of Azolla was calculated as 1807 kcal/kg. Fresh Azolla contained 94.75 per cent moisture. This high volume of water limits the amount able to be consumed by poultry and therefore, significantly reduces the amount of effective nutrient intake. Drying reduced the volume of Azolla considerably and concentrated the nutrients (Haustein *et al.*, 1990). Therefore, the present experiment was conducted with dried Azolla.

The crude protein content of Azolla determined in the present study (23.14 %) was in close agreement with the results of Buckingham *et al.* (1978), Subudhi and Singh (1978), Parthasarathy *et al.* (2001a), Basak *et al.* (2002) and Alalade and Iyayi (2006) who reported the crude protein content of Azolla meal in the range of 21.4 to 25.78 per cent. On the other hand, Sanginga and Van Hove (1989), Becerra *et al.* (1995b) and Khatun *et al.* (1999) observed higher CP content in Azolla meal (26.7 to 28 %). Contrary to this, Ali and Leeson (1995) and Ardakani *et al.* (1996) could obtained only a lower CP content of 16.5 to 17.67 per cent in Azolla meal.

The 12.20 per cent CF obtained in the present study was in line with the findings of Ali and Leeson (1995), Khatun *et al.* (1999) and Alalade and Iyayi (2006). However, Ardakani *et al.* (1996) reported a higher crude fiber content of 21.5 per cent in Azolla.

The result of EE content of Azolla was almost similar with the earlier observations of Subudhi and Singh (1978), and Basak *et al.* (2002). But Buchingham *et al.* (1978) and Becerra *et al.* (1995b) reported a higher value (5.05 and 4.6 %, respectively). Ali and Leeson (1995), Ardakani *et al.* (1996) and Alalade and Iyayi (2006) got lower values for EE than obtained in the present study.

The ash content of Azolla obtained in this experiment was 17.5 per cent. Ali and Leeson (1995) reported a very high value of 36.12 per cent ash in Azolla. However, Buckingham *et al.* (1978), Parthasarathy *et al.* (2001b), Basak *et al.* (2002) and Alalade and Iyayi (2006) recorded values almost similar to present study.

The NFE content of 43.66 per cent recorded in this study was consistent with the report of Parthasarathy *et al.* (2001b) who reported the NFE range of 38.85 to 44.06 per cent in Azolla.

The level of calcium and phosphorus was found to be 2.29 and 0.39 per cent, respectively. On screening the literature, it was observed that the calcium and phosphorus content of Azolla vary widely among various studies. The calcium level of Azolla obtained in this study was close to the report of Parthasarathy *et al.* (2001b) who indicated that *Azolla microphylla* contained 2.11 per cent calcium. Similarly, Ali and Leeson (1995) found 0.31 per cent phosphorus in Azolla, which was nearer to the result of the present study.

The variations in the nutrient composition of Azolla meal in different studies can be attributed to differences in the response of Azolla strains to environmental conditions such as temperature, light intensity and soil nutrients which consequently affect their growth morphology and composition. Moreover, species difference of Azolla could alter their nutrient composition. Furthermore, contamination with epiphytic algae could also be important to such a degree as to affect the results of chemical composition (Sanginga and Van Hove, 1989).

The present results confirm previous observation that Azolla was rich in proteins and minerals and that it could be used as a feed ingredient in poultry diets (Lizama *et al.*, 1988).

5.3 BODY WEIGHT

Mean body weight of Japanese quails at six weeks of age (Table 5) indicated that the birds utilised for the study were of uniform body weight. Perusal of the data on mean body weight at twenty six weeks of age also showed that there was not much variation among the treatment groups.

The average gain in body weight were 37.74, 37.27, 35.51 and 36.74 g on 0, 1.5, 3.0 and 4.5 per cent Azolla fed treatments, respectively. Though the control group gained numerically more weight than the Azolla supplemented groups, the range of gain was from 0.47 to 2.23 g and it was non significant. This indicated that supplementation of Azolla at 4.5 per cent level in ration did not have any influence on body weight and body weight gain in layer quails. This result is in agreement with the findings of Parthasarathy *et al.* (2002) who reported that broiler birds supplemented with 5 per cent Azolla replacing 2.6 per cent wheat bran and 2.4 per cent fish meal gained more or less similar body weight of control at 8 weeks of age.

However, he could observe a reduction in live weight gain when Azolla was supplemented from 10 to 20 per cent levels. Similarly, Alalade and Iyayi (2006) also reported non significant difference in weight gain of chicks fed with Azolla meal at levels of 0, 5, 10 and 15 per cent. However, Basak *et al.* (2002) observed significant improvement in weight gain for broiler chicks fed with 5 pr cent Azolla. The inclusion of Azolla at higher levels limited the efficient utilization by monogastric animals as it contained ADF and lignin as indicated by Buckingham *et al.* (1978).

The results of this study revealed that feeding of dried Azolla up to 4.5 per cent level did not have any adverse effect on body weight of Japanese quails.

5.4 AGE AT FIRST EGG, 10 AND 50 PER CENT PRODUCTION

The data on mean age at first egg presented in Table 6 indicated that birds in all treatment groups attained sexual maturity at the same age of 42 days. Quails fed with 1.5 and 3.0 per cent Azolla attained 10 per cent production one day later (44 days) than control birds (43 days). However, in the group offered 4.5 per cent Azolla, 10 per cent production was noted on 43rd day itself. The variation was only negligible and could not be considered as the treatment effect since the birds were fed with the experimental ration few days back. The data on mean age at 50 per cent production (Table 6) showed that Azolla supplemented groups reached this stage one day later (48 days) than control birds (47 days).

While reviewing the literature, no work could be traced to corroborate this finding. However, it can be certainly stated that the levels of Azolla tested in this study did not affect the various physiological functions in quails since 5 to 6 days feeding is enough to alter their reproductive performance.

5.5 FEED CONSUMPTION

The mean daily feed intake of birds in different treatments showed no significant difference in the entire experimental period except in the first period of 7 to 10 weeks of age (Table 7), during which period control birds (T1) consumed significantly ($P<0.05$) less feed than Azolla fed birds. It was statistically comparable among groups T2, T3 and T4. In general, feed intake was numerically more in Azolla fed groups in all the periods except third period. Similarly, the mean feed intake showed a numerical increase from first to fifth period in most of the treatment groups with certain exceptions. During the entire experimental period of seven to twenty six weeks of age, treatment T3 i.e. birds fed with 3.0 per cent Azolla, recorded numerically highest feed intake of 34.84 g per bird per day in the fourth period. It was coincided with the highest QDN and QD per cent in this group compared with other treatments. During this period QDN increased from 26.00 in the third period to 26.88 in the fourth period, which was the highest egg production recorded among treatments during the course of the experiment.

When the whole experimental period of 7 to 26 weeks of age was considered, the cumulative mean feed intake per bird per day was 28.35, 29.96, 30.05 and 29.70 g for treatments T1, T2, T3 and T4, respectively. The Azolla supplemented groups T2, T3 and T4 consumed 1.61, 1.70 and 1.35 g more feed, respectively than the control birds. Eventhough a numerical increase in feed intake was noticed with Azolla inclusion, statistical analysis revealed no significant difference among treatments. It is also imperative that much variation did not exist between Azolla fed groups. The numerical increase in feed intake in Azolla fed groups might be due to increase in egg production and or egg weight compared with control fed birds (Tables 10, 11, 12, 13 and 14). Difference in feed intake with changes in dietary ingredients as supported by Isshiki and Nakahiro (1989) could be the other possibility for the numerical increase in daily feed intake with Azolla fed groups. They stated that passage rate and feed intake changed based on type of feed ingredients used in formulating the diets. As the diet became finer, its rate of passage through gut increased with resultant enhancement in feed intake (Agwunobi 1999).

Absence of any significant influence on feed intake due to Azolla supplementation in layer quails as observed in this study is in agreement with the findings of Ali and Leeson (1995), Sarria and Preston (1995) and Basak *et al.* (2002). They could not observe any significant difference in feed intake between Azolla fed and control fed broiler chicken. On the other hand, Parthasarathy *et al.* (2001b) reported that feed intake was decreased when Azolla was increased from 0 to 15 per cent, but slight increase in feed intake at 20 per cent level. Similarly, Alalade and Iyayi (2006) observed that 10 and 15 per cent Azolla meal in the diet of chicks significantly reduced the average weekly feed intake. But average weekly feed intake were similar to control diet fed birds when they were fed with 5 per cent Azolla meal. Hence it can be conclusively stated that Azolla meal in quail layer ration up to 4.5 per cent does not have any influence on feed intake.

5.6 FEED CONVERSION RATIO (FCR)

The mean feed conversion efficiency calculated based on both per dozen eggs and per kg egg mass of layer quails as influenced by dietary inclusion of dried Azolla from 7 to 26 weeks of age presented in Tables 8 and 9, respectively indicated that significant differences existed among the treatments only during the initial period of experiment (7 to 10 weeks of age). In the other periods as well as for the whole experimental period the mean values were statistically comparable.

During the 7 to 10 weeks period mean FCR based on per dozen eggs were 0.34, 0.42, 0.51 and 0.44 for the groups T1, T2, T3 and T4, respectively. It was significantly superior (P<0.05) with the control group and poor for T3 and T4. Group T2 showed an intermittent value, which was statistically comparable to all other treatments. Similarly, FCR expressed as kg of feed per kg egg mass was superior (P<0.05) with T1 (2.66) and inferior with T3 and T4 (3.79 and 3.43, respectively) during 7 to 10 weeks of age. The mean value calculated for T2 (3.30) was statistically comparable among the other groups. Comparatively poor feed efficiency noted during the first period was due to the lower egg production as the birds were in the start of laying. However, in the subsequent periods the feed efficiency was within acceptable limits.

In the control group, kg of feed per dozen eggs was lowest in the first period (0.34) and highest in the last period (0.45), which indicated that superior values were noted in the initial period. Whereas in group T2 (1.5 % Azolla fed group) the range in FCR was from 0.39 noted during the second period to 0.45 observed in the last period. In 3.0 per cent Azolla fed group (T3), best FCR of 0.40 was recorded during the third period (15 to 18 weeks of age) while poorest value (0.51) was in the first period. In birds supplemented with 4.5 per cent Azolla, superior FCR of 0.39 was observed during 11 to 14 weeks and 15 to 18 weeks of age, whereas higher value of 0.47 was noted during the last period. While considering the five periods of study, it could be seen that the best FCR of 0.34 was noted with control group, while the highest (0.51) was with group T3.

The cumulative FCR (per dozen eggs) from 7 to 26 weeks for the treatments T1, T2, T3 and T4 were 0.41, 0.42, 0.45 and 0.43, respectively. Eventhoug this trait was statistically non significant, best value was recorded in the control group, while higher value was with T3. As compared to control group, the cumulative FCR was highest to a tune of 0.01, 0.04, and 0.02 in T2, T3 and T4, respectively. It revealed that the difference between the mean values of various treatments are negligible.

On perusal of the FCR calculated on egg mass basis (Table 9) it was observed that lowest value of 2.66 was noted with control group (T1) during 7 to 10 weeks of age, similar to FCR calculated on per dozen egg basis. While, the higher value of 3.98 was noted with birds fed with 1.5 per cent Azolla during 11 to 14 weeks of age. Cumulative means for 7 to 26 weeks of age for T1, T2, T3 and T4 were 3.02, 3.11, 3.23 and 3.12, respectively. In 1.5 per cent Azolla fed group 0.09 kg more feed was required to produce 1 kg eggs than the control birds, whereas the values with 3.0 and 4.5 per cent Azolla fed birds were 0.21 and 0.10 kg, respectively.

In general, better FCR values were obtained during 11 to 14 and 15 to 18 weeks of age. Comparatively better egg production coupled with lower feed intake noted in these periods might have contributed for this trend.

Similar results were reported by Parthasarathy *et al.* (2002). According to him, feed and protein efficiency ratio in broilers were in the same order as in basal and 5 per cent Azolla diets, replacing 2.6 per cent wheat bran and 2.4 per cent fish meal. On the other hand, Ardakani *et al.* (1996) also observed better FCR in broiler birds fed with 6 per cent fresh Azolla compared to control birds. However, Khatun *et al.* (1999) observed that FCR reduced significantly when laying hens were fed with Azolla diets formulated on a total protein and total amino acid basis. Reports of Basak *et al.* (2002) and Parthasarathy *et al.* (2002) also indicated that higher levels of Azolla (10 to 20 %) significantly reduced FCR in broiler chicken.

From this experiment it is clear that the dried Azolla could be used in laying quail ration without affecting FCR per dozen eggs and FCR per kg egg mass.

5.7 EGG PRODUCTION

The mean quail housed egg production (eggs per bird and per cent) of Japanese quails as influenced by the dietary inclusion of dried Azolla from seven to twenty six weeks of age presented in Tables 10 and 11, respectively indicated that layer quails fed with 1.5 per cent Azolla (T2) and 4.5 per cent Azolla (T4) recorded numerically highest quail housed number and per cent in all the five periods compared to control diet fed birds with slight variation in first and fifth period for T4. Quails in group T3 showed lower quail housed number and per cent during the entire experimental period with the exception in third period. Overall mean at the end of the experiment was also higher for T2 and T4 than the values for control, indicating positive effect of Azolla in this trait. On perusal of the cumulative quail housed egg number and per cent as influenced by Azolla supplementation showed that the diet containing 1.5 per cent Azolla meal was best in respect of quail housed number and per cent (120.00 and 85.71, respectively), while 4.5 per cent Azolla fed group was second the best (119.24 and 85.16, respectively), followed by T1 (117.32 and 83.31, respectively) and T3 (112.18 and 80.13, respectively). During the course of the study, Azolla inclusion in quail layer diets at 1.5 and 4.5 per cent level resulted in an increase of 2.68 and 1.92 eggs and 2.40 and 1.85 per cent eggs when calculated based on quail housed number and per cent, respectively as compared to control birds. However 3 per cent Azolla inclusion resulted in a reduction of 5.14 eggs or 3.18 per cent from that of control.

The peak in egg production in this study was recorded during 15 to 18 weeks of age in all the treatments. In a span of 28 days quails fed with standard layer ration (T1) laid 26.04 eggs. Those fed a ration containing 1.5 per cent Azolla laid 26.94 eggs, whereas 3.0 per cent Azolla fed groups laid 26.28 eggs. A maximum number of 27.25 eggs was recorded with quails fed a ration supplemented with 4.5 per cent Azolla. The difference in mean QHN between 1.5 and 4.5 per cent Azolla fed groups was only 0.76, that is below one egg. Mean QHN given in Table 10 also indicated that supplementation of Azolla at 1.5 and 4.5 per cent level resulted in production of 2.68 and 2.40 more eggs, respectively than those fed a standard diet.

The mean quail day egg production (eggs per bird and per cent) of Japanese quails as influenced by the dietary inclusion of dried Azolla from seven to twenty six weeks of age presented in Tables 12 and 13, respectively indicated comparatively similar trends to that of quail housed number and per cent.

The mean QDN from 7 to 26 weeks of age was 118.61, 120.38, 115.32 and 119.34 and QDP was 83.73, 85.98, 80.83 and 85.23 for T1, T2, T3 and T4, respectively. While comparing the egg production based on active birds alive during the study period, an edge in egg production was observed with 1.5 and 4.5 per cent Azolla supplemented groups over the control birds. In comparison to control birds 1.77 and 0.73 more eggs were laid by 1.5 and 4.5 per cent Azolla fed groups, respectively. The corresponding figures with QD per cent was 2.25 and 1.50. The difference between 1.5 and 4.5 per cent Azolla fed quails were only 1.04 eggs and 0.75 per cent. Here also birds offered a diet having 3 per cent Azolla laid less number of eggs than the control birds.

Statistical analysis of the data on quail housed egg number and per cent and quail day number and per cent revealed no significant difference among treatment groups.

Any adverse effect of Azolla feeding to quails were not reflected in the overall egg production which was found comparable among the different dietary groups as has been reported by earlier workers with hens. Singh and Subudhi (1978) reported that the number of eggs per week was more in the treatment of 100 per cent feed plus 5 per cent Azolla. They also stated that egg production in the treatment of 75 per cent feed plus 12.5 per cent Azolla was identical to the control.

Likewise, Khatun *et al.* (1999) reported that the hen day egg production improved in birds fed with 50, 100, 150 and 200 g Azolla meal /kg feed using digestible protein and digestible amino acid over the control diet and the diet with 50, 100, 150 and 200 g Azolla meal /kg feed using total protein and total amino acid basis. Islam (2002) also studied inclusion of other aquatic plants in the diet of layers and reported comparable egg production in all the treatments. On the other hand Bratova and Ganovski (1983), Agwunobi (1999) and Khang and Ogole (2004b) reported improvement in egg production consequent to supplementation of algal meal, water yam and duckweed meal, respectively in laying hens.

Numerical increase in egg production with substitution of Azolla meal in quail layer diet despite the isocaloric and iso nitrogenous nature of the diets suggest that some nutrients present in Azolla might have supported higher egg production. Report of Becerra *et al.* (1995b) also supports this theory. They could not observe any difference in performance of meat type ducks received diets containing Azolla without added supplements of vitamins and minerals compared with control diet. Besides provitamin A activity, there is some evidence that oxycarotenoids (present in Azolla) might have a stimulatory effect on egg production in hens (Guenthner *et al.*, 1973 and Karunajeewa, 1978). The lowest egg production in 3.0 per cent Azolla fed birds in this study might be due to increased egg weight in this group (Table14).

The results of the study clearly indicated that dried Azolla could be advocated without compromising egg production in Japanese quails up to 4.5 per cent level.

5.8 EGG WEIGHT

Perusal of the mean egg weight of different dietary treatments during the course of the experiment presented in Table 14 revealed higher values for the birds fed with different levels of Azolla in all the five periods with slight variation in the second and fourth periods. The mean egg weight values were statistically significant ($P \leq 0.05$) at second, third and fourth periods. In the second period (11 to 14 weeks of age) the mean egg weight was statistically more ($P<0.05$) with the group fed with 3 per cent Azolla, while it was less ($P<0.05$) with control group (T1) and those fed with 1.5 per cent Azolla (T2). Those fed with 4.5 per cent Azolla showed an intermittent value and was comparable with other groups. During 15 to 18 weeks of age all the Azolla supplemented groups laid heavier eggs than the control birds. However, the egg weight of T1 and T4 was statistically similar. The egg weight recorded during the fourth period from 19 to 22 weeks of age was heavier ($P<0.05$) with 3 per cent Azolla fed groups and was statistically different from all other groups. The mean egg weight in all the treatments during the first period was higher than that of second, third and fourth periods, that is from 11 to 22 weeks of age. However, during 23 to 26 weeks of age birds in all the treatments laid heavier eggs than those in the first period. It can be attributed to the variation in maximum temperature which was 34.73^{0}C in the first period and shown an increase in trend in the second, third and fourth period compared to first period (Table 4). It supports the statement that as ambient temperature increases egg size decreases (North and Bell, 1990).

The mean cumulative egg weight from 10 to 26 weeks of age for T1, T2, T3 and T4 were 11.27, 11.41, 11.64 and 11.39 g, respectively. It was numerically more with the group fed with 3 per cent Azolla followed by those fed with 1.5 per cent Azolla, 4.5 per cent Azolla and lastly the control group.

While analysing the egg weight data a striking difference could be noted with Azolla supplemented groups. Layer quails fed a diet containing 3 per cent Azolla laid heavier eggs to the extend of 0.37 g than control birds. Likewise, those fed with 1.5 and 4.5 per cent Azolla laid heavier eggs to a tune of 0.14, and 0.12 g, respectively than control birds.

The statistical analysis of the mean cumulative egg weight showed that birds fed with 3 per cent Azolla laid significantly heavier eggs whereas those of control birds was significantly lower ($P<0.05$). Egg weight of groups supplemented with 1.5 and 4.5 per cent Azolla were medium and was statistically comparable with both T3 and T1.

The results obtained in this study were similar to the earlier observations of Khatun *et al.* (1999) who reported that feeding Azolla meal on a digestible protein and digestible amino acid basis resulted in heavier egg weight.

Morris and Gour (1988) reported that feeding of birds with ration containing critical amino acids in balanced proportion resulted in heavier egg weight. Sarria and Preston (1995) opined that Azolla contained superior balance of critical amino acids and Lejune *et al.* (2000) stated that Azolla meal was a rich source of minerals and vitamins especially carotene, precursor of vitamin A. Therefore, it can be stated that the improved egg size noted for diets formulated on Azolla meal might be due to better critical amino acid balance (Khatun *et al.*, 1999). It was also supported by the findings of Haustein *et al.* (1990) who reported that protein content increased significantly ($P<0.001$) both in the albumen (84.75 and 86.10 per cent) and in the yolk (16.28 and 17.24 per cent) when the layers were fed with 15 or 25 per cent lemna, an aquatic plant, respectively compared with the protein content of eggs from hens fed the control diet (84.30 and 15.64 per cent). In addition, the higher linoleic acid, an essential fatty acid necessary for higher egg weight present in aquatic plants as stated by Lipstein *et al.* (1980) could also be a contributing factor for heavier eggs laid by Azolla treated groups.

This finding confirms that inclusion of dried Azolla in the diet of Japanese quail layers are advantageous with respect to the most important economic traits, egg number and egg weight.

5.9 EGG QUALITY TRAITS

The egg quality characteristics including internal quality traits viz., shape index, albumen index, yolk index, shell thickness and internal quality units (IQU), as influenced by dietary inclusion of varying levels of dried Azolla were evaluated and are presented in Tables 15, 16, 17, 18 and 19, respectively.

The overall mean shape index of eggs of different treatments indicated that substantial variation did not exist between treatments. Numerically higher value (77.69) was noted with eggs of control birds, followed by those fed with 4.5 per cent Azolla, 3.0 per cent Azolla and 1.5 per cent Azolla in descending order. The variation in shape index values in the Azolla fed groups from that of standard quail layer fed birds were in the range from 0.26 noted with 4.5 per cent Azolla fed birds (T4) to 1.24 observed in 1.5 per cent fed group (T2). As the difference in mean shape index values between standard quail layer and Azolla fed groups is meagre, it suggest that Azolla supplementation in quail layer diet does not have any tangible influence.

The mean albumen indices of T1, T2, T3 and T4 were 0.11, 0.13, 0.11 and 0.12, respectively. Eventhough the statistical analysis failed to reveal any significance, numerically better index was observed in Azolla fed groups T2 and T4, which could be attributed to better height of albumen in these groups. Better albumen height due to increase in viscosity as a result of higher ovomucin content was reported by Leeson and Summers (2001).

The mean yolk index of quail eggs as influenced by dietary supplementation of dried Azolla given in Table 17 indicated that the values with Azolla fed groups were lower compared to standard quail layer fed group in all the five periods except period III. The range in yolk index values with birds fed control diet was from 0.46 to 0.50. In Azolla supplemented groups, the range was from 0.43 to 0.49 for 1.5 per cent level inclusion, 0.43 to 0.48 for 3 per cent level inclusion and 0.43 to 0.46 for 4.5 per cent level inclusion. The cumulative mean yolk indices from 7 to 26 weeks of age were 0.48, 0.45, 0.45 and 0.44 for the groups T1, T2, T3 and T4, respectively. Statistical analysis of the data revealed significant differences in all the five periods except period III and in the cumulative yolk index values. The cumulative mean was significantly ($P<0.01$) higher with the eggs of control birds and lower for all Azolla fed birds. The yolk index values of different levels of Azolla fed birds were statistically similar. As yolk index is a reflection of the height and diameter substantial variation in any one of these could have contributed for the lower values in Azolla supplementd quails. A close scrutiny revealed that yolk diameter of Azolla fed birds were more than the control in all the periods with similar yolk height for both control and treatment groups. Increased egg weight recorded with all the Azolla supplemented groups might have contributed for the increased yolk diameter values in these groups. In general, the yolk indices of all the treatment groups were of within the standards (0.4 to 0.5) for quail eggs as reported by Sreenivasaaih (1998).

There were no difference in shell quality between control and birds receiving any of the diets containing Azolla (Table 18). The cumulative mean value was 0.19 in control and 0.2 in all Azolla treated groups. Egg shell thickness was numerically higher for all the diets containg Azolla. It might be due to higher calcium content or optimum Ca:P ratio of Azolla meal (Buckingham *et al.*, 1978).

Similar results were reported by Ross and Dominy (1990). They got same value (0.20 mm) for shell thickness in Japanese quails when they were fed with spirulina. Mc Dowell *et al.* (1990) and Rao (2005) reported better shell quality for eggs of hens fed with aquatic plants hydrilla, algae and *Cissus quandrangularis,* respectively.

Mean internal quality unit of quail eggs as influenced by dietary inclusion of dried Azolla presented in Table 19 revealed that mean values were significantly influenced only during periods I and IV.

The cumulative mean internal quality units calculated for different dietary treatments T1, T2, T3 and T4 were 58.52, 54.26, 51.92 and 55.55, respectively. It did not show any significant effect due to dietary inclusion of Azolla. A numerically higher mean value was registered with control group. The reduction in mean IQU from the control group were 4.26, 6.60 and 2.97 for 1.5, 3.0 and 4.5 per cent Azolla fed groups, respectively.

The numerically lower IQU noted in Azolla supplemented groups might be due to significantly higher egg weight in these groups. Solarte *et al.* (2005) also reported lower Haugh unit in eggs of hens due to higher egg weight.

As specific works to assess the effect of Azolla meal in the diet of poultry on egg quality parameters are lacking, the results obtained in this study could not be corroborated. However, the internal quality traits of eggs as observed in this study indicated that Azolla could be safely included in the quail layer diet.

5.10 YOLK COLOUR

Yolk carotenoids measurement serves as an indicator of yolk colour assessment. The colour of egg yolk is contributed by oxycarotenoids, commonly known as xanthophylls pigments, derived from hens feed. As xanthophylls increases, the beta carotene activity increases. Hence the intensity of yolk colour has much significance.

The results of the present study showed that there was an accumulation of carotenoids in egg yolks of quail layers that were supplemented with different levels of dried Azolla. The mean yolk carotenoids of quail eggs as influenced by various dietary treatments showed a definite trend in this trait (Table 20). The increase in yolk carotenoids was directly proportional to the level of Azolla in the diet. In all the Azolla supplemented groups, a proportional increase in yolk carotenoids level was also observed with period. The trend in carotenoids accumulation was similar from the first period till the end of the study.

Statistical analysis of this trait revealed significant differences among the treatments. Yolk carotenoids of birds offered Azolla was significantly high ($P<0.01$) compared to control diet fed birds. Each incremental level of Azolla in rations resulted significant improvement in yolk carotenoids. The maximum yolk carotenoids level was noted with 4.5 per cent level of Azolla inclusion (50.81 µg/g).

As compared to control group, 4.5 per cent level Azolla feeding caused cent per cent increase in yolk carotenoids level.

The difference in mean yolk carotenoids levels between the first and last periods in Azolla fed groups also showed a definite trend. In control, the mean yolk carotenoids at 10th week of age was 23.43 µg/g and it reached a maximum level of 26.00 µg/g at the end of 18th week of age. Then the level slowly fell to 25.14 at 22 weeks and 25.15 at 26th week of age. On the other hand, the mean yolk carotenoids level of 31.44 noted on 10th week reached to a level of 39.75 µg/g at 26th week of age in group fed with 1.5 per cent Azolla. The mean yolk carotenoids level at 10th week and 26th week of age in 3.0 and 4.5 per cent Azolla fed groups were 35.25 and 45.26 and 45.71 and 57.41 µg/g, respectively. The difference in yolk carotenoids between 10th to 26th week of age in 1.5, 3.0 and 4.5 per cent Azolla supplemented groups were 8.31, 10.01 and 12.00 µg/g respectively. However, in control birds the difference between minimum and maximum level was only 2.57 µg/g. The increase in yolk carotenoids noted in each period in Azolla fed groups can be attributed to increase in intake of azolla. North and Bell (1990) also stated that the older the broiler, the higher the per cent of xanthophylls transferred from the feed to the body.

The results obtained in this study were consistent with the observations of Singh and Subudhi (1978) and Khatun *et al.* (1999). As there was an increase in carotenoids content of egg yolk, it could be stated that Azolla is a good source of carotenoids. Partali *et al.* (1987) reported that the profile of carotenoids deposited in to yolk directly reflected the relative proportions of carotenoids in the maternal diet. Lipstein *et al.* (1980) also reported that yolk pigmentation was found to be linearly related to dietary xanthophylls content. These results are also in agreement with Blount *et al.* (2002) who reported that a positive correlation exist between dietary carotenoids and yolk carotenoids profile.

As antioxidants, carotenoids are capable of quenching free radicals generated as byproducts of oxidative metabolism, and can there by protect DNA, proteins and lipids from oxidation including in egg yolk and embryo tissue (Surai *et al.*, 2001). Yolk deposition of these pigments may also translate into additional health benefits to consumers as the role of carotenoids as antioxidant in the prevention of cardiovascular diseases. Therefore, Azolla can be recommended in quail layer ration for the enrichment of eggs with carotenoids.

5.11 PROCESSING YIELDS

The effect of dietary treatments employed in this study on the mean per cent weight of giblet, ovary and oviduct, dressed and ready to cook yield per cent are presented in Table 21.

Mean dressed yield per cent of T1, T2, T3 and T4 were 83.09, 83.73, 81.57 and 83.63, respectively. T2 had the best dressed yield per cent followed by T4, T1 and T3. The magnitude of difference in per cent dressed yield between treatments were narrow. Comparatively lower dressed yield observed in T3, might be due to lower final live weight of birds (220.52 g) compared to T1, T2 and T4 (222.27, 223.31 and 223.30 g, respectively). Basak *et al.* (2002) reported higher dressing per cent in broiler birds fed with 5 per cent Azolla.

Mean ready to cook yield was 58.07, 59.71, 57.99 and 60.07 per cent, respectively for T1, T2, T3 and T4. The statistical analysis of data did not show any significant difference among treatment groups. It was highest for 4.5 per cent Azolla fed groups.

The mean giblet (4.60, 4.65, 4.80 and 4.75 %) and ovary and oviduct weight (5.08, 5.10, 5.25 and 5.91 %) respectively for T1, T2, T3 and T4 were statistically similar for all dietary groups. However, the weight of giblet as well as ovary and oviduct showed an increasing trend with increase in the proportion of Azolla in the diet. These trends are consistent with the result of Zhengwei *et al.* (2000) who reported that retinoic acid, precursor of vitamin A, has a stimulating effect on the growth of ovary and oviduct of female Japanese quails. Increased egg production in Azolla fed birds was also supported by accelerated growth of ovary and oviduct.

5.12 SERUM PROFILES

5.12.1 Cholesterol

An increase in the dietary proportion of Azolla resulted in a linear reduction ($P<0.01$) of serum total cholesterol levels (Table 22). The mean values of serum cholesterol level were 167.92, 147.79, 140.35 and 113.99 mg % for the groups T1, T2, T3 and T4, respectively. Azolla supplementation at all levels caused a significant reduction in mean cholesterol values. However, T2 was comparable with both control and as well as 3.0 per cent Azolla fed group. The reduction in mean serum cholesterol was to the extent of 53.93 mg % in 4.5 per cent Azolla fed groups from that of standard quail layer fed groups. The reduction in serum cholesterol in 3.0 and 1.5 per cent Azolla supplemented groups were 27.57 and 20.13 mg %, respectively.

The reduction is serum cholesterol consequent to Azolla supplementation in quail layers observed in this study is in agreement with Kaya *et al.* (2003) who reported that 100 ppm Yucca powder supplementation significantly reduced serum cholesterol in laying quails to 109.40 mg/dl from 163.55 mg/dl in control fed birds.

The reason for reduced cholesterol could be attributed to the presence of phytosterol composed of sitosterol, campesterol and stigmasterol in Azolla (Arai *et al.*, 1998). The mechanism by which plant sterols reduce cholesterol absorption was studied by Wester (2000) and reported that these sterols had been shown to reduce micelle solubilisation of cholesterol and thereby reduce serum cholesterol. Moreover saponins in Azolla (Arai *et al.*, 1998) forms large mixed micelle by interaction with bile acids, which prevents absorption from the small intestine and increase excretion of cholesterol. The resulting accelerated metabolism of cholesterol in the liver causes its serum level to go down (Francis *et al.*, 2002).

5.12.2 Creatinine

The mean values of serum creatinine were 0.37, 0.28, 0.38 and 0.43 mg/dl for T1, T2, T3 and T4, respectively. Statistical analysis revealed no significant difference.

5.12.3 Protein

The mean protein content of serum at twenty six weeks of age among different treatment groups were 3.29, 2.97, 3.37 and 3.02 g/dl for T1, T2, T3 and T4, respectively which showed no significant difference. This confirms that protein of Azolla was efficiently utilised as supported by increase in egg production and egg weight. These results were in agreement with the report of Rubio *et al.* (2003).

5.12.4 Uric acid

Uric acid is the major end product of protein metabolism in birds. As there were no significant difference with respect to mean values of serum uric acid (3.10, 3.27, 3.31 and 3.27 mg/dl in T1, T2, T3 and T4, respectively) among different treatments it could be stated that protein of Azolla were of good quality, which lead to better protein utilization and resulted in reduced uric acid excretion. Eventhough Buckingham *et al.* (1978) reported higher per cent of purine in Azolla it did not reflect in the serum uric acid level up to 4.5 per cent level.

5.13 LIVABILITY

In general, livability was better in Azolla fed birds compared to control (Table 23). These results are comparable with the findings of Parthasarathy *et al.* (2002) who reported that the feeding of Azolla up to a level of 20 per cent did not have any adverse effect on the livability of broiler chicken.

Better survivability in Azolla fed groups can be attributed to the presence of saponins and carotenoids in Azolla (Arai *et al.*, 1998). Saponins reportedly induced production of cytokines such as interleukins and interferons that might mediate their immunostimulant effects (Francis *et al.*, 2002). Increased level of carotenoids in Azolla, which is an immunostimulant also increases survivability.

5.14 ECONOMICS

The cost benefit analysis of supplementing different levels of Azolla in quail layer feed was worked out and are presented in Table 24.

Cost of feed was the only factor that altered the total production cost of different groups. Other costs were constant. The margin of return over feed cost was highest in 4.5 per cent Azolla fed group (Rs.2185.91) and the second highest was in 1.5 per cent Azolla fed group (Rs. 2157.51). Control ranked next (Rs.2107.51) and T3, the group fed 3 per cent Azolla (Rs.1936.77) stood last in the series. As the Azolla is an unconventional feed and the production cost was also less, profit was more in Azolla fed groups. The profit increased as the level of inclusion of Azolla increased with the exception in T3. It may be due to less number of eggs as it produced higher egg mass.

The feed cost per kg decreased from 9.32 to 8.97 as the level of Azolla increased from zero to 4.5 per cent. Similarly the margin of return over feed cost ranged from 2107.51 in T1, to 2185.91 in T4. The margin of return over feed cost per egg worked out to be.38.46, 37.86, 36.84 and 38.61 paise in T1, T2, T3 and T4, respectively. The return over feed cost per quail housed increased with inclusion of Azolla with the exception of T3 (3.0 % Azolla). The results suggest that the return was more at 4.5 per cent level inclusion.

Considering the cost benefit analysis it is safe to conclude that Azolla can be included in quail layer rations up to 4.5 per cent level.

Summary

6. SUMMARY

An experiment was conducted at the Department of Poultry Science, College of Veterinary and Animal Sciences, Kerala Agricultural University, Mannuthy to study the effect of inclusion of dried Azolla in Japanese quail layer ration. The study was carried out during the laying phase of Japanese quails from 6 to 26 weeks of age. One hundred and ninety two, Japanese quail pullets were weighed individually and distributed randomly to four treatment groups with four replicates of twelve birds each. Quail layer ration containing 22 per cent crude protein, 2650 kcal per kg metabolisable energy, 3.0 per cent calcium and 0.45 per cent phosphorus formed the basal diet (T1). Dried Azolla was included in the basal diet at levels of 1.5, 3.0 and 4.5 per cent to form the treatments T2, T3 and T4, respectively. All the rations were made isocaloric and isonitrogenous.

Each replicate was housed in separate cage maintaining uniform standard management conditions. The maximum and minimum temperature (^{0}C) and per cent relative humidity in the forenoon and afternoon inside the experimental house were recorded daily. The mean initial body weight at sixth week and the final body weight at the end of twenty six weeks of age were recorded. Data collection was done for five periods of 28 days each from 7 to 26 weeks of age. Egg production was recorded daily replicate wise and expressed as quail housed and quail day egg production. Replicate wise data on feed intake was recorded throughout the experiment and the feed conversion ratio based on per dozen eggs and per kg egg mass were calculated. At the end of each period all the eggs collected for three consecutive days were weighed to calculate the mean egg weight. Five eggs randomly picked from each replicate for the last three days of each period were utilised for egg quality analysis. The shape index, albumen index, yolk index, internal quality unit and shell thickness were recorded. Two eggs were randomly collected from each replicate for carotenoid estimation at the end of each twenty eight day period. Two birds from each replicate were sacrificed at the end of the experiment to study the mean per cent dressed yield, ready to cook yield and per cent weight of giblet and ovary and oviduct. Blood samples were collected at the time of slaughter for the estimation of serum total cholesterol, serum creatinine, serum total protein and serum uric acid. Economics over feed cost was calculated based on the prevailing cost of feed ingredients and quail eggs during the course of the study.

The overall performance of the birds fed different dietary regiments are presented in Table 25.

The results obtained in this study are summarised hereunder.

1. The overall mean maximum and minimum temperatures (°C) and relative humidity (%) in the forenoon and in the afternoon inside the experimental house during the experimental period were 35.67, 24.65, 82.04 and 71.67, respectively.

2. The mean body weight of birds in the treatments T1, T2, T3 and T4 at six weeks of age was 185.23, 186.04, 185.01 and 186.56 g, respectively. The corresponding values at twenty six weeks of age were 222.27, 223.31, 220.52 and 223.30 g, respectively. The mean body weight gain for the above treatments during the study period was 37.74, 37.27, 35.51 and 36.74 g, respectively. There was no significant difference between the treatments in body weight at both ages and in body weight gain.

3. Birds in all the treatments attained sexual maturity at the same age of 42 days. The mean ages at 10 per cent production for the treatment groups T1, T2, T3 and T4 were 43, 44, 44 and 43 days, respectively. Birds fed with varying levels of Azolla attained 50 per cent production one day later (48 days) than the control diet fed birds (47 days).

4. The cumulative mean daily feed intake of Japanese quails from seven to twenty six weeks of age were 28.35, 29.96, 30.05 and 29.70 g for the groups T1, T2, T3 and T4, respectively. The differences were statistically non significant.

5. The mean cumulative feed conversion ratio calculated based on per dozen eggs for the groups T1, T2, T3 and T4 were 0.41, 0.42, 0.45 and 0.43, respectively. The corresponding values calculated based on per kg egg mass were 3.02, 3.11, 3.23 and 3.12, respectively. The cumulative mean FCR was numerically inferior for group T3 followed by T4, T2 and T1 in that order. Statistical analysis revealed no significant difference between treatments.

6. The mean cumulative quail housed egg number for the period from 7 to 26 weeks of age was 117.32, 120.00, 112.18 and 119.24 for the treatment groups T1, T2, T3 and T4, respectively and the corresponding per cent were 83.31, 85.71, 80.13 and 85.16. Cumulative quail housed egg number and per cent were statistically comparable between treatments.

7. The mean cumulative quail day egg number was 118.61, 120.38, 115.32 and 119.34 and the corresponding per cent quail day egg production were 83.73, 85.98, 80.83 and 85.23, respectively for T1, T2, T3 and T4. Quail day egg production of the treatments during the five periods were statistically similar.

8. The cumulative mean egg weight from 7 to 26 weeks of age was highest for T3 (11.64 g) followed by T2 (11.41 g), T4 (11.39 g) and T1 (11.27 g). Cumulative egg weight was significantly ($P<0.05$) higher in 3.0 per cent Azolla fed group.

9. Among the egg quality characteristics studied, (viz., shape index, albumen index, yolk index, internal quality unit and shell thickness) only the yolk index showed a significant difference among treatments. The cumulative mean yolk index was significantly ($P<0.01$) lower with Azolla fed quails.

10. The mean yolk carotenoids level was significantly higher ($P<0.01$) in Azolla fed groups in all individual periods and for the whole experimental period taken together.

11. Mean per cent giblet and ovary and oviduct weight were numerically higher for Azolla fed groups (T2, T3, and T4) compared to birds fed standard quail layer diet (T1). The group fed with 1.5 per cent Azolla (T2) recorded numerically higher dressed yield (83.73 %) and the group fed with 4.5 per cent Azolla, (T4) recorded numerically higher ready-to-cook-yield (60.07 %). While the statistical analysis of the mean values of these traits showed no significant difference.

12. Mean serum total cholesterol level was significantly ($P<0.01$) lower in Azolla fed treatments (147.79, 140.35 and 113.99 mg %, respectively for T2, T3 and T4) compared to control (167.92 mg %). On the other hand, serum total protein, creatinine and uric acid were not influenced due to Azolla inclusion in quail layer diet.

13. Livability was comparatively better in Azolla fed groups compared with the group fed standard quail layer diet (T1).

14. The feed cost for the production of one egg accounted to 31.54, 32.14, 33.17 and 31.19 paise for the treatments T1, T2, T3 and T4, respectively. The margin of return over feed cost per egg was found to be 38.46, 37.86, 36.84 and 38.61 paise for the treatments T1, T2, T3 and T4, respectively. The corresponding values for return over feed cost per quail housed were Rs. 43.91, 44.95, 40.35 and 45.54, respectively.

The results of this study revealed that incorporation of Azolla in quail layer diet up to 4.5 per cent did not influence body weight, feed intake, feed conversion ratio and quail housed egg production and per cent. Whereas, cumulative mean egg weight was significantly higher with 3.0 per cent Azolla fed group. Inclusion of Azolla in quail layer diet resulted significant increase in egg yolk carotenoids level. A level dependent significant reduction in mean serum cholesterol with Azolla feeding was also observed. Overall evaluation of the study indicated that incorporation of the dried Azolla at 4.5 per cent level in quail layer ration was beneficial.

Table 25. Summary of performance of Japanese quail layers (7 to 26 week) influenced by dietary inclusion of dried Azolla in experimental diets

Sl. No	Characteristics	Dietary inclusion of dried Azolla in experimental diets (%)			
		T_1 0	T_2 1.5	T_3 3.0	T_4 4.5
1	BW 6^{th} wk (g)	185.23	186.04	185.01	186.56
2	BW 26^{th} wk (g)	222.27	223.31	220.52	223.30
3	Age at 50 % production (days)	47	48	48	48
4	Feed intake/day (g)	28.35	29.96	30.05	29.70
5	FCR/ kg egg mass	3.02	3.11	3.23	3.12
6	FCR / dozen egg	0.41	0.42	0.45	0.43
7	QH egg number	117.32	120.00	112.18	119.24
8	QD egg number	118.61	120.38	115.32	119.34
9	Egg weight (g)*	11.27^{b}	11.41^{ab}	11.64^{a}	11.39^{ab}
10	Yolk index**	0.48^{A}	0.45^{B}	0.45^{B}	0.44^{B}
11	Yolk carotenoids (µg/g)**	25.10^{D}	35.68^{C}	40.71^{B}	50.81^{A}
12	R-to- C yield (%)	58.07	59.71	57.99	60.07
13	Serum total cholesterol (mg %)**	167.92^{A}	147.79^{AB}	140.35^{B}	113.99^{C}
14	Livability (%)	91.67	95.83	93.75	97.92
15	Margin of return over feed cost/egg (paise)	38.46	37.86	36.84	38.61

* Mean values bearing same superscript within a row did not differ significantly ($P \leq 0.05$)
** Mean values bearing same superscript within a row did not differ significantly ($P \leq 0.01$)

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EFFECT OF DIETARY SUPPLEMENTATION OF AZOLLA (*Azolla pinnata*) ON PRODUCTION PERFORMANCE IN JAPANESE QUAIL (*Coturnix coturnix japonica*)

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ABSTRACT

The utility of dried Azolla in the production performance of Japanese quails were evaluated using one hundred and ninety two layer quails for a period of 20 weeks. They were randomly allotted to four treatment groups with four replicates of 12 quails each. Quail layer ration containing 22 per cent crude protein, 2650 kcal per kg metabolisable energy, 3.0 per cent calcium and 0.45 per cent phosphorus formed the basal diet (T1). Dried Azolla was included in the basal diet at levels of 1.5, 3.0 and 4.5 per cent to form the treatments T2, T3 and T4, respectively. All the rations were made isocaloric and isonitrogenous.

Data collection was done for five periods of 28 days each from 7 to 26 weeks of age. At the end of the trial, blood was collected from two birds per replicate and was utilised for serum profile studies.

The body weight at 6 and 26 weeks of age and the body weight gain during experimental period did not differ significantly between dietary treatments. Age at sexual maturity, 10 and 50 per cent production were not influenced by inclusion of Azolla in quail diets. The quails fed with Azolla recorded numerically higher feed intake than control group. The cumulative feed conversion ratio was numerically higher in Azolla fed groups. Eventhough the cumulative mean quail housed and quail day egg number and per cent production were statistically comparable among the dietary groups, the groups T2 and T4 performed better than the control (T1). The cumulative mean egg weight from 7 to 26 weeks of age was highest for T3 followed by T2, T4 and T1. Cumulative egg weight was significantly ($P<0.05$) higher in 3.0 per cent Azolla fed group. The statistical analysis of the overall mean values of egg quality traits revealed no significant difference between dietary groups with the exception in yolk index. The cumulative mean yolk index was significantly ($P<0.01$) lower in Azolla fed birds. The mean yolk carotenoids level was significantly higher ($P<0.01$) with Azolla supplemented groups in all individual periods and for the whole experimental period taken together. Mean per cent giblet and ovary and oviduct weight were numerically higher for Azolla supplemented groups. The group fed

with 1.5 per cent Azolla (T2) recorded numerically higher dressed yield (83.73 %) and the group fed with 4.5 per cent Azolla (T4) recorded numerically higher ready-to-cook-yield (60.07 %). While the statistical analysis of the mean values of these traits showed no significant difference. Mean serum total cholesterol was significantly (P<0.01) lower in 3.0 and 4.5 per cent Azolla fed groups compared to control. Serum total protein, creatinine, and uric acid were not influenced due to Azolla inclusion. Livability was comparatively better in Azolla fed birds. The cost of feed per egg was lowest in T4 followed by T1, T2 and T3.

Overall evaluation of the results of the study indicated that incorporation of the dried Azolla at 4.5 per cent level in quail layer ration was beneficial.