CALCIUM AND PHOSPHORUS REQUIREMENTS OF INDIGENOUS LAYER DUCKS

(*Anas platyrhynchos*)

By
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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I hereby declare that this thesis entitled "**CALCIUM AND PHOSPHORUS REQUIREMENTS OF INDIGENOUS LAYER DUCKS (*Anas platyrhynchos*)**", is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Mannuthy
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CERTIFICATE

Certified that this thesis entitled "CALCIUM AND PHOSPHORUS REQUIREMENTS OF INDIGENOUS LAYER DUCKS (*Anas platyrhynchos*)", is a record of research work done independently by **Ravi S.**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

The poultry production in India has made substantial progress in the commercial sector during the past three decades. The annual production of eggs in the world was 820 billion during the year 1998 with a contribution of 32.4 billion eggs from India (Anon, 1999). However, there exists large discrepancy in per capita egg consumption throughout the world.

Unlike chicken industry, the current developments in ducks are constrained due to various reasons. Although ducks are being reared all over the world, the duck farming is widespread only in Central and Southeast Asia. In India, they are concentrated mostly in Eastern, Northeastern and Southern regions and it provides jobs for more than three lakhs of rural families in India (Ramakrishnan, 1996).

In India, ducks (*Anas platyrhynchos domesticus*) occupy second position next to chicken with a population of 24.48 million (Anon, 1994), of which about 92 per cent are indigenous varieties. This species forms about 8.5 per cent of the total poultry population in the country with relatively higher returns.

In India the leading states in duck population are West Bengal, Assam, Bihar, Kerala, Andhrapradesh, Orissa and Tamilnadu. Duck production in the country remained in the hands of the poor and socially backward strata of the society and it remains neglected in the absence of adequate attention by research workers, developmental agencies and public/ private enterprises.

Kerala with a coastal stretch of 590 Km has 11.8 lakhs of ducks, constituting about 3.6 per cent of the duck population in the country, ranks fourth position among states in India. The distribution of ducks in Kerala state shows a peculiar scenario such that 49 per cent of the duck population is concentrated in Alappuzha district alone (Anon, 2001).

Most of the indigenous ducks in India are reared under extensive system by herding them in harvested paddy fields, riverbanks, canals and/or ponds. The types of feed resources available from the rice fields are diverse and are mainly paddy grains, crabs and snails. This is considered to be insufficient for optimum egg production as reflected by low egg production rate in herded ducks under extensive system of rearing in Kerala. Even though ducks are aquatic species, water for swimming is not essential and studies have shown that there was better egg production under intensive system of rearing ducks. Ketaren (1998) reported that egg production rate was 55.6 per cent under confined system of rearing while in herded ducks it was 26.9 to 41.3 per cent.

In poultry production, the mineral nutrition is equally important as other nutrients since the imbalances, deficiencies and excesses produce severe consequences in biological system. The major minerals, calcium and phosphorus are vital for egg production and shell formation in laying ducks and they use variety of mechanisms to control the calcium-phosphorus ratio and its metabolism. The ratio of these elements in the diet has been the subject of interest since calcium and phosphorus compete each other for absorption in the intestines.

The availability of mineral resources for inclusion in the diets to maintain the egg production and shell quality has been a crucial problem faced by duck farmers in this region. In order to address the above problem, the present study was undertaken to assess the requirements of dietary calcium and phosphorus in indigenous layer ducks under cage system of rearing.

REVIEW OF LITERATURE

Studies on the optimum requirements of calcium and available phosphorus for ducks are very scanty and the available literature is not conclusive. Bolton and Blair (1977) indicated that the Poultry Research Centre (PRC) has adopted a level of 2.75 per cent calcium and 0.5 per cent available phosphorus with 18 per cent crude protein and 2650 Kcal of ME for feeding breeding ducks. Reddy and Reddy (1979) suggested 2.5 per cent calcium and 0.45 per cent available phosphorus for layer ducks. Rao (1981) suggested three types of rations viz., starter grower and layer for Khaki Campbell ducks at different ages of 0 to 3, 4 to 12 and above 12 weeks, respectively. Who also suggested that the protein content in the above diets shall be 21, 17 and 18 per cent, respectively with energy contents of 2850, 2900 and 2800 K cal ME/ Kg diet.

On the other hand, the Bureau of Indian Standards-BIS (1992) does not specify nutritional requirements for ducks. NRC (1994) has estimated the nutrient requirements for starting, growing and breeding ducks but not for layer ducks. Ketaren (1998) recommended 2.9 to 3.25 per cent calcium and 0.6 per cent available phosphorus for laying ducks.

2.1 Body Weight

Andrews *et al.* (1984) reported that the 20th week body weight was 1438 and 1443 g in Desi ducks under the intensive and semi-intensive systems of management. Both groups were fed diet with 3.31 per cent Ca, 1.17 per cent total phosphorus, 17.30 per cent CP and 2650 Kcal ME /Kg

and reported that the ducks in the intensive system had apparently better body weight compared to those in semi-intensive system. The difference between systems of rearing was statistically non significant. These authors also reported that the final body weight was 1311 g in intensive system and 1281 g in semi-intensive system of rearing.

Hamid *et al.* (1988) reported a body weight of 1703.89 g in indigenous ducks, 1788.44 g in Khaki Campbell ducks and 1743.28 g in Indian Runner, at 20 weeks of age.

Narahari and Sundararasu (1988) could not observe any significant difference with body weight of Khaki Campbell and Desi ducks fed dry and wet mash mixed with water at the ratio of 3:1, from 21 to 40 weeks of age.

Gajendran *et al.* (1990) studied the performance of Desi and Khaki Campbell ducks under intensive system of rearing in maritime monsoon type of climate. The ducks were housed on deep litter system from 21 to 40 weeks of age and fed with layer mash containing 13 per cent CP and 2475 Kcal ME/Kg. The body weights recorded at 20 weeks of age were 1 465 ± 2.387 g and 1.402 ± 1.335 g for Desi ducks and Khaki Campbell ducks respectively and there was no significant difference between the body weights.

Chen (1992) reported that the average body weight of laying Tsaiya ducks was 1.38 kg at 40 weeks age.

Dutta *et al.* (1993) studied the pattern of body weight gain in Khaki Campbell ducks at different ages under open range, deep litter and semi intensive systems of management in Assam Agricultural University, Khanappara. Individual feeding was followed for all ducks and they were fed with layer ration from 20th week onwards. The body weight at 20 weeks of age was 1347.33 g in open range, 1351.33 g in deep litter and 1386.67g in semi range system with an overall mean of 1361.78 g.

Hengmin and Lingping (1997) conducted experiments with 40, one-day old Tianfu ducklings, which were randomly divided into two groups of 20 each. The control group received 0.65 per cent phosphorus and the second group fed diet containing phosphorus level of 0.366 per cent. Both the groups received diet containing 0.8 per cent calcium and the results of the experiment showed that the phosphorus deficient (0.366 %) ducklings were visibly smaller than control group and their gain in weight was much lower.

Mahanta (1997) reported the body weights of two varieties of indigenous ducks, Chara and Chemballi of Kerala. The body weights at 20 and 40 weeks of age were 1538.15 and 1494.07 g in Chara ducks and 1497.51 and 1475.45 g in Chemballi ducks, respectively, under semi intensive system of rearing.

Anon (2002) reported a body weight of 1466 g at 20th week and 1354 g at 40th week in indigenous ducks of Kerala under cage system of rearing. There was no significant difference between the body weights at 20 and 40 weeks of age.

2.2 Age at Sexual Maturity (ASM)

Hutt (1953) reported the age at sexual maturity in Khaki Campbell (KC) ducks as 139 to 143 days while Mostageer *et al.* (1971) reported late sexual maturity, at 151.3 days of age in Khaki Campbell ducks.

Chavez and Lasmini (1978) reported age at first egg in Indonesian native ducks of Tegal, Alabio and Bali as 178, 179 and 189 days, respectively.

Singh and Pal (1978) showed that, White Pekin ducks attained sexual maturity at an earlier age when fed with higher levels of crude protein, viz., 22, 25 and 27 per cent and the difference was significant in comparison to those fed with 17 per cent protein.

Sarma *et al.* (1986) ascertained the age at sexual maturity in Khaki Campbell ducks under different levels of dietary protein in iso-caloric diets containing 2800 Kcal ME/ Kg. The ASM was found to be 161 days in the group fed with 17 per cent crude protein and it was concluded that the ducks fed 21 per cent protein attained sexual maturity earlier than those fed with 17 and 19 per cent levels of protein with an overall mean ASM of 157.3 days.

Hamid *et al.* (1988) studied the performance in growing ducks of indigenous, Khaki Campbell and Indian Runner and reported that the age at sexual maturity was 154, 140 and 143 days, respectively.

Narahari and Sundararasu (1988) found no significant differences in ASM between dry and wet mash fed groups of Khaki Campbell and desi ducks, from 21 to 40 weeks of age.

Gajendran *et al.* (1990) studied the production traits in Desi and Khaki Campbell ducks fed layer mash containing 13 per cent CP and 2475 ME Kcal /Kg from 21 to 40 weeks of age. The ASM recorded were 145.21 ± 2.72 days for Desi ducks and 140.16 ± 4.04 days in Khaki Campbell ducks and the ASM between Desi and KC ducks did not show any significant difference.

Baruah *et al.* (1991) studied the productivity of indigenous ducks, viz., Pati of Assam, Khaki Campbell and their crosses reared under the farm conditions. The mean age at sexual maturity was reported at 144.2, 150.4 and 146.4 days, respectively and thirty per cent egg production was recorded at the age of 167.2, 158.6 and 161.8 days respectively. These authors also reported the period of gap between the age at first egg and 30 per cent production. This was very large in Pati (23 days) compared to Khaki Campbell (8 days) and their crosses (15 days).

Rashid *et al.* (1995) reported sexual maturity at the age of 209, 182 and 187.5 days, in Desi, Khaki Campbell and their crosses, respectively, with out supplemental feeding under rural conditions of Bangladesh.

Mahanta (1997) reported that the age at first egg was 129 days in two varieties of indigenous ducks, Chara and Chemballi of Kerala. In these

varieties, the ages at 10 and 50 per cent production were 153 and 187days in Chara and 148 and 184 days in Chemballi ducks respectively.

Bandyopadhyay and Sikdar (2000) stated that high egg producing strains started egg production at about 18 weeks of age.

Das *et al.* (2000) conducted a study under the field conditions in Assam and the ASM was calculated on the basis of age at which the ducks reached 30 to 40 per cent egg production. The values of mean ASM were 229.19, 169.16 and 220.24 days respectively in Desi, Khaki Campbell and their crosses. Highly significant ($P<0.01$) influence was observed in respect of ASM and egg production and both these traits were significantly affected by month of hatch ($P<0.01$). Significantly early ASM was observed in ducks hatched during months of June and July followed by those hatched in May, March, April and February in that order.

Anon (2002) reported the average age at first egg as 149.03 days and the mean age at 50 per cent production as 164 days in indigenous ducks of Kerala, under cage system of rearing.

2.3 Egg production

Mostageer *et al.* (1971) showed the egg production of 58.22, 198.59 and 87.12 eggs in Desi ducks, Khaki Campbell and their crosses respectively up to 72 weeks of age.

Konovalov (1974) found that, growing ducks fed with 80 per cent of full feeding, during 50 to 150 days of age, consequently showed an increase in egg production in laying stage.

Avens *et al.* (1980) compared the production performance of Khaki Campbell ducks in individual cages and floor pens with four ducks per pen. The dimension of the cage was 0.41 x 0.46 x 0.69 m and that of the pen was 1.8 x 1.8 m. The pelleted layer ration containing 3.2 per cent calcium and 0.73 per cent available phosphorus with 18 per cent protein and 11.4 MJ ME was fed. The mean egg production per duck was 95.3 eggs in cage system and 86.6 eggs in floor rearing up to 40 weeks of age.

Reddy *et al.* (1981) on feeding Khaki Campbell ducks with layer diet containing 2.74 per cent calcium, 0.52 per cent available phosphorus, 19 per cent crude protein, 2400 Kcal ME/Kg during the period from 21 to 52 weeks of age and reported 69.1 per cent production rate with 154.8 eggs per duck.

Andrews *et al.* (1984) compared the performance of Desi ducks under intensive and semi-intensive systems of rearing and reported the duck-day egg production of 14.9 and 12.6 per cent in intensive and semi-intensive system of management respectively during the period from 21 to 44 weeks of age.

Eswaran *et al.* (1985) reported 35.13 and 61.50 eggs in Desi and Khaki Campbell ducks, respectively for 100 days production from age at first egg with corresponding percentages of 42.7 and 65.7. The egg production up to 280 days of age was 51.66 and 60.16 per cent respectively.

Narahari and Sundararasu (1988) reported slight, but insignificant improvement in egg production in the wet mash fed groups and reported that those ducks fed on dry mash although showed difficulty in deglutition initially, was able to adopt it soon.

Baruah *et al.* (1991) studied the per cent duck-day egg production in local native ducks for eight laying periods and reported gradual increase in egg production from first to fourth laying period. The rate of production per duck ranged from 3.45 to 9.41 eggs per period.

Chen (1992) reported 218 eggs per duck up to 360 days of age in native ducks.

Zakaria (1994) reported that decreasing crude protein from 19 to 17 per cent level in the diets containing 3000, 3200 and 3400 K cal ME /Kg had no effect on egg production in layer ducks.

Rashid *et al.* (1995) studied on the performance of Desi, Khaki Campbell and their crosses with and with out extra feeding under rural condition of Bangladesh and reported that the egg production up to 300 days of age was 41, 67 and 110 eggs, respectively when the ducks were fed with out supplemental feeding. When the ducks were fed with supplementary feeding, the egg production recorded were 71, 92 and 166 eggs per duck, respectively.

Narahari and Sundararasu (1996) reported that when the Khaki Campbell ducks were reared in cages, consumed less feed, matured later and laid fewer number of eggs with more thin shelled eggs and breakages than the ducks reared on deep litter irrespective of the roof insulation. The fly problem was higher with caged ducks. As such, the ducks were found to be more suitable for rearing on deep litter rather than in cages.

Mahanta (1997) reported that the mean cumulative egg number up to 40 weeks of age was 70.60 eggs in Chara and 72.40 eggs in Chemballi ducks of Kerala.

Applegate *et al.* (1998) reported that the peak egg production is normally reached between 28 and 30 weeks of age in Pekin ducks.

Ketaren (1998) reported that the egg production rate was increased from 38.3 to 48.9 eggs by supplementing concentrated feed to herded ducks. He also reported that, Alabio ducks produced on an average of 248 eggs per year at the laying rate of 67.9 per cent.

Tian Fwu *et al.* (1998) reported that the Tsaiya ducks fed diet with 3.0 per cent calcium showed higher egg production (85.56 per cent) than other treatment groups. Where in the duck housed egg production were 71.43, 80.84, 83.84 and 74.64 per cent respectively in groups fed 2.0, 2.5, 3.5 and 4.0 per cent calcium levels.

Bandyopadhyay and Sikdar (2000) stated that high egg producing strains start egg production at about 18 weeks of age. There is a popular belief that ducks need water for swimming, but it is not essential at any stage of duck farming. It is essential that ducks should be able to immerse their head and not complete body in the water, otherwise their eyes become scaly, crusty and blindness may follow in rare cases.

Das *et al.* (2000) studied the egg production in Desi ducks, Khaki Campbell and their crosses under field conditions in Assam and reported an average egg production of 19.45, 71.98 and 34.20 in Desi, Khaki Campbell and their crosses respectively, up to 40 weeks of age.

Anon (2002) reported the duck housed number of 80.64 eggs per duck up to 40 weeks of age in indigenous ducks of Kerala, under cage system of rearing, with duck housed percentage of 57.60.

2.4 Feed Consumption

Restricted feeding in ducks can be advantageous in that restriction of a diet containing 15 per cent protein and 2600 Kcal ME /Kg was found better than *ad lib* feeding of a diet with reduced protein (13%) at the same energy concentration (Konovalov, 1974).

Bulbule (1982) stated that the feed consumption varies from 135 to 170 g /duck /day depending upon the rate of production. He also stated that the Khaki Campbell ducks consumed 12.63 and 16.25 kg of balanced feed, under confinement up to the age of 20 and 24 weeks, respectively.

Andrews *et al.* (1984) reported that the Desi ducks consumed on an average of 191g and 185g of feed per day in the intensive and semi-intensive system of rearing when both groups were fed with the diet containing 3.31 per cent calcium and 1.17 per cent total phosphorus with 17.30 per cent crude protein and 2650 Kcal ME/Kg diet, during the period from 21 to 44 weeks of age.

Eswaran *et al.* (1985) reported that Desi ducks consumed 181 to 184 g feed per duck/day.

Gajendran *et al.* (1990) studied the feed consumption pattern in Desi and Khaki Campbell ducks from 21 to 40 weeks of age when fed a layer mash containing 13 per cent crude protein and 2475 Kcal ME /Kg diet and reported that the mean daily feed consumption of 155 g in Desi ducks and 165 g in Khaki Campbell ducks.

Baruah *et al.* (1991) reported the average daily feed consumption for eight laying periods as 190.06 g in Pati duck, 174. 29 g in Khaki Campbell and 178.01 g in their crosses. The difference in the feed consumption among three genetic groups was highly significant ($P<0.01$) during the first to fifth laying periods and significant ($P<0.05$) during the sixth and seventh period.

Tian Fwu *et al.* (1998) reported the mean daily feed consumption of 194.89 and 193.49 g at 3.0 and 3.5 per cent calcium level was lower than that recorded at 2, 2.5, and 4 per cent calcium levels, where the mean values were 203.87, 200.12 and 202.14 g respectively.

Bandyopadhyay and Sikdar (2000) stated that ducks are to be fed with wet mash 3 to 4 times daily after two weeks of age and reported that 0.03 ppm aflatoxin in the feed was considered toxic to ducklings.

Anon (2002) reported the mean daily feed consumption of 171.88 g from 21 to 40 weeks of age in indigenous layer ducks of Kerala, under cage system of rearing.

2.5 Feed Conversion Ratio

In Khaki Campbell ducks, Avens *et al.* (1980) reported a mean feed conversion ratio of 3.0 in cage and floor rearing systems by feeding a duck layer ration containing 3.2 per cent calcium and 0.57 per cent available phosphorus.

In Khaki Campbell ducks Reddy *et al.* (1981) reported the feed conversion ratio of 2.08 when fed with a layer diet containing 2.74 per cent calcium, 0.52 per cent available phosphorus, 19 per cent crude protein and 2400 Kcal ME/Kg from 21 to 52 weeks of age.

In Desi ducks Andrews *et al.* (1984) reported the feed efficiency of 19.5 and 22.7 in intensive and semi-intensive system respectively. Both the groups were fed with the diet containing 3.31 per cent calcium, 1.17 per cent total phosphorus, 17.30 per cent crude protein and 2650 Kcal ME/Kg diet during the period from 21 to 44 weeks of age.

Eswaran *et al.* (1985) reported an overall feed efficiency (kg feed per dozen eggs) of 13.54 ± 8.85 for Desi ducks and 11.68±4.77 for Khaki Campbell from 21 to 44 weeks of age.

Narahari and Sundararasu (1988) reported that, there was no significant difference in feed efficiency between dry and wet mash feeding in Desi and Khaki Campbell ducks from 21 to 40 weeks of age.

Gajendran *et al.* (1990) reported the mean feed efficiency of 4.883 ± 0.58 (kg feed per dozen eggs) in Desi ducks and 10.049 ± 0.75 (kg feed per dozen eggs) in Khaki Campbell ducks from 21 to 40 weeks of age.

Baruah *et al.* (1991) stated the feed conversion ratio in the order of 10.87, 5.01 and 6.91 respectively in Pati, Khaki Campbell and their crosses.

Tian Fwu *et al.* (1998) reported that the feed conversion efficiency of 3.41 and 3.48 at 3.0 and 3.5 per cent calcium levels and these values were better than that recorded with 2.0, 2.5 and 4.0 per cent levels of calcium, wherein the mean values were 4.16, 3.61 and 3.98 respectively.

Anon (2002) reported the mean FCR of 3.6 recorded from 21 to 40 weeks of age and 3.35 from 25 to 40 weeks of age in indigenous ducks of Kerala, under cage system of rearing.

2.6 Egg weight

In Khaki Campbell ducks Reddy *et al.* (1981) studied the egg weight on feeding graded levels of crude protein 15,17 and 19 per cent with constant level of 2.75 per cent calcium and 0.55 per cent available phosphorus. The egg weights recorded were 59.38, 60.67 and 56.68 g respectively.

Andrews *et al.* (1984) reported that the mean egg weight of Desi ducks was 60.4 g in the intensive system and 60.7 g in the semi-intensive system, when both the groups were fed the diet with 3.31 per cent calcium, 1.17 per cent total phosphorus.

Eswaran *et al.* (1985) reported the egg weight at 280 days of age as 71.40 ± 0.95 g and 62.4 1± 0.50 g for Desi ducks and Khaki Campbell ducks respectively.

Keshavarz (1985) reported that, available phosphorus levels could be reduced in older birds without affecting performance of laying hens. Feeding the diet with 0.24, 0.44 and 0.64 per cent available phosphorus from 56 to 72 weeks of age had no effect on egg weight.

Portsmouth (1985) reported that the amount of calcium supplied should be based upon knowledge of the inputs and outputs. A bird eating 100 g of feed per day at the beginning of lay with the egg weight of 53 to 56 g will require some two gram of calcium and the available phosphorus requirement of 300 to 350 mg/hen/day in order to provide a sound shell.

Patra *et al.* (1989) reported the egg weight of 66 to 70 g at the age of 40 weeks in Kakhi Campbell ducks.

Mahanta *et al.* (1993) studied the physical quality and component parts of Pati (indigenous) and Khaki Campbell duck eggs and reported that the mean egg weight of 60.55 ± 0.29 and 56.44 ± 0.38 g in indigenous and Khaki Campbell ducks, respectively.

Mahanta (1997) reported the weight of first egg as 61.27 g in Chara and 61.87 g in Chemballi ducks of Kerala. The mean egg weight at 40 weeks of age was 69.94 g in Chara and 68.94 g in Chemballi ducks under semi intensive system of rearing.

Ketaren (1998) reported that, egg weight was increased from the average of 66.9 to 71.1 g by supplementing 24 g prawn head meal per head to the laying herded duck diet during off-season.

Tian Fwu *et al.* (1998) ascertained that the mean egg weight was lower in the groups fed 3.0 and 3.5 per cent calcium levels (64.93 and64.68 g). Whereas, higher mean egg weight recorded in groups fed 2, 2.5 and 4 per cent calcium levels was 66.58, 66.55 and 66.50 g respectively.

Anon (2002) reported the mean egg weight of 57.42 g in indigenous layer ducks of Kerala, under cage system of rearing from 21 to 40 weeks of age.

2.7 Shell quality

Reddy *et al.* (1981) reported the mean shell thickness of 0.42 mm in Khaki Campbell duck eggs and it was significantly ($P<0.01$) higher in group fed the diet with 2.75 per cent calcium and 0.54 per cent available phosphorus with 15 per cent protein and 2400 Kcal ME /Kg during the period from 21 to 52 weeks of age.

Eswaran *et al.* (1985) reported the shell thickness of 0.38 ± 0.007 mm in Desi duck eggs and 0.36 ± 0.004 mm in Khaki Campbell duck eggs.

Keshavarz (1985) reported that feeding the diet with 0.24, 0.44 and 0.64 per cent available phosphorus levels had no effect on shell strength in chicken eggs from 56 to 72 weeks of age and concluded that available phosphorus levels could be reduced in older birds without affecting performance of laying hens.

In White Pekin breeder ducks, Davis *et al.* (1993) reported the shell thickness values ranged between 0.54 and 0.53 mm at 40 weeks of age. They also found that the shell weight was increased from a low of 8.2 g at 32 weeks to a high of 9.4 g at 49 weeks of age.

Mahanta *et al.* (1993) studied the physical quality and component parts of Pati and Khaki Campbell duck eggs and reported that the mean shell thickness of 0.34 ± 0.004 mm and 0.328 ± 0.004 mm in indigenous and Khaki Campbell duck eggs respectively and reported a shell weight of 12.11 ±0.01 per cent in Pati ducks and 12.01 ± 0.13 per cent in Khaki Campbell duck eggs.

In Tsaiya ducks, Tian Fwu *et al.* (1998) reported the shell strength of 5.04 Kg/cm^2, shell thickness of 0.37 mm and shell weight of 9.58 per cent at dietary calcium level of 4.0 per cent and stated that these values were higher, compared to lower levels of calcium in the diet.

2.8 Serum calcium and phosphorus

In ducklings Hengmin and Lingping (1997) reported that the serum calcium concentration of 2.94±0.06 mmol per litre and phosphorus concentration of 3.66 mmol per litre for phosphorus deficient diet (0.366 per cent phosphorus) and the corresponding values for the control diet (0.65 per cent phosphorus) groups were 3.10 ±0.10 and 5.10 ± 0.09 mmol per litre respectively.

2.9 Tibia Ash

Kalango and Ademosun (1973) studied the effect of dietary calcium levels 2.0, 2.75, 3.50 and 4.25 per cent with two levels of available phosphorus 0.4 and 0.6 per cent in haro layers in battery cages and in deep litter for a period of 48 weeks. They concluded that while increasing the dietary calcium levels from 3.50 to 4.25 per cent, the tibia ash was increased from 57.8 to 60.4 per cent and the calcium content of tibia ash was significantly affected by dietary Ca levels ($P<0.05$). The Ca content in tibia ash was increased from 35.8 to 37.5 per cent while increasing the dietary Ca level from 3.50 to 4.25 per cent.

Hengmin and Lingping (1997) reported 36.74 per cent tibia ash containing 13.01 per cent calcium and 8.31 per cent phosphorus in ducklings

fed a control diet with 0.65 per cent available phosphorus at three weeks of age. Whereas at a phosphorus level of 0.366 per cent in the diet, the corresponding values for ash, calcium and phosphorus in tibia were 22.67, 7.81 and 4.70 per cent respectively.

2.11 Livability

Scott and Heuser (1952) stated that, niacin is very much important in duck rations and any feed slightly deficient in niacin causes leg weakness.

Nesbitt *et al.* (1962) and Bulbule (1992) stated that ducks are quite susceptible to aflatoxin in the feed and also reported that the aflatoxin level to the extent of 0.03 ppm in feed is toxic to ducks.

Mahanta (1997) reported the livability of 92.12 per cent in Chara ducks and 82.27 per cent in Chemballi ducks respectively, in semi intensive system of rearing up to 40 weeks of age.

Materials and Methods

MATERIALS AND METHODS

An experiment was carried out at the Centre for Advanced Studies in Poultry Science., Kerala Agricultural University to study the calcium and phosphorus requirements of indigenous layer ducks. At 18th week of age, 90 female ducks were wing badged and housed in 45 California type cages at the rate of two ducks per cage. The dimensions of the cages were 60 x 45 x 40 cm. A floor area of 1350 cm^2 per duck was provided during the experiment. The cages had been erected in a well-ventilated and lighted house.

At 20th week of age, the body weight of ducks were recorded individually. The experimental feed was given from 21 to 40 weeks of age. Three levels of calcium viz., 3.0, 3.5 and 4.0 per cent with three levels of available phosphorus viz., 0.40, 0.50 and 0.60 per cent were employed in the diet in a 3 x 3 factorial arrangement. Thus, there were nine treatment combinations and each treatment was replicated five times comprising two birds per cage. The allotment of birds to different treatment groups as well as to the different cages was made at random. The birds under each treatment group were allocated to one of the dietary combinations as outlined below.

	Available Phosphors Level (%)		
Calcium level (%)	0.4	0.5	0.6
3.0	T_1	T_2	T_3
3.5	T_4	T_5	T_6
4.0	T_7	T_8	T_9

The feed ingredients used in the ration were analysed for proximate composition and for calcium and total phosphorus contents as per the procedure described in AOAC (1990). The experimental rations containing 18 per cent CP and 2650 Kcal ME/Kg was formulated (Table 1) as suggested by Srivastava and Panda (1982). The calcium and available phosphorus levels in the experimental diets were maintained by adding varying quantities of oyster shell grit and dicalcium phosphate.

Feed was given as wet mash three times daily and water was provided *ad lib*. The routine management practices were followed throughout the experimental period.

The experiment consisted of five periods of 28 days each from 21 to 40 weeks of age. Individual body weights were recorded at the termination of experiment at 40 weeks of age to observe the changes in body weight, if any, under the different feeding regime.

Table 1 The per cent inclusion of ingredients and the chemical composition of experimental diets.

Calcium %	3.0			3.5			4.0		
Available P %	0.4	0.5	0.6	0.4	0.5	0.6	0.4	0.5	0.6
Diet number	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
Ingredients									
Yellow maize	46	46	46	48	48	48	45.5	45.5	45.5
Rice polish	15	15	15	13	13	13	17	17	17
Wheat bran	5	5	5	4	4	4	0	0	0
Soyabean meal	14	14	14	14	14	14	14	14	14
GOC	6	6	6	5	5	5	6	6	6
Fish meal	7	7	7	8	8	8	8	8	8
Min.mixture*	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Shell grit	4.75	4.25	3.75	5.75	5.25	4.8	7.2	6.5	6.0
DCP	0.25	0.75	1.25	0.25	0.75	1.2	0.3	1.0	1.5
Total	100	100	100	100	100	100	100	100	100
Analysed value									
CP%	17.9	18.0	18.0	18.1	18.1	18.2	18.1	18.0	18.1
Ca %	3.05	3.01	3.02	3.50	3.49	3.53	4.03	4.05	4.02
Total P %	1.25	1.52	1.78	1.30	1.62	1.85	1.32	1.59	1.87
Calculated value									
Available P %	0.40	0.50	0.60	0.40	0.50	0.60	0.40	0.50	0.60
ME Kcal/kg	2650	2660	2655	2660	2655	2660	2665	2650	2655

* *Mineral mixture -Manufactured by KSE Ltd., Irinjalakuda.*
(Calcium 32 per cent, Phosphorus 5 per cent, Manganese 0.27 per cent, Iodine 0.01 per cent, Zinc 0.26 per cent, Copper (ppm) 100, Iron (ppm) 1000, Fluorine 0.03 per cent)

Daily egg production of ducks under different treatment groups was recorded during the entire experimental period. From this data, duck-housed and duck-day egg production were calculated for each period. Feed intake was measured treatment wise at the end of each week and was calculated as the mean daily feed consumption by each bird in each treatment, week wise and period wise.

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

The mean egg weight in each treatment was arrived at based on the individual egg weights recorded daily. From this data, mean egg weights and the total egg mass per week as well as per period was determined in each treatment.

During the last three consecutive days of each 28-day period, three eggs from each treatment were selected at random for shell quality studies. The eggs were weighed and shell quality was determined. The egg shell thickness was recorded by using "Ames pocket Thickness Measures" after removing shell membrane. The shell weight of each egg was recorded after breaking the eggs. The per cent shell was calculated based on egg weight.

At the end of 40 weeks of age, three birds from each treatment group were selected at random for estimation of serum calcium and serum inorganic phosphorus and for collection of tibia. The estimation of serum calcium was done by using Atomic Absorption Spectrophotometer (AAS) after diluting it with 0.1 per cent Lanthanum. The serum inorganic phosphorus was estimated by using kit according to the modified metal method.

As per the method described by Kalango and Ademosun (1973), the birds were fasted overnight, slaughtered and dressed. The muscular layers covering the tibia of each bird adhering connective and soft muscular tissue were removed by boiling the bone in one per cent solution of sodium hydroxide for about ten minutes. Then the tibia was thoroughly washed and dried in the hot air oven at 100° C for 8 h. The cooled tibia were weighed and defatted as per Panda *et al.* (2002) by soaking in petroleum ether for 48 h. Then the dried bone samples were ashed at 600 ± 30°C for 12 h for estimation of bone ash.

The weight of tibial ash was expressed as percentage of the weight of the dried tibia and the Ca and P in the tibia were estimated as per AOAC (1990).

The data collected were subjected to statistical analysis as per Snedecor and Cochran (1980).

Results

RESULTS

The week wise, period wise and the overall effects due to varying levels of dietary calcium (Ca) and available phosphorus (AP) in the diets for layer ducks are presented in Tables 2 to 30. The independent effects of the experimental diets are presented in Appendices 1 to 15. The data pertaining to the period I, that is from 21 to 24 weeks of age was not included for statistical analysis for want of minimum number of observations.

4.1 Body weight

The mean body weight of ducks in the different treatment groups at the end of 20 weeks of age, prior to the commencement of the experiment is presented in Table 2. The results revealed that, the mean body weight of ducks at 20th week ranged from 1400±9.11 to 1465±53.24 g among the nine treatment groups. The body weight of ducks intended for feeding calcium levels 3.0, 3.5 and 4.0 per cent averaged 1418±9.01, 1427±18.98 and 1448±21.46 g respectively. Those groups earmarked for feeding diets containing available phosphorus levels 0.4, 0.5 and 0.6 per cent showed average body weight of 1440±13.06, 1430±18.41 and 1423±20.29 g respectively at 20th week. The statistical analysis revealed that there was no significant difference in body weights at 20 weeks of age, among the treatment groups.

Table 2. The mean body weight (g) of indigenous layer ducks at 20 weeks of age before feeding varying levels of calcium and available phosphorus in the diet

	Available phosphorus %			
Ca %	0.4	0.5	0.6	Overall Mean
3.0	1415±23.13	1438±7.52	1400±9.11	1418±9.01
3.5	1442±11.77	1436±51.85	1405±27.43	1427±18.98
4.0	1465±29.28	1415±27.08	1465±53.24	1448±21.46
Overall Mean	1440±13.06	1430±18.41	1423±20.29	1431±9.96

Table 3 The mean body weight (g) of indigenous layer ducks at 40 weeks of age as influenced by varying levels of calcium and available phosphorus in the diet

	Available P levels (%)			
Ca %	0.4	0.5	0.6	Overall Mean
3.0	1552±42.84	1578±26.37	1546±37.58	1559±19.71
3.5	1473±18.10	1508±29.49	1579±58.28	1520±24.0
4.0	1562±65.43	1563±33.37	1535±49.23	1553±27.51
Overall Mean	1529±26.98	1549±17.88	1553±26.71	1544±13.76

The changes in the body weight at the termination of the experiment, at 40 weeks of age are presented in Table 3. The overall mean body weight of ducks fed Ca levels of 3.0, 3.5 and 4.0 per cent was 1559±19.71, 1520±24.0 and 1553±27.51 g and that with 0.4, 0.5 and 0.6 per cent available phosphorus levels was 1529±26.98, 1549±17.88 and 1553±26.71 g respectively. The Ca and AP levels in the diet did not influence the mean body weight significantly at 40 weeks of age.

4.2 Age at Sexual Maturity (ASM)

The age at first egg (AFE) and the ages at 10 and 50 per cent production in groups of ducks fed varying levels of dietary calcium and available phosphorus are presented in Tables 4 a, b and c respectively.

4.2.1 Age at first egg (AFE)

The absolute values of age at first egg (AFE) in the flock of ducks (Table 4a) fed diets containing 3.0, 3.5 and 4.0 per cent Ca level was 154, 158 and 148 days and that fed 0.4, 0.5 and 0.6 per cent available phosphorus level was161, 154 and 148 days respectively.

4.2.2 Age at 10 per cent production

The age at 10 per cent production (Table 4b) recorded with 3.0, 3.5 and 4.0 per cent Ca level was 163, 161 and 157 days and that fed with 0.4, 0.5 and 0.6 per cent of AP was 163, 158 and 155 days respectively.

Table 4 (a) The absolute value of Age at First Egg (AFE) in days in the flock of indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

	Available phosphorus %			
Ca %	0.4	0.5	0.6	Lowest value
3.0	163	154	155	154
3.5	161	158	175	158
4.0	157	158	148	148
Lowest value	161	154	148	148

Table 4 (b) The absolute value of age at 10 per cent production (days) in the flock of indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

	Available phosphorus %			
Ca %	0.4	0.5	0.6	Overall
3.0	163	154	155	163
3.5	161	158	175	161
4.0	157	158	148	157
Overall	163	158	155	148

Table 4 (c) The absolute values of age at 50 per cent production (days) in the flock of indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

	Available phosphorus %			
Ca %	0.4	0.5	0.6	Overall
3.0	172	166	179	172
3.5	176	182	189	183
4.0	188	166	168	171
Overall	183	167	178	166

4.2.3 Age at 50 per cent production

The age at 50 per cent production (Table 4c) recorded with 3.0, 3.5 and 4.0 per cent calcium level was 172, 183 and 171 days and that with 0.4, 0.5 and 0.6 per cent available phosphorus levels was 183, 167 and 178 days respectively. The number of days to reach the 50 per cent production from the age at first egg in various levels of calcium were 18, 25 and 23 days and that with various levels of available phosphorus were 22, 13 and 30 days respectively. Thus, the overall number of days to reach 50 per cent production from age at first egg was 22 days in this study.

4.3 Egg Production

4.3.1 Duck Housed Number (DHN)

The mean duck housed number (DHN) is presented week wise in Table 5 and period wise in Table 6. The overall cumulative mean effects due to Ca and P levels from 21 to 40 weeks of age are given in Table 7 and that from 25 to 40 weeks of age are furnished in Table 8. Since there was no mortality, the duck day number (DDN) of eggs was the same as that of duck housed number and hence DDN are not presented separately.

4.3.2 Week wise Duck Housed Number of Eggs

The week wise egg production per duck in the nine experimental groups from 21 to 40 weeks of age is presented in Table 5. The magnitude of variations in weekly egg production due to Ca are depicted in Figure 1 and that due to AP levels in Figure 2. The results revealed that the egg

production started at 22nd week in groups T_2 and T_9 while the group T_1 started laying at 24th week and the group T_6 started laying very late, at 25 weeks of age. During 21 to 25 weeks of age, the mean egg number per week among the groups ranged from 0.1 to 4.7 eggs per duck, the lowest being recorded in T_6 and the highest in group T_2.

The week wise mean duck housed number ranged from 1.3 to 5.1 eggs per duck among different treatments at 26th week of age. At 27th week, all groups except T_6 and T_7 crossed 50 per cent production per week with a range of values from 3.7 to 5.2 eggs/duck. This further increased to the tune of 4.7 to 5.5 eggs at 28th week of age and the average value of 5.02 was calculated as the overall mean egg number per duck per week (Table 5).

The egg production in all groups except T_2 and T_7 showed a declining trend of 3.4 to 5.4 eggs per duck per week at 29th week of age. The overall mean egg number, which was 5.02 at 28th week, reduced drastically to 4.4 at 29th week. Subsequently, it was highly fluctuating during 29 to 35 weeks of age and the overall weekly production averaged 5.0 eggs at 36th week. The egg production reduced further to 3.83 at 37th week. It increased to 4.9 eggs at 38th week and thereafter the declining trend evidenced again to 4.1 eggs at 39th week and then to 3.96 eggs at 40 weeks of age (Figure 3).

Table 5. Week wise Mean Duck Housed Number (DHN) of Eggs in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

Ca %		3			3.5			4.0		
Av.P %	0.4	0.5	0.6	0.4	0.5	0.6	0.4	0.5	0.6	Overall Mean
Diet No.	T1	T2	T3	T4	T5	T6	T7	T8	T9	
Age-wk.										
21	0	0	0	0	0	0	0	0	0	0
22	0	0.1	0	0	0	0	0	0	0.5	0.07
23	0	0.7	0.7	0.1	0.6	0	0.5	0.6	1.9	0.57
24	1.0	2.5	1.5	1.3	1.3	0	0.7	2.7	2.8	1.53
25	2.4	4.7	2.1	2.3	2.4	0.1	0.9	4.6	4.3	2.64
26	3.5	4.1	3.0	3.2	2.7	1.6	1.3	5.1	4.9	3.27
27	4.4	4.6	3.7	4.8	4.3	2.2	2.8	4.9	5.2	4.10
28	5.3	3.9	5.0	5.2	4.7	5.5	5.3	4.8	5.5	5.02
29	4.2	4.4	3.4	4.1	4.6	5.4	5.4	4.2	3.9	4.40
30	5.4	4.1	4.8	4.7	4.3	4.7	4.9	3.6	5.3	4.64
31	4.4	4.6	4.5	3.4	5.0	5.1	4.4	3.7	4.2	4.37
32	5.4	4.1	4.5	4.1	4.1	5.1	5.6	2.8	5.5	4.58
33	3.9	2.8	4.3	4.0	4.7	5.1	4.9	4.1	4.8	4.29
34	5.2	5.7	3.5	4.3	4.3	4.8	5.7	3.4	5.5	4.71
35	5.4	4.2	4.1	3.5	4.2	4.4	4.2	4.4	5.1	4.39
36	5.9	5.1	4.0	4.7	4.8	5.2	6.2	4.3	4.8	5.00
37	4.8	3.6	2.6	3.7	3.1	3.3	3.6	4.1	5.7	3.83
38	4.3	5.1	3.2	4.1	5.9	5.7	5.3	4.7	5.8	4.90
39	4.3	3.9	3.2	4.3	3.2	3.2	5.2	4.8	4.8	4.10
40	3.9	4.1	2.7	4.0	4.3	3.4	4.2	3.4	5.6	3.96
Cumulative	73.7	72.3	60.8	65.8	68.5	64.8	71.1	70.2	86.1	70.37

Fig 1. Weekly Duck Housed number(DHN) as influenced by calcium levels in the diet from 21 to 40 weeks of age

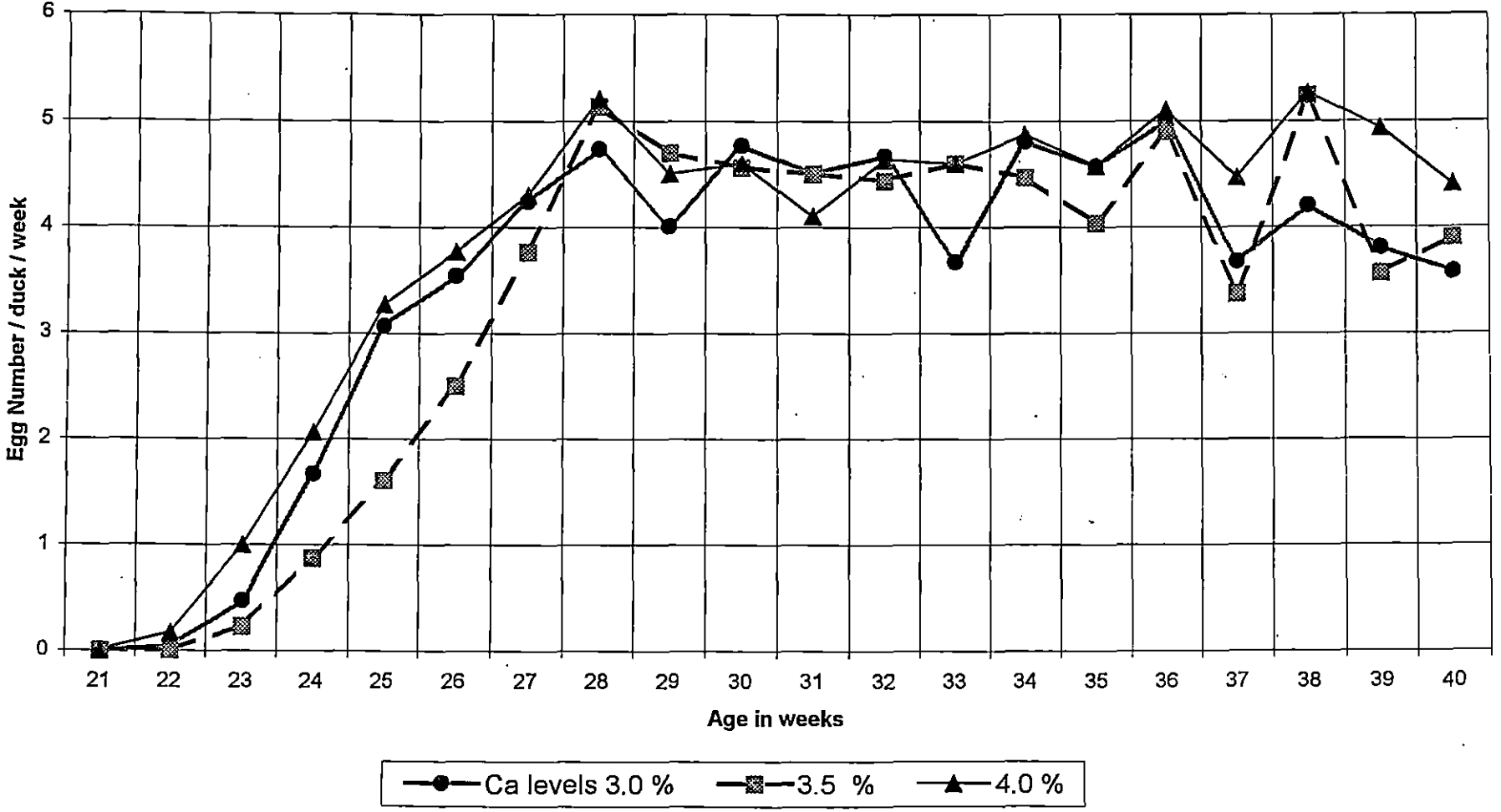


Fig 2 . Weekly Duck Housed number(DHN) as influenced by available phosphorus levels in the diet from 21 to 40 weeks of age

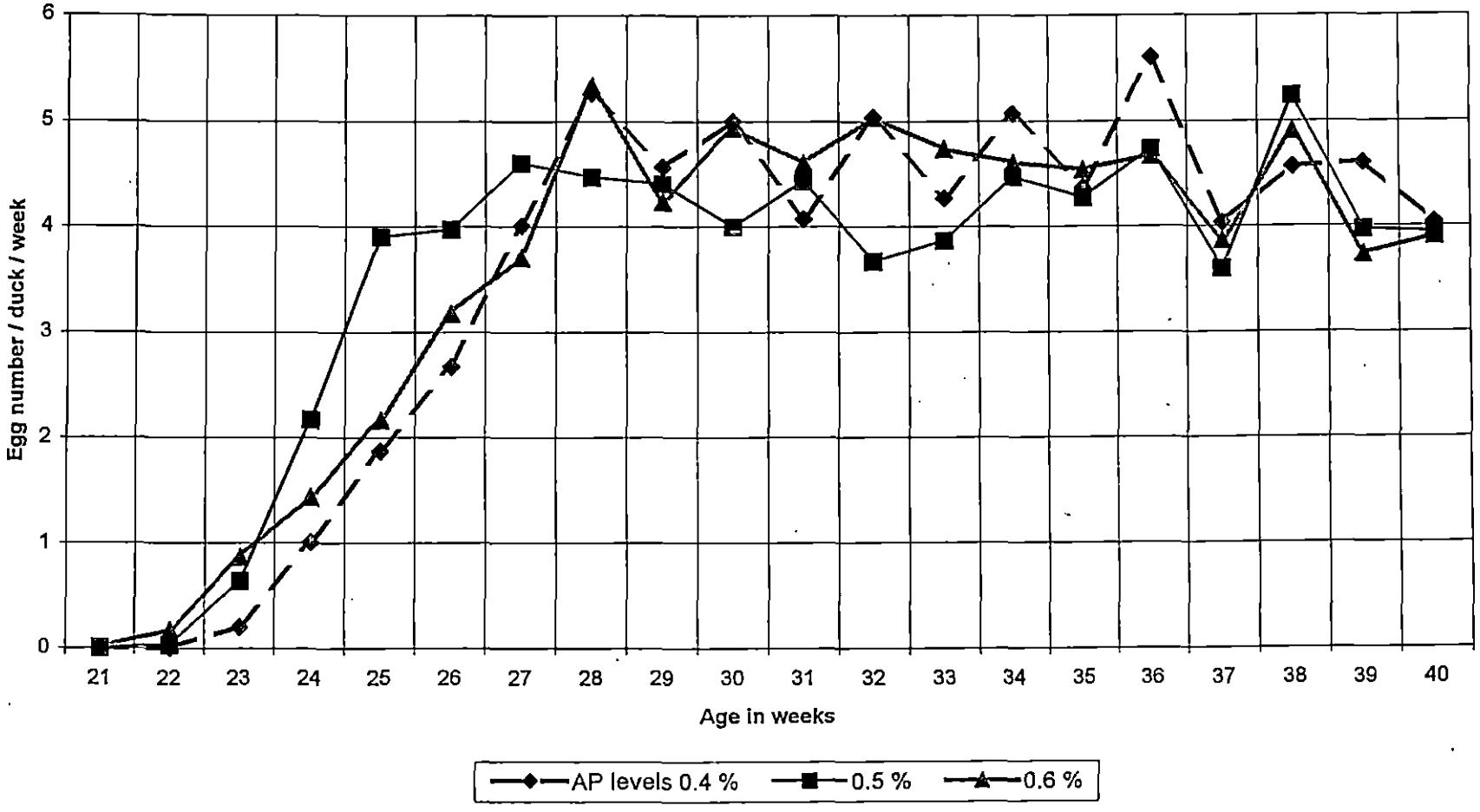
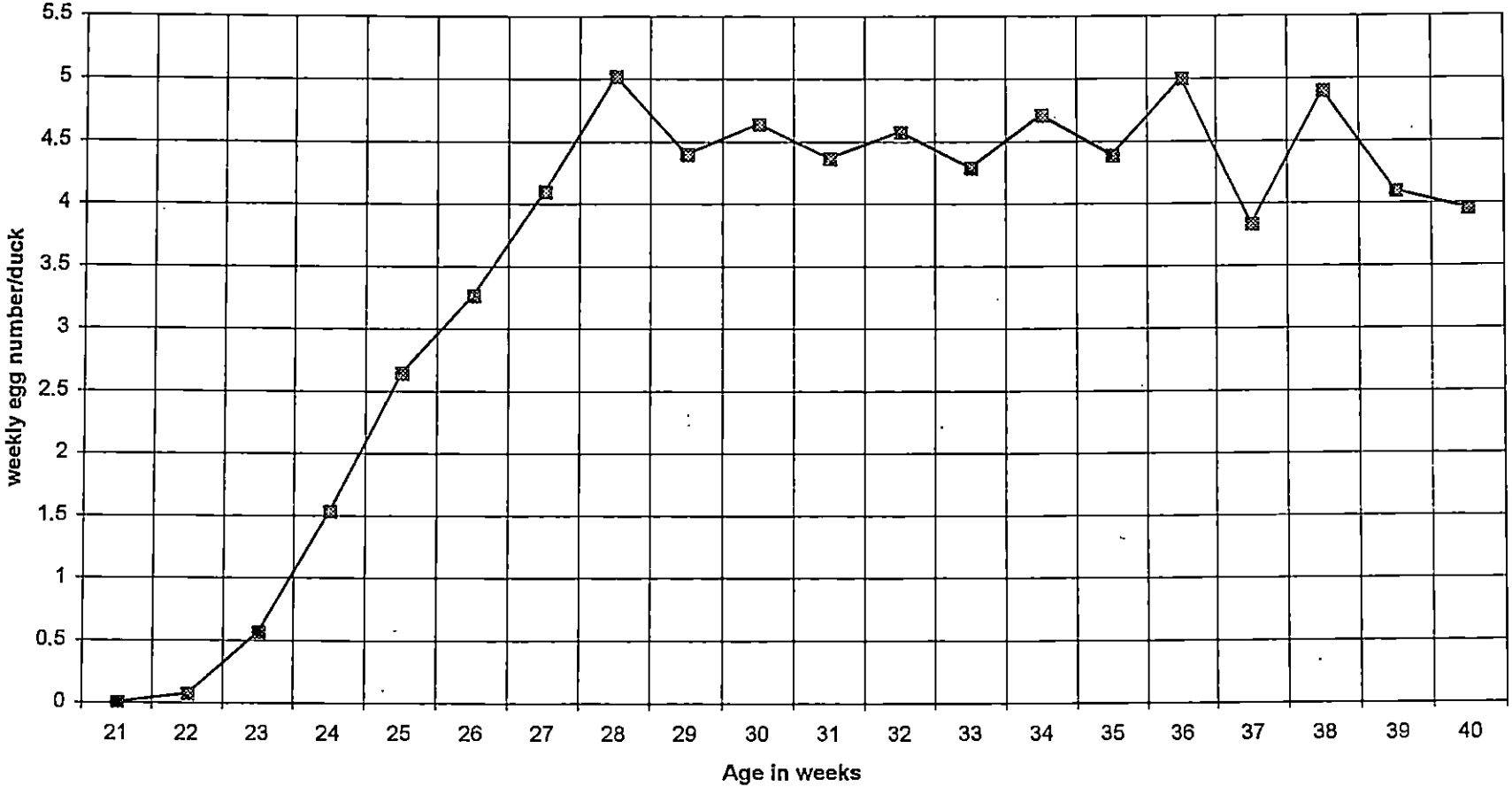


Fig 3 . Overall weekly Duck Housed Number(DHN) as influenced by calcium and available phosphorus levels in the diet from 21 to 40 weeks of age



4.3.3 Period wise Duck Housed Number of Eggs

The period wise variations in egg number due to Ca and available phosphorus (AP) are presented in Table 6. In period I, from 21 to 24 week of age, it was 2.2, 1.1 and 3.2 eggs with groups fed calcium levels 3.0, 3.5 and 4.0, per cent respectively. Whereas, it averaged 1.2, 2.8 and 2.5 eggs with available phosphorus levels 0.4, 0.5 and 0.6 per cent respectively. The overall mean egg number per duck was only 2.2 eggs in period I. The data pertaining to periods II to V on statistical analysis revealed that the calcium levels influenced the egg number significantly in periods II and V. In both these periods the mean egg numbers recorded with groups fed 4.0 per cent calcium were significantly higher ($P<0.05$) than that of 3.5 per cent Ca. The Calcium levels did not influence the egg number in periods III and IV while in period V, the mean egg number recorded with 3.0, 3.5 and 4.0 per cent levels of calcium were 15.2, 16.1 and 19.1 respectively. Where as, the AP levels did not influence the production in any of the periods studied.

The 28-day period wise overall mean egg number put together for all treatments was 2.2 in period I and it increased to 15.0 eggs in period II and further increased to 18.0 eggs in period III. Whereas, the increase was slight during period IV (18.4 eggs) and thereafter it declined to 16.8 eggs during the period V from 37 to 40 weeks of age.

The overall period wise mean presented in Table 6 also revealed that the production performance from 25 to 40 weeks of age was 18.1 eggs with

Table 6. Period wise Duck Housed Number (DHN) of eggs in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

Periods	Age in weeks	Ca levels (%)			Available P levels (%)			Overall Mean
		3.0	3.5	4.0	0.4	0.5	0.6	
I	21-24	2.2	1.1	3.2	1.2	2.8	2.5	2.2
II	25-28	15.6 ^{ab}	13.0 ^{b}	16.5 ^{a}	13.8	16.9	14.4	15.0 ^{c}
III	29-32	17.9	18.2	17.8	18.7	16.5	18.8	18.0 ^{a}
IV	33-36	18.0	18.0	19.1	19.3	17.3	18.5	18.4 ^{a}
V	37-40	15.2 ^{b}	16.1 ^{b}	19.1 ^{a}	17.2	16.7	16.4	16.8 ^{b}
Overall Mean	25-40	16.7 ^{b}	16.3 ^{b}	18.1 ^{a}	17.3	16.9	17.0	17.1
Cumul.EN	21-40	68.9 ^{b}	66.4 ^{b}	75.7 ^{a}	70.2	70.2	70.6	70.4
Cumul.EN	25-40	66.7 ^{b}	65.3 ^{b}	72.3 ^{a}	69.0	67.4	68.1	68.2

Note: *Mean values bearing same superscripts between calcium levels and within overall mean column did not differ significantly ($P < 0.05$)*

4.0 per cent calcium. This was superior over the other two levels ($P<0.05$), wherein the mean egg number recorded with 3.0 and 3.5 per cent was comparable (16.7 and 16.3 eggs) statistically. The interaction effect of calcium and available phosphorus levels was significant and the average egg number with 4.0 per cent Ca and 0.6 per cent AP was high (86.1%).

4.3.4 Cumulative Mean Duck Housed Number of Eggs

In the present study, the overall cumulative mean egg number from 21 to 40 weeks of age (Table 7) was 70.4 eggs per duck. Among the Ca diets, the highest cumulative mean egg number was recorded with 4.0 per cent calcium level. The mean values recorded with the three levels of calcium were 68.9, 66.4 and 75.7 eggs and those with three levels of available phosphorus were 70.2, 70.2 and 70.6 eggs, respectively. The cumulative egg number from 25 to 40 weeks of age was comparable between 3.0 and 3.5 per cent Ca levels (66.7 and 65.3 eggs) while that recorded with 4.0 per cent Ca (72.3 eggs) was significantly higher than other levels (Table 8). The cumulative mean egg production recorded with the three levels of AP (69.0, 67.4 and 68.1 eggs) was comparable among each other.

The overall cumulative egg number till 40 weeks of age with 3.0 per cent Ca diets was 73.7, 72.3 and 60.8 eggs with T_1, T_2 and T_3 diets containing available P levels 0.4, 0.5 and 0.6 per cent respectively. Similarly with 3.5 per cent Ca diets, T_4, T_5 and T_6, the corresponding egg production was 65.8, 68.5 and 64.8 eggs. The cumulative egg production

Table 7. The overall mean Duck Housed Number (DHN) of eggs from 21 to 40 weeks of age in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

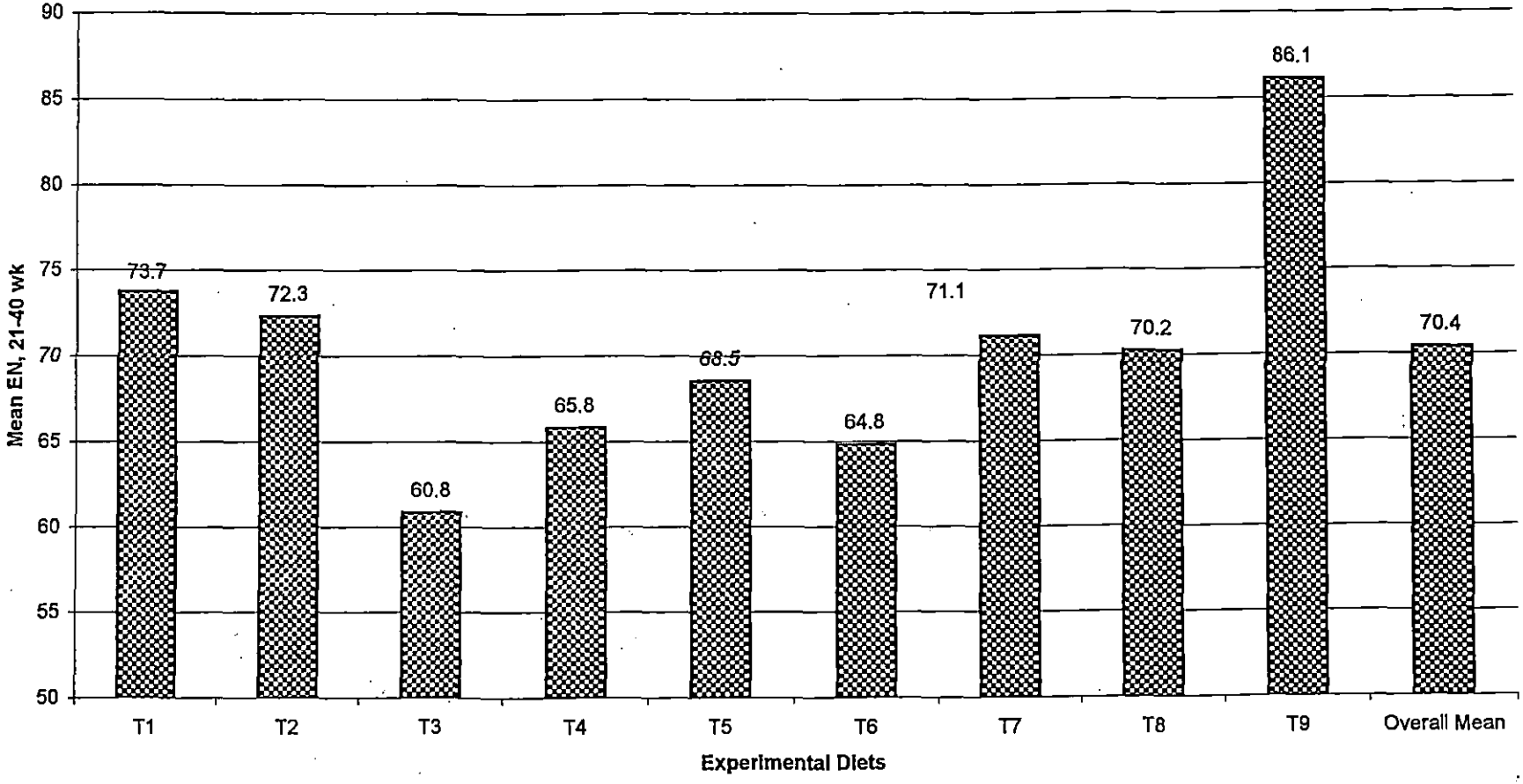
	Available phosphorus %			
Ca %	0.4	0.5	0.6	Overall Mean
3.0	73.7	72.3	60.8	68.9
3.5	65.8	68.5	64.8	66.4
4.0	71.1	70.2	86.1	75.7
Overall Mean	70.2	70.2	70.6	70.4

Table 8. The overall mean Duck Housed Number (DHN) of eggs from 25 to 40 weeks of age in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

	Available phosphorus %			
Ca %	0.4	0.5	0.6	Overall Mean
3.0	72.7	69.3	58.6	66.7 [b]
3.5	64.4	67.6	64.8	65.3 [b]
4.0	69.9	66.9	80.9	72.3 [a]
Overall Mean	69.0	67.4	68.1	68.2

Note: *Mean values bearing same superscripts did not differ significantly ($P < 0.05$)*

Fig 4. Duck Housed Number (DHN) as influenced by various experimental diets from 21 to 40 weeks of age



with 4.0 per cent Ca diets (T_7, T_8 and T_9) containing 0.4, 0.5 and 0.6 per cent AP was 71.1, 70.2 and 86.1 eggs respectively (Figure 4).

4.3.5 Duck Housed Per cent (DHP) Production

The period wise Duck Housed Per cent (DHP) Production is presented in Table 9 and the cumulative results are presented in Tables 10 and 11.

4.3.6 Period wise Duck Housed Per cent (DHP) Production

In period I, the Duck Housed Per cent (DHP) Production was 7.3±2.76, 3.9±1.86 and 10.4±4.44 with Ca levels and 4.3±2.34, 8.9±1.85 and 8.8±6.15 per cent with AP levels respectively (Table 9).

In period II, it was averaged 55.6±4.00, 46.4±4.05 and 59.0±5.00 per cent with Ca levels. The Ca levels did not influence egg production significantly in periods III (63.2±3.69, 64.6±2.62 and 62.9±3.49 per cent) and in period IV (64.4±3.22, 64.3±3.17 and 68.3±3.33 per cent). In period V, the mean egg production with 3.0 and 3.5 per cent Ca levels (54.4±4.20, 56.6±3.49 per cent) were comparable and that with 4.0 per cent Ca (68.1±3.05 per cent) was significantly higher in comparison with other levels. The available P levels did not influence the duck housed per cent production in any of the periods. It was 49.3±4.33, 60.5±4.08 and 51.3±4.80 per cent in period II and 66.3±2.49,58.1±3.34 and 66.3±3.50 per cent in

Table 9. Period wise duck-housed percent (DHP) production in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

Periods	Age in weeks	Ca levels (%)			Available P levels (%)			Overall mean
		3.0	3.5	4.0	0.4	0.5	0.6	
I	21-24	7.3±2.76	3.9±1.86	10.4±4.44	4.3±2.34	8.9±1.85	8.8±6.15	7.3±2.03
II	25-28	55.6±4.0^{ab}	46.4±4.05^{b}	59.0±5.0^{a}	49.3±4.33	60.5±4.08	51.3±4.80	53.7±2.60^{c}
III	29-32	63.2±3.69	64.6± 2.62	62.9±3.49	66.3±2.49	58.1±3.34	66.3±3.50	63.6±1.86^{a}
IV	33-36	64.4±3.22	64.3± 3.17	68.3±3.33	68.9±2.56	61.9±3.36	66.2±3.56	65.7±1.85^{a}
V	37-40	54.4±4.20^{b}	56.6±3.49^{b}	68.1±3.05^{a}	61.5±4.21	59.0±2.28	58.6±4.86	59.7±2.23^{b}
Overall Mean	25-40	59.4±1.94^{b}	58.0±1.90^{b}	64.6±1.92^{a}	61.5±1.97	60.0±1.63	60.6±2.21	60.7±1.12

Note: *Mean values bearing same superscripts between calcium levels and within overall mean column did not differ significantly ($P < 0.05$)*

period III and 68.9±2.56, 61.9±3.36 and 66.2±3.56 per cent in period IV and 61.5±4.21, 59.0±2.28 and 58.6±4.86 per cent in period V.

4.3.7 Cumulative Mean Duck Housed Per cent (DHP) Production

The overall cumulative mean egg production from 25 to 40 weeks of age ranged from 52.0 to 71.9 per cent among dietary treatments with a mean of 60.7±1.12 per cent over all treatments put together (Table 11). The per cent production due to Ca levels was 59.4±1.94, 58.0±1.90 and 64.6±1.92 per cent and that due to AP levels was 61.5±1.97, 60.0±1.63 and 60.6±2.21 per cent respectively. The cumulative per cent production was comparable between 3.0 and 3.5 per cent Ca levels and that recorded with 4.0 per cent Ca was significantly higher than other levels. The cumulative mean egg production with the three levels of AP was comparable among each other. The overall mean per cent from 21 to 40 weeks of age was ranged from 43.2 to 61.3 with an overall mean of 50.0±1.54 per cent (Table 10). The per cent production due to Ca levels were 49.1±2.56, 47.2±2.61 and 53.7±2.8 per cent and that due to AP levels were 50.1±2.65, 49.7±2.62 and 50.2±2.70 per cent respectively. The interaction was also significant. There was two peak egg production (71.7) at 28 and 36 week of age with an overall mean of 60.7 per cent (Fig. 5).

4.4 Feed consumption

4.4.1 Period wise Mean Daily Feed Consumption

The period wise daily feed consumption from 21 to 40 weeks of age for groups fed varying levels of calcium and available phosphorus is presented in Table 12 and its overall cumulative effect in Table 13. The mean daily feed

Fig 5. Weekly Duck Housed per cent (DHP) production as influenced by calcium and available phosphorus levels in the diet (21 to 40 weeks)

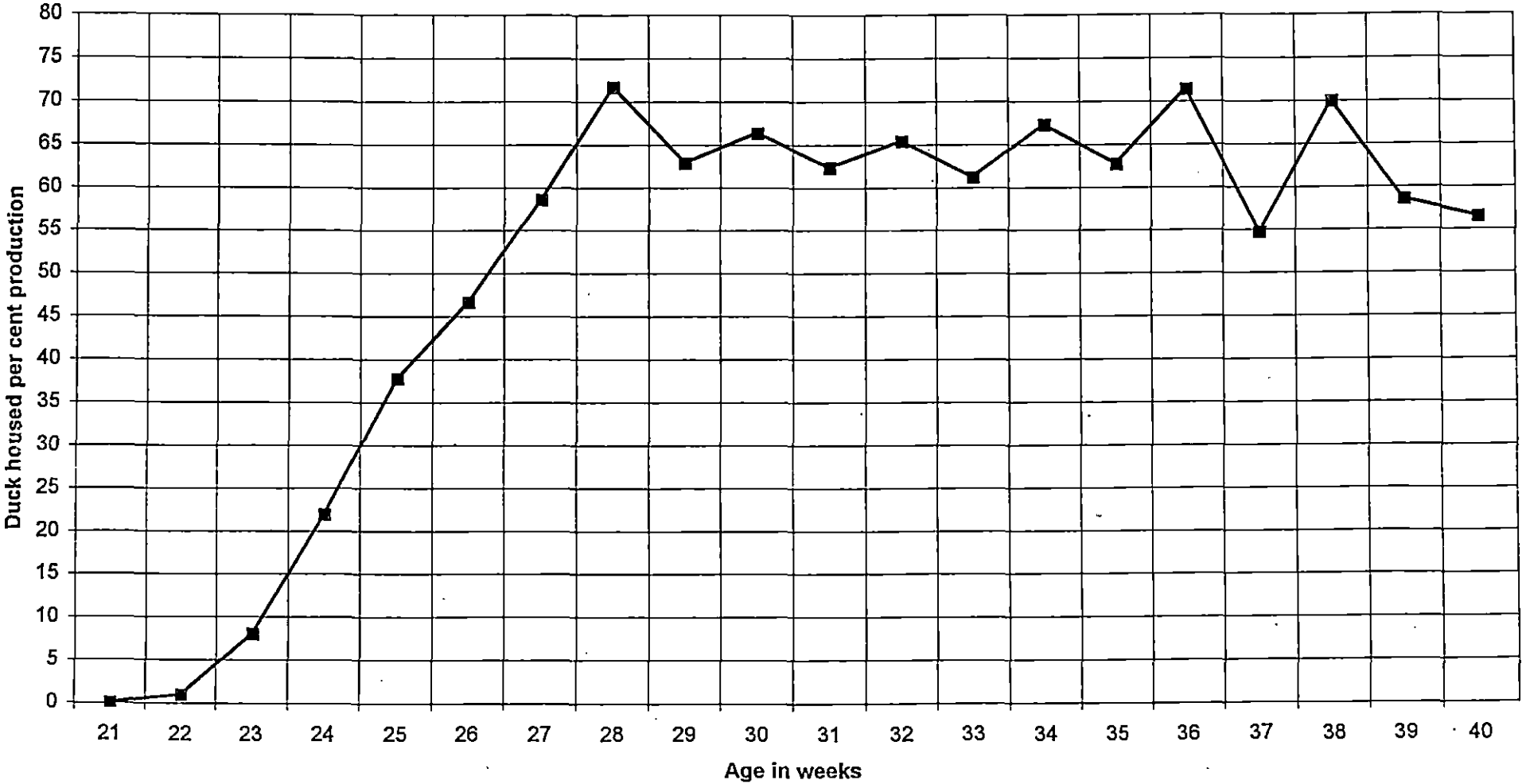


Table 10. The overall mean percent duck-housed production from 21 to 40 weeks of age in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

	Available phosphorus %			
Ca %	0.4	0.5	0.6	Overall Mean
3.0	52.4±5.7	51.6±4.65	43.2±4.65	49.1±2.56
3.5	47.0±4.81	48.2±4.90	46.3±5.77	47.2±2.61
4.0	50.8±5.78	49.2±4.78	61.3±5.01	53.7±2.80
Overall Mean	50.1±2.65	49.7±2.62	50.2±2.70	50.0±1.54

Table 11. The overall mean percent duck-housed production from 25 to 40 weeks of age in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

	Available phosphorus %			
Ca %	0.4	0.5	0.6	Overall Mean
3.0	64.6±3.35	61.6±2.66	52.0±3.49	59.4 ±1.94 [b]
3.5	57.5±2.70	58.6±3.03	57.9±4.16	58.0 ±1.90 [b]
4.0	62.4±4.04	59.4±2.87	71.9±2.27	64.6 ±1.92 [a]
Overall Mean	61.5±1.97	60.0±1.63	60.6±2.21	60.7±1.12

Note: *Mean values bearing same superscripts did not differ significantly ($P < 0.05$)*

consumption during the first period with calcium levels 3.0, 3.5 and 4.0 per cent was 99.3±2.09, 100.9±2.42 and 106.1±2.40 g respectively. The mean daily feed consumption was 113.9±4.34, 113.0±3.58 and 119.9±4.45 g in period II, 138.7±3.71, 129.8±3.33 and 136.6±2.93 g in period III, 150.9±3.21, 147.2±1.45 and 158.4±4.00 g in period IV and 145.4±2.14,144.4±1.37 and 147.9±2.29 g in period V for the three levels of calcium respectively. The overall mean daily feed consumption from 25 to 40 weeks of age due to the three levels of Ca were 137.2±2.65, 133.6±3.36 and 140.7±2.69 g respectively and the statistical analysis revealed that the calcium levels did not influence the feed consumption significantly.

In period I, the mean daily feed consumption with available phosphorus levels 0.4, 0.5 and 0.6 per cent was 101.7±2.45, 103.3±2.27 and 101.3±2.63 g. It increased to 112.3±3.77, 119.9±4.05 and 114.7±4.55 g in period II, 133.7±3.07, 138.5±3.96 and 132.9±3.25 g in period III, 151.7±2.94, 153.8±3.02 and 151.0±4.03 g in period IV and 146.6±2.00, 145.4±1.66 and 145.7±2.35 g in period V with AP level of 0.4, 0.5 and 0.6 per cent respectively. The overall mean daily feed consumption from 25 to 40 weeks of age due to the three levels of phosphorus were 136.1±2.66, 139.4±2.43 and 136.1±2.70 g respectively and the statistical analysis revealed that the available phosphorus levels did not influence the feed consumption significantly.

Table 12. Mean period wise daily feed consumption (g) in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

Periods	Age	Ca levels (%)			Available P levels (%)			Overall Mean
		3.0	3.5	4.0	0.4	0.5	0.6	
I	21-24	99.3±2.09	100.9±2.42	106.1± 2.40	101.7±2.45	103.3±2.27	101.3±2.63	102.1±1.39
II	25-28	113.9±4.34	113±3.58	119.9± 4.45	112.3±3.77	119.9±4.05	114.7±4.55	115.6±2.38[d]
III	29-32	138.7±3.71	129.8±3.33	136.6± 2.93	133.7±3.07	138.5±3.96	132.9±3.25	135.0±1.98[c]
IV	33-36	150.9±3.21	147.2±1.45	158.4± 4.00	151.7±2.94	153.8±3.02	151.0±4.03	152.2±1.90[a]
V	37-40	145.4±2.14	144.4±1.37	147.9± 2.29	146.6±2.0	145.4±1.66	145.7±2.35	145.9±1.14[b]
Overall Mean	25-40	137.2±2.65	133.6±3.36	140.7± 2.69	136.1±2.66	139.4±2.43	136.1±2.70	137.2±1.49

Note: *Mean values bearing same superscripts within in the overall mean column did not differ significantly ($P < 0.05$)*

Table 13. The overall mean daily feed consumption (g) from 21 to 40 weeks of age in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

	Available phosphorus %			
Ca %	0.4	0.5	0.6	Overall Mean
3.0	129.2±4.85	136.2±5.37	123.4±4.79	129.6±2.92
3.5	125.4±4.77	127.5±4.37	128.3±4.47	127.1±2.58
4.0	132.9±5.10	132.8±4.44	135.6±5.41	133.8±2.84
Overall Mean	129.2±2.81	132.2±2.74	129.1±2.86	130.2±1.61

The period wise mean daily feed consumption over all treatments put together was 102.1±1.39 g in period I and it increased to 115.6±2.38, 135.0±1.98 and 152.2±1.90 g in periods II, III and IV respectively. The mean daily feed consumption was declined to 145.9±1.14 g in period V. The statistical analysis revealed that the mean daily feed consumption was influenced significantly by periods.

4.4.2 Cumulative Mean Daily Feed Consumption

The overall mean daily feed consumption from 21 to 40 weeks of age is presented in Table 13. It was ranged from 123.4±4.79 to 136.2±5.37 g with an overall mean of 130.2±1.61 g. The mean daily feed consumption due to Ca levels was 129.6±2.92, 127.1±2.58 and 133.8±2.84 g and that due to AP levels was 129.2±2.81, 132.2±2.74 and 129.1±2.86 g respectively. The Ca and available P levels did not influence the mean daily consumption significantly.

4.4.3 Feed Conversion Ratio (FCR)

The period wise FCR on the basis of dozen eggs from 21 to 40 weeks of age is presented in Table 14 and its overall effect for 25 to 40 weeks of age is presented in Table 15. The FCR on the basis of kilogram egg mass for 21 to 40 weeks of age is presented in Table 16 and its cumulative conversion ratio for 25 to 40 weeks of age is presented in Table 17.

4.4.4 Period wise Mean FCR / Dozen Eggs

Table 14 showed that the mean FCR during the first period with 3.0, 3.5 and 4.0 per cent Ca levels were 19.7±7.34, 20.5±2.46 and 15.4±6.76 and that with 0.4, 0.5 and 0.6 per cent available P levels were 28.6±3.24, 13.1±2.48 and 10.7±4.06 respectively. The overall FCR during this period was 18.5±3.41.

The mean FCR was 2.5±0.08, 3.0±0.487 and 2.6±0.528 in period II, 2.6±0.171, 2.4±0.139 and 2.6±0.283 in period III, 2.9±0.196, 2.8±0.139 and 2.8±0.203 in period IV and 3.3±0.359, 3.0±0.075 and 2.6±0.164 in period V respectively, for the three levels of Ca in the diet. The calcium levels did not influence the FCR significantly in any of the periods studied. Likewise, the available phosphorus levels also did not influence the FCR in any of the above periods. The mean FCR was 2.8±0.43, 2.4±0.171 and 2.9±0.573 in period II, 2.4±0.123, 2.8±0.129 and 2.4±0.109 in period III, 2.7±0.17, 3.0±0.13 and 2.6±0.162 in period IV and 2.9±0.066, 2.9±0.046 and 3.2±0.487 in period V respectively for the three levels of available phosphorus viz., 0.4, 0.5 and 0.6 per cent in the diet. The overall cumulative mean FCR from 25 to 40 weeks of age due to the three levels of Ca were 2.8±0.135, 2.8±0.137 and 2.7±0.141 and that due to AP levels were 2.7±0.116, 2.8±0.095 and 2.8±0.186 respectively. The statistical analysis revealed that neither the Ca nor the available phosphorus levels significantly influenced the FCR.

The period wise overall mean FCR was 2.7±0.23, 2.5±0.11, 2.8±0.09 and 3.0±0.15 in period II, III, IV and V respectively. The statistical analysis revealed that the period wise overall mean FCR at period III was significantly better than that recorded for the period V ($P<0.01$).

4.4.5 Cumulative Mean FCR / Dozen Eggs

The overall mean cumulative FCR from 25 to 40 weeks of age presented in Table 15 showed that it was ranged from 2.4±0.13 to 3.1±0.34 among treatment groups with an overall mean of 2.8±0.08 (Fig.6). The effect of Ca levels were 2.8±0.14, 2.8±0.14 and 2.7±0.14 and that due to AP levels were 2.7±0.12, 2.8±0.10 and 2.8±0.19 respectively, showing better ratio with 4.0 per cent Ca and 0.4 per cent AP. The numerical values with other levels of Ca and AP were almost similar.

4.4.6 Period wise FCR / Kg Egg Mass

The Feed Conversion Ratios (FCR) / kg egg mass with groups fed varying levels of dietary calcium (Ca) and available phosphorus (AP) are presented in Table 16. The FCR recorded in period I was 32.3±10.83, 33.8±5.85 and 27.2±12.45 with 3.0, 3.5 and 4.0 per cent calcium levels and 48.2±4.34, 21.1±3.40 and 31.1±7.55 with 0.4, 0.5 and 0.6 per cent available phosphorus levels respectively.

Table 14. Mean Feed Conversion Ratio (FCR) per dozen eggs in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

Periods	Age in weeks	Ca levels (%)			Available P levels (%)			Overall Mean
		3.0	3.5	4.0	0.4	0.5	0.6	
I	21-24	19.7±7.34	20.5±2.46	15.4±6.76	28.6±3.24	13.1±2.48	10.7±4.06	18.5±3.41
II	25-28	2.5±0.08	3.0±0.49	2.6±0.53	2.8±0.43	2.4±0.17	2.9±0.57	2.7 ±0.23^{ab}
III	29-32	2.6±0.17	2.4±0.14	2.6±0.28	2.4±0.12	2.8±0.22	2.4±0.11	2.5±0.11^{b}
IV	33-36	2.9±0.20	2.8±0.14	2.8±0.20	2.7±0.17	3.0±0.13	2.6±0.16	2.8±0.09^{ab}
V	37-40	3.3±0.36	3.0±0.08	2.6±0.16	2.9±0.07	2.9±0.05	3.2±0.49	3.0±0.15^{a}
Overall Mean	25-40	2.8±0.14	2.8±0.14	2.7±0.14	2.7±0.12	2.8±0.10	2.8±0.19	2.8±0.08

Note: *The period wise overall mean values bearing same superscripts did not differ significantly ($P< 0.01$).*

Table 15. The overall mean Feed Conversion Ratio (FCR) per dozen eggs in indigenous layer ducks from 25 to 40 weeks of age as influenced by varying levels of calcium and available phosphorus in the diet

	Available phosphorus %			
Ca %	0.4	0.5	0.6	Overall Mean
3.0	2.5±0.119	2.8±0.152	3.1±0.338	2.8±0.135
3.5	2.8±0.135	2.7±0.102	3.0±0.407	2.8±0.137
4.0	2.8±0.315	2.9±0.251	2.4±0.125	2.7±0.141
Overall Mean	2.7±0.116	2.8±0.095	2.8±0.186	2.8±0.078

The period wise FCR per Kg egg mass for periods II to V on statistical analysis revealed that the Ca and AP levels did not influence significantly in any of the periods. The FCR with Ca levels 3.0, 3.5 and 4.0 per cent averaged 3.8±0.052, 4.7±0.697 and 4.1±0.740 in period II, 3.8±0.236, 3.5±0.134 and 3.8±0.289 in period III, 3.7±0.229, 3.8±0.162 and 3.8±0.222 in period IV and 4.2±0.326, 3.9±0.101 and 3.4±0.176 in period V respectively. For AP levels 0.4, 0.5 and 0.6 per cent, it averaged 4.4±0.588, 3.7±0.185 and 4.5±0.827 in period II,, 3.5±0.119, 4.0±0.207 and 3.6±0.153 in period III, 3.6±0.22, 4.0±0.126 and 3.7±0.138 in period IV and 3.7±0.113, 3.8±0.072 and 4.0±0.503 in period V, respectively.

The period wise overall mean FCR/ kg egg mass was 4.2±0.323, 3.7±0.121, 3.8±0.104 and 3.8±0.156 in periods II to V respectively, with almost similar ratios in periods III to V. The differences between the mean values were non-significant.

4.4.7 Overall FCR / Kg Egg Mass

The cumulative overall mean FCR recorded from 25 to 40 weeks of age with calcium levels 3.0, 3.5 and 4.0 per cent were 3.9±0.115, 4.0±0.205 and 3.8±0.194 and that with available phosphorus levels 0.4, 0.5 and 0.6 per cent were 3.8±0.179, 3.9±0.081 and 4.0±0.234 respectively. The statistical analysis revealed that the Ca and AP levels did not influence the cumulative FCR/ kg egg mass (Table 17). The overall mean cumulative FCR from 25 to 40 weeks of age showed that it was ranged from 3.6 to 4.3 among treatment group with an overall mean of 3.9 (Fig.6).

Table 16. Mean Feed Conversion Ratio per Kg egg mass in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in diet

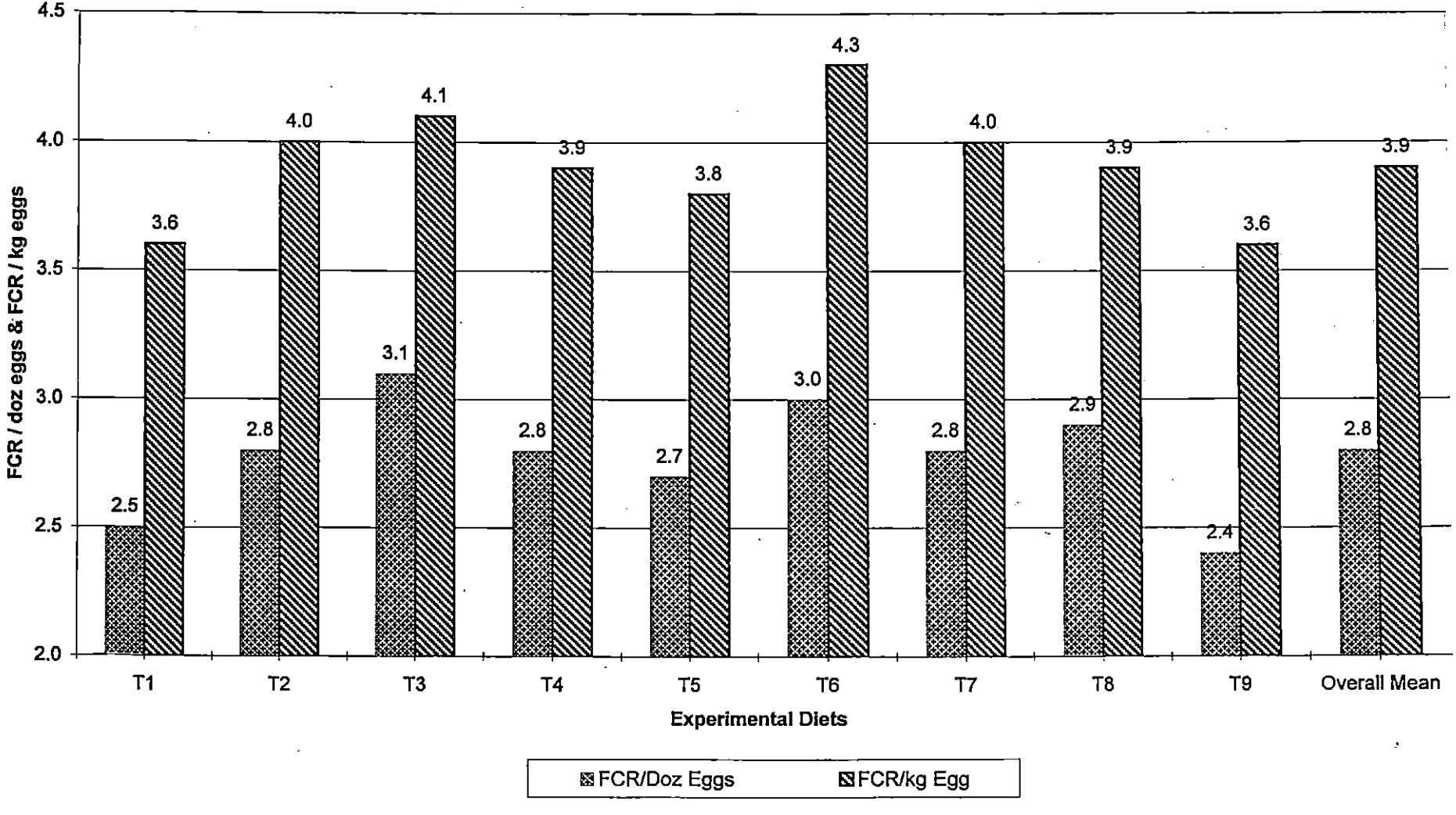
Periods	Age in weeks	Ca levels (%)			Available P levels (%)			Overall Mean
		3.0	3.5	4.0	0.4	0.5	0.6	(NS)
I	21-24	32.3±10.83	33.8±5.85	27.2±12.45	48.2±4.34	21.1±3.40	31.1±7.55	31.1±5.61
II	25-28	3.8±0.052	4.7±0.697	4.1±0.740	4.4±0.588	3.7±0.185	4.5±0.827	4.2±0.323
III	29-32	3.8±0.236	3.5±0.134	3.8±0.289	3.5±0.119	4.0±0.207	3.6±0.153	3.7±0.121
IV	33-36	3.7±0.229	3.8±0.162	3.8±0.222	3.6±0.220	4.0±0.126	3.7±0.138	3.8±0.104
V	37-40	4.2±0.326	3.9±0.101	3.4±0.176	3.7±0.113	3.8±0.072	4.0±0.503	3.8±0.156
Overall Mean (NS)	25-40	3.9±0.115	4.0±0.205	3.8±0.194	3.8±0.179	3.9±0.081	4.0±0.234	3.9±0.099

NS - No significant difference

Table 17. The overall mean Feed Conversion Ratio (FCR) per Kg egg mass in indigenous layer ducks from 25 to 40 weeks of age as influenced by varying levels of calcium and available phosphorus in diet

	Available phosphorus %			
Ca %	0.4	0.5	0.6	Overall Mean
3.0	3.6±0.131	4.0±105	4.1±0.260	3.9±0.115
3.5	3.9±0.070	3.8±0.082	4.3±0.645	4.0±0.205
4.0	4.0±0.548	3.9±0.222	3.6±0.169	3.8±0.194
Overall Mean	3.8±0.179	3.9±0.081	4.0±0.234	3.9±0.099

Fig 6. FCR per dozen and per Kg egg mass as influenced by various experimental diets from 25 to 40 weeks of age



4.5 Egg Weight (EW)

The data pertaining to the period wise mean EW is presented in Table 18 and the cumulative data is presented in Table 19.

4.5.1 Period wise mean EW

The period wise mean egg weight (g) in groups fed varying levels of dietary calcium (Ca) and available phosphorus (AP) are presented in Table 18. The mean egg weight during period I (21 to 24 weeks of age) with calcium levels 3.0, 3.5 and 4.0 per cent were 49.7±0.822, 51.1±0.93 and 48.8±0.36 g and that with available phosphorus levels 0.4, 0.5 and 0.6 per cent were 50.2±0.63, 51.0±0.575 and 47.1±1.705 g respectively.

The mean EW for period II to V on statistical analysis revealed that the effects of calcium and AP levels were significant in all periods except period IV. In period II, the mean egg weight recorded with 3.0 and 3.5 per cent calcium levels (54.6±0.46 and 54.2±0.65 g) were comparable and both these values were significantly higher than that recorded with 4.0 per cent calcium (53.3±0.31 g). In period III, the mean EW recorded with the three levels of calcium were 58.4±0.344, 56.7±0.188 and 57.7±0.65 g and all these values were significantly different among each other ($P<0.01$). Whereas, the calcium levels did not influence the egg weights significantly in period IV and the average egg weights were 62.0±0.38, 61.7±0.22 and 61.9±0.47 g respectively. In period V, the trend of

results exhibited in period II was repeated. Wherein, the mean EW was similar with 3.0 and 3.5 per cent calcium levels (65.4±0.66 and 65.5±0.31 g) and both these values were significantly higher ($P<0.01$) than that recorded with 4.0 per cent Ca (63.3±0.41 g).

In period II, the mean EW recorded with 0.5 and 0.6 per cent AP levels (54.4±0.46 and 54.6±0.55 g) were comparable to each other and was significantly higher ($P<0.01$) than the mean EW recorded with 0.4 per cent available P (53.1±0.44g). In period III also, the mean EW recorded with 0.4 per cent available P (57.0±0.12 g) was significantly lower and it was comparable with that of 0.6 per cent available P level (56.9±0.39 g). Both these values were significantly lower ($P<0.01$) than that of 0.5 per cent AP (58.9±0.59 g). Whereas, the AP levels did not influence the egg weights significantly in period IV and the average egg weights recorded with the three levels of AP were 62.0±0.35, 62.0±0.34 and 61.6±0.41 g respectively. In period V, significantly higher mean EW were recorded with 0.5 and 0.6 per cent levels (65.2±0.43 and 65.1±0.71 g) in comparison to that recorded with 0.4 per cent AP level (63.9±0.40 g).

The period wise egg weight for all treatment groups put together was 49.4±0.42 g in period I. This EW was increased gradually as age advanced and reached the level of 54.0±0.29, 57.6±0.27, 61.9±0.21 and 64.7±0.31 g in periods II, III, IV and V respectively and the progressive increase in EW from period II to V was significant ($P<0.05$).

Table 18. Period wise mean egg weight in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

Periods	Age	Ca levels (%)			Available P levels (%)			Overall Mean
		3.0	3.5	4.0	0.4	0.5	0.6	
I	21-24	49.7±0.82	51.1±0.93	48.8±0.36	50.2±0.63	51.0±0.58	47.1± 1.71	49.4±0.42
II	25-28	54.6±0.46^{a}	54.2±0.65^{a}	53.3±0.31^{b}	53.1±0.44^{b}	54.4±0.46^{a}	54.6±0.55^{a}	54.0±0.29^{d}
III	29-32	58.4±0.34^{a}	56.7±0.19^{c}	57.7±0.65^{b}	57.0±0.12^{b}	58.9±0.59^{a}	56.9±0.39^{b}	57.6±0.27^{c}
IV	33-36	62.0±0.38	61.7±0.22	61.9±0.47	62.0±0.35	62.0±0.34	61.6±0.41	61.9±0.21^{b}
V	37-40	65.4±0.66^{a}	65.5±0.31^{a}	63.3±0.41^{b}	63.9±0.40^{b}	65.2±0.43^{a}	65.1±0.71^{a}	64.7±0.31^{a}
Overall Mean	25-40	60.1±0.58^{a}	59.5±0.60^{b}	59.0±0.56^{c}	59.0±0.58^{c}	60.1±0.57^{a}	59.5±0.59^{b}	59.6±0.33

Note: *Mean values bearing same superscripts between calcium levels and within overall mean column did not differ significantly ($P < 0.05$)*

Table 19. The overall mean egg weight (g) in indigenous layer ducks from 25 to 40 weeks of age as influenced by varying levels of calcium and available phosphorus in the diet

Ca %	Available phosphorus %			
	0.4	0.5	0.6	Overall Mean
3.0	58.5±0.84^{d}	60.4±1.09^{b}	61.5±0.97^{a}	60.1±0.58^{a}
3.5	58.8±1.18^{d}	59.9±0.93^{bc}	59.9±1.01^{bc}	59.5±0.60^{b}
4.0	59.7±0.97^{c}	60.1±0.97^{bc}	57.3±0.88^{e}	59.0±0.56^{c}
Overall Mean	59.0±0.58^{c}	60.1±0.57^{a}	59.5±0.59^{b}	59.6±0.33

Note: *Mean values bearing same superscripts between experimental diets and within overall mean values did not differ significantly ($P < 0.01$)*

4.5.2 Overall Cumulative Mean EW

The overall cumulative mean egg weight from 25-40 weeks of age was ranged from 57.3±0.88 g to 61.5±0.97 g with an overall mean of 59.60±0.33g (Fig.7). The data revealed that the mean EW was decreased significantly ($P<0.01$) as the level of Ca increased in the diet. The mean EW with calcium levels 3.0, 3.5 and 4.0 per cent were 60.1±0.575, 59.5±0.599 and 59.0±0.558 g respectively. The overall cumulative mean egg weight with 0.4, 0.5 and 0.6 AP levels were 59.0±0.578, 60.1±0.566 and 59.5±0.588 g (Table 19) and the numerical differences between the mean EW was significant among each other ($P<0.01$). The interaction was also significant.

4.6 Egg Mass (EM)

The mean egg mass in kg per duck up to 40 weeks of age is presented in Table 20.

4.6.1 Period wise Mean EM

The period wise results presented in Table 20 revealed that it was highly variable between treatment groups.

4.6.2 Overall Mean EM

The overall mean egg mass presented in Table 21 revealed that values were ranged from 3.712 to 4.846 kg among experimental diets with an overall mean of 4.163 kg (Fig.8).

Fig 7. Egg Weight (g) as influenced by various experimental diets from 25 to 40 weeks of age

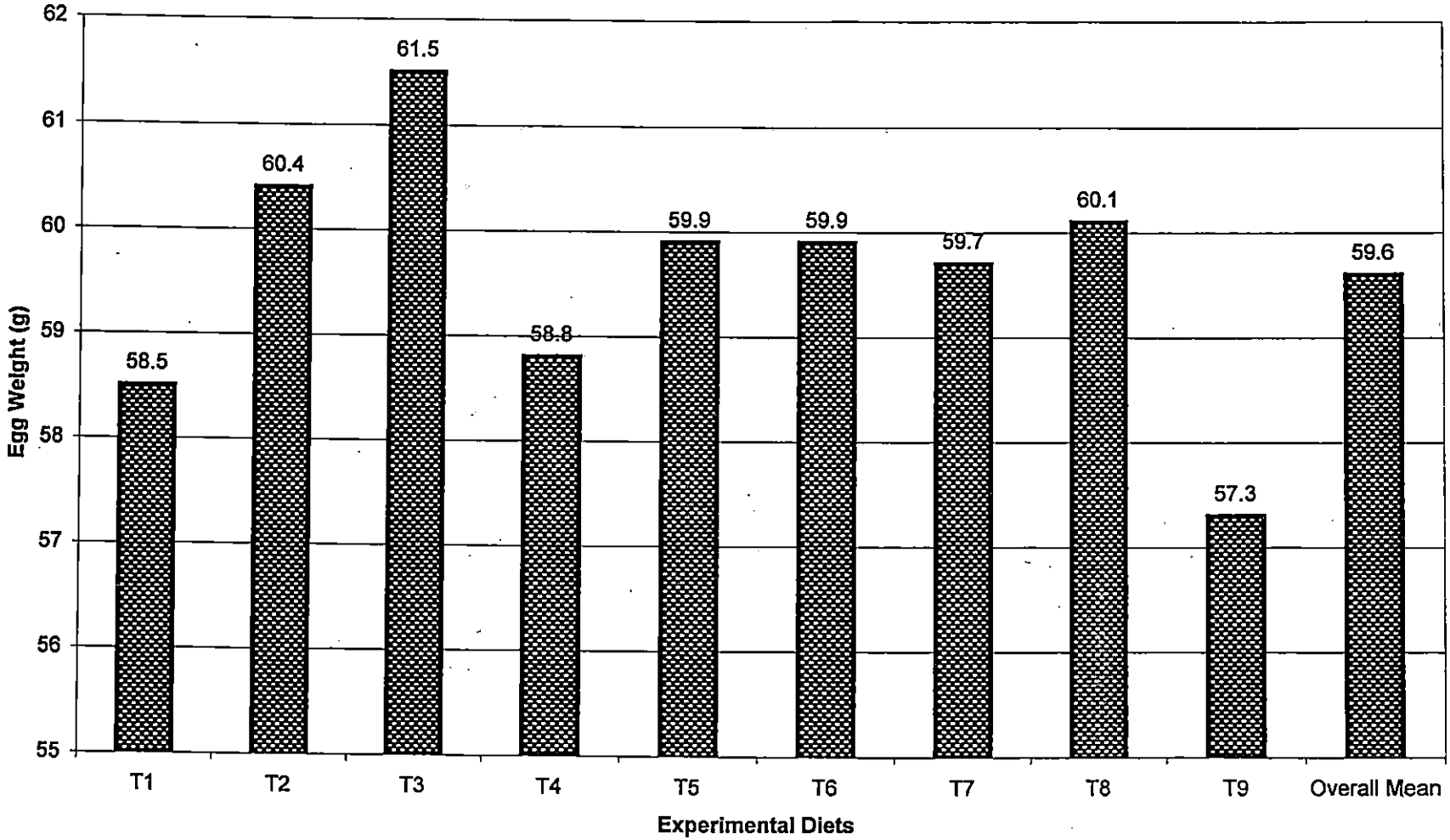


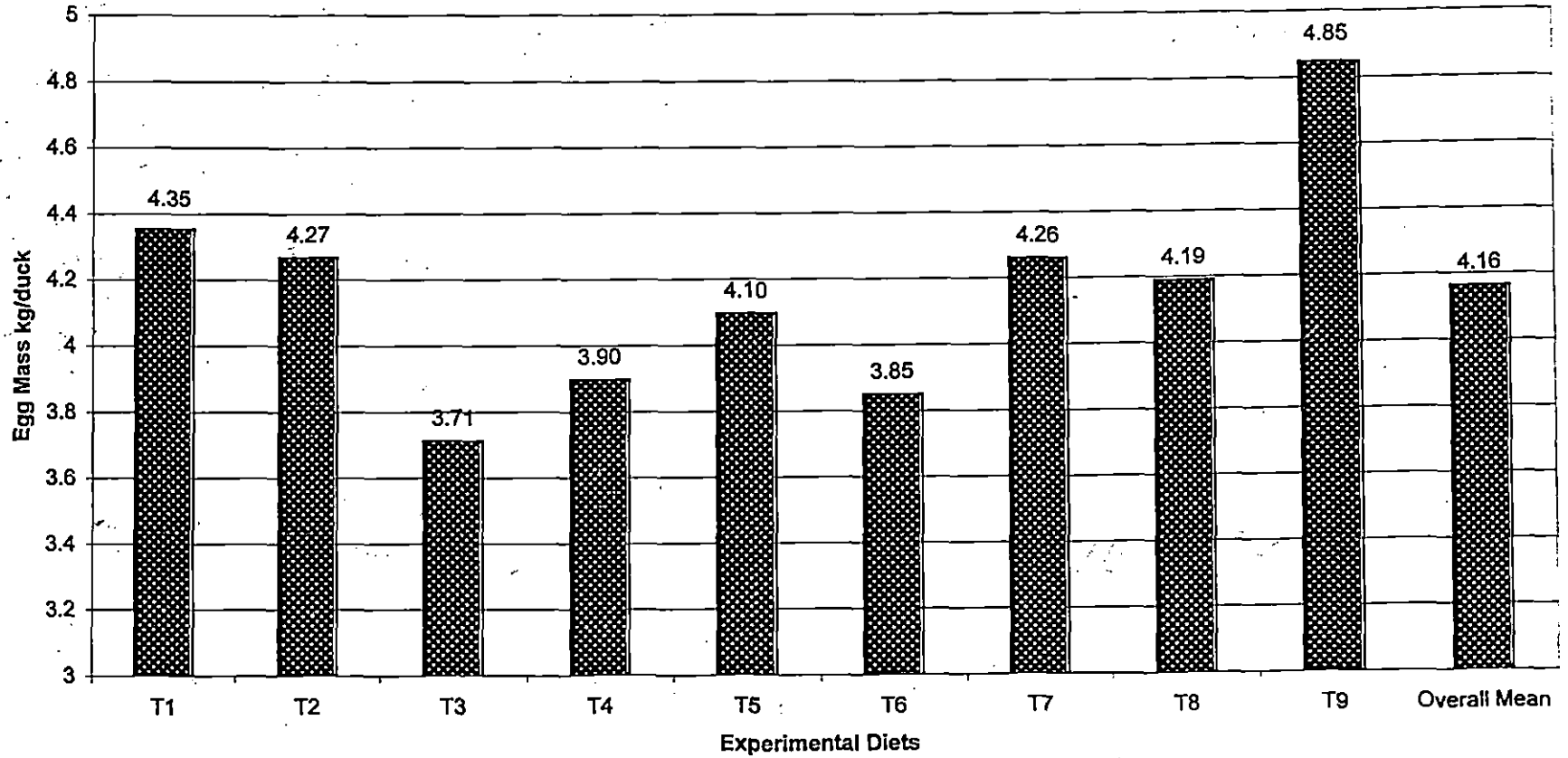
Table 20. The period wise mean egg mass (kg) per duck in indigenous layer ducks as Influenced by varying levels of calcium and available phosphorus in the diet

Ca %	3.0			3.5			4.0		
Av.P %	0.4	0.5	0.6	0.4	0.5	0.6	0.4	0.5	0.6
Diet Nos. / Periods	T1	T2	T3	T4	T5	T6	T7	T8	T9
I	0.05	0.17	0.10	0.07	0.10	0.00	0.06	0.16	0.25
II	0.84	0.93	0.78	0.79	0.80	0.52	0.56	1.03	1.02
III	1.12	1.00	0.98	0.97	1.00	1.12	1.14	0.88	1.04
IV	1.27	1.10	1.04	1.03	1.10	1.19	1.30	1.03	1.18
V	1.08	1.07	0.81	1.04	1.09	1.02	1.20	1.09	1.36
Cumulative 21-40	4.35	4.27	3.71	3.90	4.10	3.85	4.26	4.19	4.85
Overall mean 25-40	1.08	1.03	0.90	0.96	0.98	0.96	1.05	1.01	1.15

Table 21. Overall mean egg mass (kg) per duck from 21 to40 weeks in indigenous layer ducks as Influenced by varying levels of calcium and available phosphorus in the diet

	Available phosphorus %			
Ca %	0.4	0.5	0.6	Overall mean
3.0	4.35	4.27	3.71	4.11
3.5	3.90	4.10	3.85	3.95
4.0	4.26	4.19	4.85	4.43
Overall mean	4.17	4.18	4.14	4.16

Fig 8. Egg mass (kg/duck) as influenced by various experimental diets from 21 to 40 weeks of age



4.7 Shell weight

The eggshell weight recorded in each of the treatment is presented on percentage basis in Tables 22 and 23.

4.7.1 Period wise per cent Shell

The mean per cent shell recorded with varying levels of dietary calcium (Ca) and available phosphorus (AP) is presented in Table 22. The shell weight recorded in period I was 9.9±0.24, 10.1±0.21 and 10.1±0.11 per cent with calcium levels 3.0, 3.5 and 4.0 per cent and that with 0.4, 0.5 and 0.6 per cent available phosphorus levels were 10.3±0.10, 9.7±0.18 10.1±0.229 per cent respectively with an overall mean shell weight of 10.0±0.05 per cent in this period. The calcium levels did not influence the per cent shell in any of the periods till 40 weeks of age.

The available phosphorus level showed significance in period V and the mean values were 9.80±0.11, 9.30±0.14 and 9.90±0.14 per cent with 0.4, 0.5 and 0.6 per cent AP levels respectively. In this period, per cent shell recorded with 0.4 and 0.6 per cent AP levels were comparable and both these values were significantly higher than that recorded with 0.5 per cent level ($P<0.05$). This trend by the AP levels were exhibited in the overall effects also.

Table 22. Period wise mean per cent shell (by weight) of eggs from indigenous layer ducks fed varying levels of calcium and available phosphorus in the diet

Periods	Age in weeks	Ca levels (%)			Available P levels (%)			Overall Mean
		3.0	3.5	4.0	0.4	0.5	0.6	
I	21-24	9.9±0.24	10.1±0.21	10.1±0.11	10.3±0.10	9.7±0.18	10.1± 0.23	10.0±0.05
II	25-28	10.0±0.17	9.8±0.17	10.1±0.07	10.2±0.15	9.8±0.14	9.9±0.15	10.0±0.09[a]
III	29-32	9.8±0.10	10.1±0.16	10.3±0.18	10.0±0.16	9.9±0.17	10.2±0.15	10.0±0.09[a]
IV	33-36	9.9±0.17	9.8±0.15	9.8±0.13	10.0±0.11	9.6±0.16	9.9±0.15	9.8±0.09[b]
V	37-40	9.6±0.18	9.7±0.15	9.7±0.09	9.8±0.11[a]	9.3±0.14[b]	9.9±0.14[a]	9.7±0.08[c]
Overall Mean	25-40	9.8±0.08	9.8±0.07	10.0±0.07	10.0±0.07[a]	9.7±0.08[b]	10.0±0.07[a]	9.9±0.5

Note: *Mean values bearing same superscripts within phosphorus levels ($P < 0.01$) and that within the overall mean values did not differ significantly ($P < 0.05$)*

Table 23. The overall mean percent shell (by weight) of eggs from 25 to 40 weeks of age in indigenous layer ducks fed varying levels of calcium and available phosphorus in the diet

	Available phosphorus %			
Ca %	0.4	0.5	0.6	Overall Mean
3.0	10.0±0.13	9.6±0.16	9.8±0.13	9.8±0.08
3.5	9.9±0.14	9.7±0.15	10.0±0.13	9.8±0.07
4.0	10.1±0.10	9.7±0.13	10.1±0.13	10.0±0.07
Overall Mean	10.0 ±0.07[a]	9.7±0.08[b]	10.0 ±0.07[a]	9.9±0.05

Note: *Mean values bearing same superscripts within the overall mean values did not differ significantly ($P < 0.05$)*

The period wise overall mean per cent shell was 10.0 per cent up to period III and thereafter it was reduced significantly to 9.8±0.085 and 9.7±0.084 per cent in periods IV and V respectively.

4.7.2 Overall per cent Shell

The mean per cent shell among the various experimental diets was ranged from 9.6±0.163 to 10.1±0.130 with an overall mean of 9.9±0.046 per cent shell. The overall per cent shell from 25 to 40 week of age were 9.8±0.083, 9.8±0.07 and 10.0±0.073 per cent with calcium levels, 3.0, 3.5 and 4.0 per cent respectively and was comparable among each other. The overall per cent shell with 0.4 and 0.6 per cent AP levels were 10.0 per cent and this was significantly higher than the value of 9.70±0.081 per cent shell recorded with 0.5 per cent AP level ($P<0.05$).

4.8 Shell Thickness

The period wise and cumulative shell thickness are presented in Table 24 and 25.

4.8.1 Period wise Shell Thickness

The eggshell thickness (mm) in groups fed varying levels of calcium (Ca) and available phosphorus (AP) is presented in Table 24. The mean shell thickness of eggs in period I was 0.53±0.007, 0.54±0.005 and 0.53±0.007 mm with calcium levels 3.0, 3.5 and 4.0 per cent and that with 0.4, 0.5 and 0.6 per cent available phosphorus levels were 0.54±0.006, 0.53±0.006 and

0.53±0.008 mm respectively with an overall mean shell thickness of 0.53 mm in this period.

The calcium levels did not show much variation in shell thickness in any of the periods studied and it ranged from 0.53to 0.55 mm. From 25 to 40 weeks of age, the overall shell thickness was 0.54±0.002 mm in all levels of calcium. The effect of available phosphorus levels were significant only in period III. In this period the shell thickness recorded was significantly higher in groups fed 0.6 per cent available phosphorus in comparison with other AP levels ($P<0.05$). In period II, the shell thickness was 0.54±0.004 mm and in periods IV and V it was comparable with all levels of available phosphorus.

The period wise overall mean shell thickness, which was 0.53±0.004 mm during the first period increased to 0.54±0.004 mm during the period II. It was declined to 0.53±0.004 mm in period III. Even though it was increased to 0.55±0.004 mm in period IV it again declined to 0.54±0.005 mm in period V. Thus the overall mean shell thickness for all treatments put together was 0.54±0.002 mm.

4.8.2 Overall Shell Thickness

The overall shell thickness from 25-40 weeks of age presented in Table 25 revealed that it was 0.54±0.004 mm with all the three levels of Ca and 0.54±0.004, 0.53±0.004 and 0.55±0.003 mm respectively with the three levels of AP, was comparable among each other. Among the various

Table 24. Period wise mean shell thickness of eggs from indigenous layer ducks fed varying levels of dietary calcium and available phosphorus.

Periods	Age in weeks	Calcium levels (%)			Available phosphorus levels (%)			Overall Mean
		3.0	3.5	4.0	0.4	0.5	0.6	
I	21-24	0.53±0.007	0.54±0.005	0.53±0.007	0.54±0.006	0.53±0.006	0.53±0.008	0.53±0.004
II	25-28	0.54±0.010	0.54±0.008	0.54±0.005	0.54±0.01	0.54±0.008	0.54±0.006	0.54±0.004^{ab}
III	29-32	0.53±0.005	0.53±0.007	0.54±0.008	0.52±0.006^{b}	0.52±0.006^{b}	0.55±0.006^{a}	0.53±0.004^{c}
IV	33-36	0.55±0.007	0.55±0.004	0.55±0.007	0.55±0.006	0.54±0.006	0.55±0.007	0.55±0.004^{a}
V	37-40	0.53±0.008	0.55±0.007	0.53±0.011	0.53±0.006	0.52±0.01	0.55±0.007	0.54±0.005^{bc}
Overall Mean	25-40	0.54±0.004	0.54±0.004	0.54±0.004	0.54±0.004	0.53±0.004	0.55±0.003	0.54±0.002

Note: *The period wise mean values and the overall mean values bearing same superscripts did not differ significantly (P< 0.05).*

Table 25. The overall mean shell thickness (mm) of eggs from 25 to 40 weeks of age in indigenous layer ducks fed varying levels of dietary calcium and available phosphorus.

	Available phosphorus %			
Ca %	0.4	0.5	0.6	Overall Mean
3.0	0.54±0.003	0.53±0.007	0.55±0.006	0.54±0.004
3.5	0.54±0.005	0.54±0.007	0.55±0.006	0.54±0.004
4.0	0.54±0.007	0.53±0.01	0.55±0.005	0.54±0.004
Overall Mean	0.54±0.004	0.53±0.004	0.55±0.003	0.54±0.002

treatments, the mean shell thickness was ranged from 0.53 to 0.55 mm with an overall mean value of 0.54±0.002 mm.

4.9 Serum calcium and phosphorus

The Ca and P in the serum at 40 weeks age as influenced by Ca and AP in the diet are presented in Table 26 and 27. The calcium and available phosphorus levels in the diet did not affect the serum calcium percentages. The serum Ca averaged 15.06±0.609, 15.06±0.770 and 16.13±0.369 mg/dl with dietary calcium levels and 15.90±0.507, 15.31±0.69 and 15.02±0.647 mg/dl with dietary available P levels, respectively. The overall mean serum Ca per cent recorded in the experiment was 15.42±0.35 mg/dl (Table 26).

Though, the serum phosphorus recorded with 3.0 and 3.5 per cent dietary calcium were comparable, the same recorded with 4.0 per cent dietary Ca was significantly lower than that recorded with 3.5 per cent dietary Ca ($P<0.05$) and the mean values recorded with the three levels of dietary Ca were 3.27±0.128, 3.34±0.096 and 2.92±0.164 mg/dl respectively (Table 27). Whereas, the serum phosphorus with dietary AP levels averaged 3.18±0.142, 3.02±0.182 and 3.34±0.071 mg/dl respectively and was comparable among each other. The serum phosphorus values were ranged from 2.53±0.169 to 3.42±0.141 mg/dl among treatment groups with an overall mean of 3.18±0.081 mg/dl.

Table 26. Serum calcium mg/ dl at 40 weeks of age in indigenous layer ducks fed varying levels of calcium and available phosphorus in the diet

Ca %	Available phosphorus % 0.4	0.5	0.6	Overall Mean
3.0	15.88±0.16	14.21±1.28	15.09±1.42	15.06±0.61
3.5	14.80±1.22	15.36±1.63	15.01±1.70	15.06±0.77
4.0	17.00±0.60	16.36±0.38	15.04±0.33	16.13±0.37
Overall Mean	15.90±0.51	15.31±0.69	15.02±0.65	15.42±0.35

Table 27. Serum phosphorus mg/dl at 40 weeks of age in indigenous layer ducks fed varying levels of calcium and available phosphorus in the diet

Ca %	Available phosphorus % 0.4	0.5	0.6	Overall Mean
3.0	3.33±0.225	3.10±0.311	3.39±0.155	3.27 ± 0.128^{ab}
3.5	3.39±0.159	3.42±0.261	3.20±0.060	3.34 ± 0.096^{a}
4.0	2.82±0.259	2.53±0.169	3.42±0.141	2.92 ± 0.164^{b}
Overall Mean	3.18±0.142	3.02±0.182	3.34±0.071	3.18±0.081

Note: *Mean values bearing same superscripts did not differ significantly ($P < 0.05$)*

4.10 Tibia Ash (per cent)

The calcium levels in the diet did not influence the tibia ash per cent significantly at 40 weeks of age (Table 28). It was averaged 60.28±0.390, 61.06±0.639 and 60.60±0.767 per cent with the three levels of calcium respectively. Whereas, 0.6 per cent available phosphorus increased the tibia ash (62.34±0.512 per cent) significantly ($P<0.05$) in comparison with that recorded with 0.4 and 0.5 per cent available phosphorus (59.67±0.292 and 59.93±0.544 per cent). The overall mean tibia ash per cent was 60.65±0.349 per cent at 40 weeks of age.

4.10.1 Tibia Ash calcium (per cent)

The data presented in Table 29 revealed that, the tibia ash calcium at 40 weeks of age was significant only between dietary Ca levels 3.0 and 4.0 per cent ($P<0.05$). The intermediary level of 19.96±0.197 per cent tibia ash calcium recorded with 3.5 per cent dietary calcium was comparable with 19.48±0.249 and 20.56±0.434 per cent tibia ash calcium recorded with 3.0 and 4.0 per cent dietary Ca levels respectively. However, the difference between these mean values were statistically significant ($P<0.05$). The tibia ash calcium 20.62±0.443 per cent recorded with 0.6 per cent available phosphorus was significantly higher than dietary AP levels 0.4 and 0.5 per cent. Wherein, the tibia ash calcium recorded was comparable with each other (19.71±0.119 and 19.67±0.280 per cent respectively). The overall

Table 28. Tibia ash per cent at 40 weeks of age in indigenous layer ducks fed varying levels of calcium and available phosphorus in the diet

	Available phosphorus %			
Ca %	0.4	0.5	0.6	Overall Mean
3.0	60.17±0.020	59.86±1.189	60.82±0.415	60.28±0.390
3.5	59.95±0.028	60.10±1.154	63.13±0.595	61.06±0.639
4.0	58.88±0.736	59.84±0.886	63.08±0.935	60.60±0.767
Overall Mean	59.67±0.292^{b}	59.93±0.544^{b}	62.34±0.512^{a}	60.65±0.349

Note: *Mean values bearing same superscripts did not differ significantly ($P < 0.05$)*

Table 29. Calcium per cent in tibia ash at 40 weeks of age in indigenous layer ducks fed varying levels of calcium and available phosphorus in the diet

	Available phosphorus %			
Ca %	0.4	0.5	0.6	Overall Mean
3.0	19.60±0.158	18.70±0.309	20.15±0.259	19.48±0.249[b]
3.5	19.92±0.334	20.08±0.331	19.87±0.482	19.96±0.197[ab]
4.0	19.92±0.005	20.22±0.095	21.85±0.952	20.56±0.434[a]
Overall Mean	19.71±0.119[b]	19.67±0.280[b]	20.62±0.443[a]	20.00±0.193

Note: *Mean values bearing same superscripts within overall mean values did not differ significantly ($P < 0.05$)*

Table 30. phosphorus per cent in Tibia ash at 40 weeks of age in indigenous layer ducks fed varying levels of calcium and available phosphorus in the diet

	Available phosphorus %			
Ca %	0.4	0.5	0.6	Overall Mean
3.0	4.65±0.202	3.95±0.318	3.95±0.319	4.18±0.181
3.5	4.49±0.124	5.00±0.115	3.53±0.052	4.34±0.221
4.0	4.70±0.057	4.45±0.259	4.45±0.029	4.53±0.088
Overall Mean	4.61±0.077[a]	4.47±0.195[a]	3.98±0.163[b]	4.35±0.099

Note: *Mean values bearing same superscripts did not differ significantly ($P < 0.05$).*

mean tibia ash calcium for all treatment groups put together was 20.00±0.193 per cent. The interaction was also significant.

4.10.2 Tibia Ash phosphorus (per cent)

At 40 weeks of age, the calcium levels in the diet did not influence the tibia ash phosphorus significantly (Table 30) and the mean values were 4.18±0.181, 4.34±0.221 and 4.53±0.088 per cent with dietary Ca levels 3.0, 3.5 and 4.0 per cent respectively. Whereas, the tibia ash P recorded with dietary levels 0.4 and 0.5 per cent available phosphorus were comparable with each other and both these values were significantly ($P<0.01$) higher than that recorded with 0.6 per cent available phosphorus in the diet. The tibia ash P recorded with the AP levels were 4.61±0.077, 4.47±0.195 and 3.98±0.163 per cent respectively. The overall mean tibia ash phosphorus at 40 weeks of age was 4.35±0.099 per cent. The interaction was also significant.

Discussion

DISCUSSION

5.1 Body Weight

The mean body weight (BW) at 20 weeks of age presented in Table 2 ranged from 1400±9.11 to 1465±53.24 g with an overall mean of 1431±9.96 g. The differences in body weights were narrow and did not differ statistically between groups T_1 to T_9. This indicated that the body weight was uniform in all groups at the commencement of the experiment. The overall mean body weight of 1431 g recorded in the present study could be considered as optimum for indigenous layer ducks at 20 weeks of age. These results are in agreement with the 20th week body weights reported by Andrews *et al.* (1984) in Kerala ducks under intensive (1438 g) and semi-intensive (1443 g) systems of rearing. The BW obtained in the present study are close to that reported by Gajendran *et al.* (1990) in Desi ducks on deep litter system of rearing (1465 g) and that reported in Kuttanad ducks (Anon 2002) under cage system of rearing (1466 g).

Mahanta (1997) reported slightly higher body weights at 20th week under semi intensive system of rearing in two varieties of indigenous layer ducks of Kerala (1538.15 and 1497.51 g). The BW observed in the present study is also slightly higher than that of Khaki Campbell ducks reported by Dutta *et al.* (1993) in open range (1347.33 g), deep litter (1351.33 g) and semi range (1386.67 g) systems of management. On the other hand,

Hamid *et al.* (1988) reported higher body weight of 1703.89 g in indigenous ducks. The variations in 20th week body weight reported by various authors can be attributed to the changes in the genetic architecture of duck flocks, system of rearing and type of feed used.

The 40th week body weight (Table 3) ranged from 1473±18.10 g to 1579±58.28 g among the experimental diets with an overall mean of 1544±13.76 g showing an increase of 113 g over a period of 20 weeks. The increase in body weight with the Ca levels 3.0, 3.5 and 4.0 per cent was 141, 93 and 105 g and that due to available phosphorus (AP) levels, 0.4, 0.5 and 0.6 per cent was 89, 119 and 130 g respectively. The statistical analysis revealed that the Ca and AP levels did not influence the 40th week body weight significantly. Therefore it can be concluded that the dietary Ca levels of 3.0, 3.5 and 4.0 per cent and AP levels 0.4, 0.5 and 0.6 per cent did not adversely affect the 40th week body weight. The 40th week BW recorded in the present study was higher than that reported by Chen (1992) in Tsaiya ducks (1380 g). Andrews *et al.* (1984) reported lower BW at 40th week of age in Kerala ducks (1311 g) fed diet containing 3.31 per cent Ca and 1.17 per cent total P (17.30 per cent CP and 2650 Kcal ME /Kg). Narahari and Sundararasu (1988) could not observe any significant difference in BW between dry and wet mash fed groups of Khaki Campbell and Desi ducks from 21 to 40 weeks of age. On the other hand, Hengmin and Lingping (1997) observed that Tianfu ducklings fed P deficient diet (0.366 per cent P) were visibly smaller.

5.2 Age at sexual maturity

5.2.1 Age at first egg (AFE)

The AFE in 3.0, 3.5 and 4.0 per cent dietary Ca levels was at 154, 158 and 148 days and those fed diets with 0.4, 0.5 and 0.6 per cent AP levels was 161, 154 and 148 days, respectively. The age at first egg (AFE) was early in the group T_9 fed 4.0 per cent Ca with 0.6 percent available P. Numerically better BW at 20^{th} week of age in this group could be the possible reason for this. These results are in close agreement with the mean age at sexual maturity of 144.2, 150.4 and 146.4 days under the farm conditions observed by Baruah *et al.* (1991) in indigenous duck Pati, Khaki Campbell and their crosses, respectively. Gajendran *et al.* (1990) also observed the ASM of 140.16 ± 4.04 days in KC ducks and 145.21 ± 2.72 days in desi ducks of Tamil Nadu. Anon (2002) stated mean AFE of 149.03 days in indigenous ducks of Kerala. The AFE varied in different studies because the values of ASM or AFE were presented as averages instead of absolute values. Mahanta (1997) reported very early AFE in Chara and Chemballi ducks (129 days) under semi intensive system of rearing.

5.2.2 Age at 10 per cent production

In the present study, the ducks fed diet containing 4.0 per cent Ca and 0.6 per cent AP level (T9) reached 10 per cent production at an early age in comparison with other groups. The age at 10 per cent production with 3.0, 3.5 and 4.0 per cent Ca levels was 163, 161 and 157 days and that

with 0.4, 0.5 and 0.6 per cent of AP levels was 163, 158 and 155 days respectively. These results are comparable with the findings of Sarma *et al.* (1986) who found the ASM of 161 days in ducks fed 17 per cent protein and stated that the ducks fed 21 per cent protein attained sexual maturity earlier than those fed with 17 and 19 per cent CP levels. Baruah *et al.* (1991) recorded 30 per cent egg production at the age of 167.2, 158.6 and 161.8 days in Desi (Pati), KC and their crosses respectively and observed large gap between first egg and 30 per cent production in Pati ducks (23 days). Kerala desi ducks attained 10 per cent production at 146 days of age (Eswaran *et al.*, 1985), while Hamid *et al.* (1988) reported delayed sexual maturity under farm conditions (154 days). Narahari and Sundararasu (1988) observed no significant differences in ASM between dry and wet mash fed groups in KC and Desi ducks while Mostageer *et al.* (1971) reported late sexual maturity at 151.3 days in KC ducks.

5.2.3 Age at 50 per cent production

The age at 50 per cent production recorded with 3.0, 3.5 and 4.0 per cent Ca level in the present study was 172, 183 and 171 days and that with 0.4, 0.5 and 0.6 per cent AP level was 183, 167 and 178 days, respectively. The values among experimental groups varied from 166 to 189 days and the lowest value recorded in the groups fed diet T_2 & T_8. This is in agreement with the value of 184 and 187 days observed by Mahanta (1997) in two varieties of indigenous ducks of Kerala. In another study the age at 50 per cent production was 164 days in indigenous ducks of Kerala

(Anon, 2002). Rashid *et al.* (1995) reported ASM at 209, 182 and 187.5 days of age in Desi, Khaki Campbell and their crosses respectively with out supplemental feeding under rural conditions of Bangladesh. Das *et al.* (2000) under the field conditions in Assam reported ASM on the basis of age at 30 to 40 per cent egg production as 229.19, 169.16 and 220.24 days in Desi, Khaki Campbell and their crosses respectively. These authors also stated highly significant influence between ASM and egg production apart from significant influence by month of hatch ($P<0.01$). The age at 50 per cent production observed in the present study is in partial agreement with Chavez and Lasmini (1978) who reported ASM at 178,179 and 189 days in Indonesian native ducks of Tegal, Alabio and Bali respectively and Eswaran *et al.* (1985) who observed 50 per cent production at 155 days in Desi ducks and at 187 days in KC ducks. The exact levels of nutrients adopted were not clear in the above works and hence the variations in the results might have been contributed by various dietary factors.

5.3 Duck Housed Number (DHN)

The mean DHN ranged from 60.8 to 86.1 eggs among various experimental diets with an overall mean of 70.4 eggs per duck up to 40 weeks of age (Table 7). A wide variation existed between experimental diets as evidenced by a difference of 25.3 eggs between the lowest and the highest mean cumulative egg number. The DHN was lowest with the diet T_3 containing 3.0 per cent Ca and 0.6 per cent AP levels. Ducks in this

group started laying very late, that is at 25 weeks of age, might be one of the reasons for low egg production with diet T_3.

The cumulative egg number per duck from 21 to 40 weeks of age was the highest with diet T_9 (86.1 eggs) which contained 4.0 per cent Ca and 0.6 per cent AP level. Ducks in this group started laying at 22 weeks of age and the rate of production was consistently high through out the study. The DHN in diets T_1, T_2, T_7 and T_8 formed a homogenous group (Table 8).

The above results are in agreement with the mean egg production in Khaki Campbell ducks (86.6 eggs) on floor rearing up to 40 weeks of age (Avens *et al.*, 1980). They also observed higher egg production (95.3 eggs) in ducks reared in individual cages on pelleted ration containing 0.73 per cent phosphorus and 3.2 per cent Ca. However, Andrews *et al.* (1984) could observe very low egg production in Desi ducks of Kerala under semi intensive system of rearing. For 100 days production from first egg, Eswaran *et al.* (1985) recorded as low as 35.13 eggs in desi ducks. The DHN up to 40 weeks of age was also low (51.66eggs). Das *et al.* (2000) under field conditions in Assam observed DHN of 19.45, 71.98 and 34.20 eggs in Desi, Khaki Campbell and their crosses respectively up to 40 weeks of age. Ketaren (1998) observed higher increased egg production (38.3 to 48.9 eggs) in herded desi ducks when supplemented with concentrated feed. Mahanta (1997) obtained 70.6 eggs in Chara ducks and 72.4 eggs in Chemballi ducks of Kerala up to 40 weeks of age under semi intensive system of rearing.

While Anon (2002) reported 80.64 eggs in indigenous ducks of Kerala in cages up to 40 weeks of age. The above findings are comparable with the present results.

The mean DHN from 21 to 40 weeks of age (Table 7) was 68.9, 66.4 and 75.7 eggs with the three Ca levels 3.0, 3.5 and 4.0 per cent respectively. While the DHN with AP levels 0.4, 0.5 and 0.6 per cent was apparently similar (70.2, 70.2 and 70.6 eggs, respectively). The corresponding values from 25 to 40 weeks of age (Table 8) with Ca levels were 66.7, 65.3 and 72.3 eggs and that with AP levels were 69.0, 67.4 and 68.1 eggs. The egg production with 4.0 per cent Ca was significantly higher ($P<0.05$) than other Ca levels and within this Ca level, the interaction effect was also significant ($P<0.05$). The better DHN was due to the combination of 4.0 per cent Ca with 0.6 per cent AP level at the Ca: AP ratio of 6.67:1.

In the present study, the 4.0 per cent Ca level produced significantly more eggs compared to 3.0 and 3.5 per cent dietary Ca levels. This indicated that the lower levels of Ca employed in this study may not be adequate to support high egg production. The AP levels employed in this study did not show significant differences in egg production (Table 8) but interaction was evident in diet T_9. With in the 4.0 per cent Ca diet, the 0.6 per cent P level showed higher egg production than the 0.4 and 0.5 per cent levels. The combined effect of Ca and AP levels in the diet T_9 was found to be advantageous. Since the DHN was statistically similar with all the three

AP levels, the 0.6 per cent AP combination with the 4.0 per cent Ca level was considered as ideal for higher egg production in layer ducks. Thus, the present study proved that, the optimum requirement of Ca was 4.0 per cent and that of available phosphorus was 0.6 per cent for indigenous ducks of Kerala under cage system of rearing.

The better egg production in periods II and V contributed to higher cumulative EN in 4.0 per cent dietary Ca level (Table 6). The period wise mean of 16.5 eggs recorded with 4.0 per cent Ca in period II was significantly higher ($P<0.05$) than the mean egg number observed with 3.5 per cent Ca level. In period V, 19.1 eggs recorded with 4.0 per cent Ca was significantly higher than that of 3.0 and 3.5 per cent Ca levels (15.2 and 16.1 eggs respectively). In this study the overall mean production was the highest at 28th week. This is in agreement with Applegate *et al.* (1998) who reported peak egg production in ducks between 28 and 30 weeks of age. The period wise mean production observed in this study is in agreement with Baruah *et al.* (1991) who reported gradual increase in egg production from first to fourth laying period. The nutrient availability of ducks, system of rearing and genetic variations in the flock might have resulted in wide variations in egg production in indigenous ducks at different regions.

5.4 Duck Housed Per cent (DHP) Production

The overall mean duck housed per cent (DHP) production from 21 to 40 weeks of age is presented in Table 10. It ranged from 47.0 ± 4.81 to

61.3 ±5.01 with an overall mean of 50.0±1.54 per cent. The DHP in Ca levels 3.0, 3.5 and 4.0 per cent was 49.1±2.56, 47.2 ±2.61 and 53.7 ± 2.80 and in AP levels 0.4, 0.5 and 0.6 per cent was 50.1±2.65, 49.7 ±2.62 and 50.2 ± 2.70 per cent respectively.

The overall mean DHP from 25 to 40 weeks of age varied from 52.0±3.49 to 71.9±2.27 with an overall mean of 60.7±1.12 per cent (Table 11). The per cent egg production in Ca levels 3.0, 3.5 and 4.0 per cent were 59.4±1.94, 58.0±1.90 and 64.6±1.92 and that with AP levels 0.4, 0.5 and 0.6 per cent were 61.5±1.97, 60.0±1.63 and 60.6±2.21, respectively. These results corroborate Eswaran *et al.* (1985) who reported an egg production of 42.7 per cent in Desi and 65.7 per cent in Khaki Campbell ducks for 100 days from AFE. The duck housed egg production of 51.66 and 60.16 per cent and the duck day production of 52.14 and 60.17 per cent in Desi and KC ducks up to 40 weeks of age and annual laying rate of 67.9 per cent in Alabio ducks (Ketaren, 1998) are close to the results of present study. Reddy *et al.* (1981) fed 2.74 per cent Ca and 0.52 per cent AP, and reported 69.1 per cent production in KC ducks, is also in agreement with the results obtained in the present study. On the other hand, Andrews *et al.* (1984) found lower duck-day yield of 14.9 per cent under intensive system and 12.6 per cent under semi-intensive system of management during 21 to 44 weeks of age, with 3.31 per cent calcium and 1.17 per cent total phosphorus. The higher egg production with 3.0 per cent Ca level (85.56 per cent) compared to 3.5 and 4.0 per cent Ca levels (83.84 and 74.64 per cent) in Tsaiya ducks as reported by Tian Fwu *et al.* (1998) could be due to the difference in the genetic variations of the stocks studied.

5.5.1 Feed Consumption

The overall mean daily feed consumption from 21 to 40 weeks of age (Table 13) ranged from 123.4±4.79 to 136.2±5.37 g and the results revealed that the dietary Ca and AP levels did not influence the daily feed consumption.

The period wise daily feed consumption from 21 to 40 weeks of age (Table 12) with Ca levels 3.0, 3.5 and 4.0 per cent averaged 137.2±2.65, 133.6±3.36 and 140.7±2.69 g and that with AP levels 0.4, 0.5 and 0.6 per cent averaged 136.1±2.66, 139.4±2.43 and 136.1±2.70 g respectively with an overall mean of 137.2±1.49 g. The difference in numerical values among treatments did not differ significantly between dietary Ca and AP levels. Bulbule (1982) recorded feed consumption of 135 to 170 g in Desi ducks under confinement.

Tian Fwu *et al.* (1998) observed higher mean daily feed consumption of 194.89, 193.49 202.14 g with 3.0, 3.5 and 4.0 per cent Ca levels. Higher feed intake was also reported by Andrews *et al.* (1984) under intensive (191 g) and semi-intensive (185g) systems of management on feeding diet containing 3.31 per cent calcium and 1.17 per cent total phosphorus. Eswaran *et al.* (1985) stated an average daily feed intake of 181 to 184 g under semi intensive system of rearing. Gajendran *et al.* (1990) obtained daily feed intake of 155 g in Desi ducks and 165 g in Khaki Campbell ducks

from 21 to 40 weeks of age. The average daily feed consumption was 190.06 g in Pati duck, 174.29 g in Khaki Campbell ducks and 178 .01 g in their crosses (Baruah *et al.*, 1991). Applegate *et al.* (1998) stated that the feed allowance has to be adjusted weekly according to egg production. Studies with desi ducks of Kerala, Anon (2002) observed mean daily feed intake of 171.88 g per duck during 21 to 40 weeks of age.

The feed consumption reports were widely varied and the mean daily feed intake in the present study was lower than the range of values reported by various authors. The low feed intake might have caused a low mean egg weight in cage rearing in the present study. The lower mean daily feed intake observed in this study might be due to cage rearing of ducks. The pattern of increase in body weight of ducks from 20 to 40 weeks of age was low in cage system of rearing. These factors might have influenced the feed intake and requirement of nutrients for maintenance and production. Much of the variations in daily feed consumption in the present study might be due to the differences in the system of rearing and genetic variations of the ducks used.

5.5.2 Feed Conversion Ratio (FCR)

The overall mean Feed Conversion Ratio (FCR) per dozen eggs from 25 to 40 weeks of age revealed that the FCR with 4.0 per cent Ca level averaged 2.7 (Table 15). The markedly higher egg number recorded with 4.0 per cent Ca was not reflected as such in the FCR because of the higher

feed consumption in this group. However, the mean FCR (2.7) in this group was relatively better. The overall mean FCR per dozen eggs among experimental diets ranged from 2.4±0.125 to 3.1±0.338 from 25 to 40 weeks of age with an overall mean of 2.8±0.078. These results are superior over the FCR (3.35) reported by Anon (2002) in indigenous ducks of Kerala for 25 to 40 weeks of age.

The FCR on per kg eggs ranged from 3.6±0.131 to 4.3±0.645 with an overall mean of 3.9±0.099 (Table 17). The FCR on the basis of kg eggs revealed the actual relationship between the mean egg weight, egg mass and feed consumption. The non-significant variations in FCR from 25 to 40 weeks of age suggest that any of the dietary Ca or AP levels tested in this study can be employed for indigenous layer ducks. However, considering significantly higher egg production with 4.0 per cent Ca level with 0.6 per cent AP level, it can be suggested that these levels are optimum for layer ducks. Since the feed consumption was uniform in all dietary treatments and the interaction effect was absent, the better numerical values of FCR noted with diet T_9 is critical in arriving at the above conclusion.

The data for period II to V on statistical analysis revealed that (Table 14) Ca and available phosphorus levels did not influence the FCR in any of the periods. However, the overall period wise FCR was significantly better during period III (2.5±0.11) and periods II & IV were in a homogenous group.

The present results are in partial agreement with Avens *et al.* (1980) who reported a mean FCR of 3.0 in Khaki Campbell ducks in cage and floor rearing systems, by feeding a duck layer ration containing 3.2 per cent Ca 0.57 per cent available phosphorus. Reddy *et al.* (1981) reported the FCR of 2.08 in KC ducks on feeding a duck layer diet containing 2.74 per cent Ca with 0.52 per cent AP level (19 per cent CP with 2400 Kcal ME/Kg diet) from 21 to 52 weeks of age. Conversely, Andrews *et al.* (1984) reported the feed efficiency of 19.5 with Desi ducks under the intensive system and 22.7 under semi intensive system with 3.31 per cent Ca and 1.17 per cent total P (17.30 per cent CP and 2650 Kcal ME/Kg diet) during 21 to 44 weeks of age. Eswaran *et al.* (1985) reported an overall feed efficiency of 13.54 ± 8.85 per dozen eggs in Desi ducks and 11.68 ±4.77 for Khaki Campbell ducks. Gajendran *et al.* (1990) reported FCR of 4.883 ± 0.58 in Desi ducks and 10.049 ± 0.75 in Khaki Campbell ducks from 21 to 40 weeks of age. Baruah *et al.* (1991) stated the FCR in the order of 10.87, 5.01 and 6.91 in groups of ducks Pati, Khaki Campbell and their crosses, respectively.

5.6 Egg quality

5.6.1 Egg weight

The egg weight (EW) differed significantly between Ca, AP levels and interaction effect was also significant. The results showed that the egg weight was low in 4.0 per cent Ca level (Tables 18 and 19). This might be due to higher egg number obtained in this level.

Considering the period from 25 to 40 weeks of age, the overall egg weight averaged 60.1±0.58, 59.5±0.60 and 59.0±0.56 g in 3.0, 3.5 and 4.0 per cent dietary Ca levels. With in 0.4, 0.5 and 0.6 per cent dietary AP levels, EW averaged 59.0±0.58, 60.1±0.57 and 59.5±0.59g, respectively. The differences in EW between Ca and AP levels were significant ($P<0.01$). The higher egg weight was recorded with 3.0 per cent Ca and 0.5 per cent AP levels ($P<0.01$). The interaction effect was also significant for EW. The higher EW noted with 3.0 per cent Ca was possibly due to the consequence of low egg number in this group. The overall mean EW in the study was 59.6±0.33 g. The early sexual maturity with diet T_9 might have contributed for low EW in 4.0 per cent Ca level. The low EW with diet T_9 could also be due to the correlated response between EN and EW. This value is considered as low when compared with the egg weight values obtained from desi ducks reared in foraging conditions. Before arriving at the optimum levels of Ca and AP levels it is suggestive of looking in to the total egg mass.

The trend of results due to calcium levels was more or less similar in periods II and V. At these periods, significantly lower egg weight was recorded with 4.0 per cent calcium, whereas in period III lower egg weight was recorded with 3.5 and 4.0 per cent Ca levels. The EW was comparable at all levels in period IV. While considering the EW in varying AP levels, higher egg weight was recorded with 0.5 and 0.6 per cent AP levels in periods II and V. The higher egg weight observed with 0.5 per cent AP level in period III was significant ($P<0.01$). The EW was comparable with AP levels in period IV (Tables 18 and 19).

The present results are in agreement with Andrews *et al.* (1984), who reported an EW of 60.4 g under the intensive system and 60.7 g under the semi intensive system among indigenous ducks of Kerala, fed with diet containing 3.31 per cent Ca and 1.17 per cent total P. While Reddy *et al.* (1981) reported the egg weight of 59.38, 60.67 and 56.68 g in KC ducks fed constant levels of 2.75 per cent Ca and 0.55 per cent AP level with graded levels of crude protein viz., 15, 17 and 19 per cent. Mahanta *et al.* (1993) reported an EW of 60.55 ± 0.29g in Pati ducks and 56.44 ± 0.38 g in Khaki Campbell ducks. Mahanta (1997) reported first EW of 61.27 and 61.87 g in Chara and Chemballi ducks of Kerala respectively under semi intensive system of management. The corresponding values at 40th week of age were 69.94 and 68.94 g. whereas, Anon (2002) reported an EW of 57.42 g in desi ducks reared in cages. The EW in the present study was lower than that reported by Eswaran *et al.* (1985) in Desi ducks (71.40 ± 0.95 g) at 40 weeks of age, but close to the EW in Khaki Campbell ducks (62 .41 ± 0.50 g) reported by the same author. Tian Fwu *et al.* (1998) obtained lower EW with diets containing Ca levels 3.0 and 3.5 per cent (64.93 and 64.68 g) with 0.46 per cent AP level compared to 4.0 per cent Ca level (66.50 g) in caged ducks.

5.6.2 Egg Mass

The cumulative mean egg mass per duck from 21 to 40 weeks of age (Tables 20 and 21) did not differ significantly between Ca and AP levels. Among the experimental diets, mean egg mass ranged

from 3.712 to 4.846 kg per duck. The total egg mass per duck recorded the highest value with diet T_9 containing 4.0 per cent Ca and 0.6 per cent AP level. The mean value in Ca levels 3.0, 3.5 and 4.0 per cent were 4.111, 3.947 and 4.431 kg and that in AP levels 0.4, 0.5 and 0.6 per cent were 4.169, 4.184 and 4.136 kg respectively. The results are suggestive of recommending dietary Ca and AP levels of 4.0 and 0.6 per cent respectively for layer ducks housed in cages.

5.6.3 Per cent Shell

The overall per cent shell from 25 to 40 weeksof age (Table 23) was comparable between Ca levels, 3.0, 3.5 and 4.0 per cent (9.8±0.08, 9.8±0.07 and 10.0±0.07 per cent respectively). However, the overall per cent shell recorded with 0.4 and 0.6 per cent AP levels (10.0 per cent) was significantly higher than that of 0.5 per cent AP level ($P<0.05$). This indicated higher shell quality with0.4 and 0.6 per cent AP levels. The shell thickness with 0.5 per cent AP level was also numerically low (0.53±0.004 mm). Higher values of per cent shell were reported by Mahanta *et al.* (1993) in Pati and Khaki Campbell eggs (12.11 ± 0.01 and 12.01 ± 0.13 per cent respectively). In Tsaiya duck eggs, Tian Fwu *et al.* (1998) showed a per cent shell weight of 9.58 with 4.0 per cent dietary Ca level.

5.6.4 Shell Thickness

The varying levels of Ca and AP levels employed in this study did not influence the shell thickness from 25-40 weeks of age (Table 25). The mean

values ranged from 0.53 to 0.55 mm were statistically comparable between Ca and AP levels. The shell thickness recorded in the present study was higher than that reported by Reddy *et al.* (1981) in KC duck eggs (0.42 mm) from group fed diet containing 2.75 per cent Ca and 0.54 per cent AP and Eswaran *et al.* (1985) in Desi eggs (0.38 ± 0.007 mm) and Khaki Campbell eggs (0.36 ± 0.004 mm). The present results are in agreement with Davis *et al.* (1993), who reported shell thickness of 0.54 and 0.53 mm in Pekin ducks egg at 40th week of age. But Mahanta *et al.* (1993) reported lower shell thickness in indigenous (0.34 ± 0.004 mm) Khaki Campbell eggs (0.328 ± 0.004 mm) and in Tsaiya duck eggs, Tian Fwu *et al.* (1998) reported a shell thickness value of 0.37 mm at 4.0 per cent dietary Ca level.

5.7 Serum Ca and P

Fortieth week serum Ca averaged 15.06±0.61, 15.06±0.77 and 16.13±0.369 mg/dl in dietary Ca levels 3.0, 3.5 and 4.0 per cent and 15.90±0.51, 15.31±0.69 and 15.02±0.65 mg/dl in dietary AP levels, 0.4, 0.5 and 0.6 per cent respectively. The overall mean serum Ca in the experiment was 15.42±0.35 mg/dl (Table 26).

The serum P recorded with dietary Ca levels 3.0, 3.5 and 4.0 per cent averaged 3.27±0.128, 3.34±0.096 and 2.92±0.164 mg/dl respectively, at 40 weeks of age. The dietary Ca levels significantly influenced the serum P values (Table 27), showing an elevated serum P with 3.5 per cent Ca diet and significantly lower serum P with 4.0 per cent dietary calcium. The

serum P values as influenced by dietary AP levels 0.4, 0.5 and 0.6 per cent were 3.18±0.142, 3.02±0.182 and 3.34±0.071 mg/dl respectively with an overall mean value of 3.18±0.081 mg/dl.

The serum P recorded with the 4.0 per cent Ca diet containing 0.4 and 0.5 per cent dietary AP levels was lower ($P<0.05$) than that of 0.6 per cent AP level. This may be viewed in relation with significantly higher egg production with 4.0 per cent Ca level. It can be inferred that AP levels of 0.4 and 0.5 per cent in the 4.0 per cent Ca diet resulted in low serum P values. Hengmin and Lingping (1997) reported serum Ca of 2.94±0.06 mmol/L and serum P value of 3.66 mmol /L in P deficient diet containing 0.366 per cent P and in diet containing 0.65 per cent P showed higher values of serum Ca (3.10 ± 0.10 mmol /L) and serum P (5.10 ± 0.09 mmol /L).

5.8 Tibia Ash

The dietary Ca levels did not influence the tibia ash per cent significantly at 40 weeks of age. The tibia ash averaged 60.28±0.390, 61.06±0.639 and 60.60±0.767 per cent with the three levels of Ca viz., 3.0, 3.5 and 4.0 per cent respectively (Table 28). The tibia ash weight was significantly higher ($P<0.05$) with 0.6 per cent AP level (62.34±0.512 per cent). The mean values of tibia ash with 0.4 and 0.5 per cent AP were statistically similar (59.67±0.292 and 59.93±0.544 per cent). These results clearly indicate that there was an increase in tibia ash with 0.6 per cent AP level. Hengmin and Lingping (1997) reported lower values of 36.74 per cent

tibia ash in ducklings fed a control diet (0.65 per cent P) and 22.67 per cent tibia ash in group fed P deficient diet (0.366 per cent P) at 3rd week.

5.8.1 Tibia ash Ca and P

The Ca in tibia ash at 40 weeks of age was influenced significantly not only by the dietary Ca levels but also by the AP levels (Table 29). These results suggest that as dietary Ca increased, there was a tendency for numerical increase in tibia ash Ca. The tibia ash Ca per cent showed significantly higher value with 4.0 per cent Ca (20.56±0.434) than that of 3.0 per cent dietary Ca level (19.48±0.249). The 0.6 per cent AP level showed significantly higher tibia ash Ca (20.62±0.443 per cent) than that in AP levels 0.4 and 0.5 per cent. Thus the dietary levels 4.0 per cent Ca and 0.6 per cent AP showed more Ca in the tibia ash. These findings suggest that 4.0 per cent Ca with 0.6 per cent AP level might be the optimum requirement for indigenous layer duck. The tibia ash P in 0.6 per cent dietary AP level showed significantly low value ($P<0.01$). The mean values recorded were 4.61±0.077, 4.47±0.195 and 3.98±0.163 per cent in 0.4, 0.5 and 0.6 per cent dietary AP levels, respectively. This indicated that the tibia ash P lowered as the AP level in the diet increased. Since the interaction between Ca and AP levels being significant, it can be concluded that the effect of Ca and P in the tibia ash is dependent on Ca and AP levels in the diet.

5.9 Livability

The livability was excellent in ducks reared in cages. There was no mortality during the period from 21 to 40 weeks of age.

Summary

SUMMARY

A 3 x 3 factorial experiment was carried out at Department of Poultry Science during the period from February to July 2002 to study the calcium (Ca) and available phosphorus (AP) requirements of indigenous layer ducks of Kerala.

At 18th week of age, 90 female ducks of indigenous variety (Kerala) were housed in 45 California type cages at the rate of two ducks per cage. The ducks were randomly allotted to nine dietary combinations of calcium (Ca) and available phosphorus (AP) with five replicates consisting of two ducks per cage in each treatment. At 20th week of age, the experiment was started after recording the individual body weights. Three levels of dietary calcium (Ca), viz., 3.0, 3.5 and 4.0 per cent with three levels of available phosphorus (AP) viz., 0.4, 0.5 and 0.6 per cent were employed. Feed was provided as wet mash thrice daily and water was provided *ad.lib* and the management practices were followed routinely throughout the experiment.

The observations were recorded from 21 to 40 weeks of age for five periods of 28 days each. Egg production was recorded daily and from this data duck-housed number (DHN) and duck housed per cent (DHP) production were arrived. The weekly feed intake was recorded treatment wise and feed conversion ratios (FCR) were calculated per dozen eggs and per kg eggs. All eggs were weighed individually throughout the

experiment. The per cent shell and shell thickness of eggs were recorded period wise. The biochemical parameters such as serum Ca and inorganic phosphorus, per cent tibia ash, tibia ash Ca and AP were studied at 40 weeks of age in order to ascertain the physiological status of layer ducks.

The overall performance of the ducks fed different dietary regimen is presented in Table 31. The week wise, period wise and the overall effects due to dietary Ca and AP levels were presented in Tables 2 to 30 and the independent effects of the experimental diets were presented in Appendices 1 to 15. The following results were obtained in this study:

1. The age at first egg (AFE) in the flock was recorded at 148 days in the group fed diet T9 containing 4.0 per cent Ca and 0.6 per cent AP. This group also reached 10 and 50 per cent production early at 157 and 171 days of age, respectively.

2. The period wise duck housed number (DHN) from 25 to 40 weeks averaged 17.1 eggs and it was significantly higher in ducks fed 4.0 per cent Ca and the interaction with 0.6 per cent AP level was significant ($P<0.05$). The cumulative egg number (EN) from 21 to 40 weeks of age was the highest (86.1 eggs) in diet T_9 containing 4.0 per cent Ca and 0.6 per cent AP. The overall mean effect due to Ca level was superior with 4.0 per cent (75.7 eggs) than 3.0 and 3.5 per cent Ca levels ($P<0.05$). The cumulative EN from 21 to 40 weeks of age ranged from 60.8 to 86.1 with overall mean of 70.4 eggs and that from 25 to 40 weeks ranged from 58.6 to 80.9 eggs with the overall mean of 68.2 eggs.

3. The overall duck housed production (DHP) from 25 to 40 weeks averaged 64.6 ±1.92 per cent with 4.0 per cent Ca, which was significantly higher than other calcium levels. The AP levels in diet did not show significant influence on DHP. The interaction effect of 71.9±2.27 per cent production with 4.0 per cent Ca and 0.6 per cent AP level was significantly higher than other diets ($P<0.05$). The cumulative egg production from 21 to 40 weeks of age ranged from 43.2 ±4.65 to 61.3 ±5.01 per cent with an overall mean of 50.0 ±1.54 per cent and that from 25 to 40 weeks of age ranged from 52.0 ± 3.49 to 71.9 ± 2.27 per cent with an overall mean of 60.7 ± 1.12 per cent.

4. The mean daily feed consumption was not significantly influenced either by Ca or AP levels in the diet. The overall mean daily feed consumption from 21 to 40 weeks of age was 130.2 ± 1.61 g and that from 25 to 40 weeks of age was 137.2 ± 1.49 g.

5. The dietary Ca and AP levels did not significantly influence the feed conversion ratios (FCR) both per dozen eggs and per kg egg basis. The numerically better FCR/dozen egg was 2.7 ± 0.141 and that per kg egg was 3.8 ± 0.194 and both were recorded with 4.0 per cent Ca. The cumulative FCR/dozen eggs from 25-40 weeks ranged from 2.4±0.388 to 3.1±0.338 among treatment groups with an overall mean of 2.8±0.078 and the FCR/ kg egg mass averaged from 3.6±0.131 to 4.1±0.260 with an overall mean of 3.9±0.099.

6. The mean egg weight (EW) of 60.1±0.57 g recorded with 3.0 per cent Ca and 0.5 per cent AP level was superior and was highly significant over other levels ($P<0.01$). The cumulative mean EW from 25-40 weeks ranged from 57.3±0.88 to 61.5±0.97g among diets with an overall mean of 59.6±0.33 g.

7. The cumulative egg mass from 21 to 40 weeks of age was 4.85 kg per duck with diet T_9 and it was numerically better than the other treatment groups. The values ranged from 3.71 to 4.85 kg among diets with an overall mean of 4.16 kg / duck.

8. The Ca levels in the diet did not influence egg shell per cent. The cumulative per cent shell from 25 to 40 weeks of age ranged from 9.7±0.15 to 10.1±0.13 among diets with an overall mean of 9.9±0.05 per cent.

9. The dietary Ca and AP levels did not influence the mean shell thickness. The cumulative shell thickness of eggs from 25 to 40 weeks ranged from 0.53 to 0.55 mm with an overall mean of 0.54±0.002 mm.

10. The serum profile studied at 40 weeks of age revealed that dietary Ca levels influenced the serum P significantly. The serum Ca values ranged from 14.21±1.28 to 17.00±0.602 mg/dl with an overall mean of 15.42±0.35 mg/dl and the serum P values ranged from 2.53±0.169 to 3.42±0.141 mg/dl with an overall mean

of 3.18±0.081 mg/dl. The mean serum inorganic P value of 2.92±0.164 mg/dl recorded with dietary Ca level 4.0 per cent was significantly lower than that of 3.5 per cent Ca level ($P<0.05$). The dietary AP levels did not influence the serum Ca and P values significantly.

11. The per cent tibia ash recorded with 0.6 per cent AP level at 40 weeks of age was significantly higher (62.34±0.512) in comparison with other levels ($P<0.05$). The mean tibia ash averaged from 58.88±0.736 to 63.08±0.935 per cent with an overall mean of 60.65±0.349 per cent.

12. The dietary Ca and AP levels influenced the tibia ash Ca, while the dietary AP level only influenced the tibia ash P at 40 weeks of age. The tibia ash Ca per cent ranged from 18.70±0.309 to 21.85±0.952 with an overall mean of 20.00±0.193 per cent while tibia ash P ranged from 3.53±0.052 to 5.00±0.115 per cent with an overall mean of 4.35±0.099 per cent. The 20.56±0.434 per cent tibia ash Ca recorded with 4.0 per cent dietary Ca was significantly higher than that of 3.0 per cent Ca level ($P<0.05$) and tibia ash recorded with 0.6 per cent AP level (20.62±0.443 per cent) was significantly higher than that of other AP levels. The tibia ash Ca recorded with diet T9 (21.85±0.952 per cent), the interaction effect was also significant.

13. Conversely, the tibia ash P was significantly reduced to 3.98±0.163 per cent with 0.6 per cent dietary AP level. This reduction might be the consequence of interaction effect by 3.0 and 3.5 per cent Ca levels with 0.6 AP level leading to a tendency of lowering tibia ash P.

14. The liveability was excellent in ducks reared in cages and was 100 per cent during 21 to 40 weeks of age.

The above results indicated that 4.0 per cent Ca in the diet was adequate to support high egg production in ducks, egg mass and FCR. The total egg mass/duck was found to be comparable with all levels of Ca and AP in the diet. In general, the overall effects of all dietary AP levels appear to be similar. But in as much as the interaction effect was significant for EN, the 0.6 per cent AP level within 4.0 per cent Ca level (diet T_9) was considered superior over other AP levels. Therefore it would be logical to set the requirements of available phosphorus at 0.6 per cent level for layer ducks.

Considering all the traits studied it can be concluded that the 4.0 per cent calcium with 0.6 per cent available phosphorus with 18 per cent crude protein and 2650 kcal ME/kg was optimum for indigenous layer ducks under cage system of rearing.

Table 31. Summary of production performance of indigenous layer ducks fed varying levels of Ca and P in the diet

Dietary Ca levels %		3.0			3.5			4.0		
Dietary Available P levels %	0.4	0.5	0.6	0.4	0.5	0.6	0.4	0.5	0.6	
Diet Number	T1	T2	T3	T4	T5	T6	T7	T8	T9	Overall Mean
1 Cumulative EN (21 to 40 wk)	73.7	72.3	60.8	65.8	68.5	64.8	71.1	70.2	86.1	70.4
Overall mean from 25 to 40 weeks										
2 DHProduction %	64.6^{ab}	61.6^{abc}	52.0^{c}	57.5^{bc}	58.6^{bc}	57.9^{bc}	62.4^{abc}	59.4^{bc}	71.9^{a}	60.7
3 Period wise EN	18.0^{ab}	17.3^{abc}	14.7^{c}	16.1^{bc}	16.7^{bc}	16.2^{bc}	17.5^{abc}	16.7^{bc}	20.2^{a}	17.10
4 Daily Feed Intake (g)	136.3	145	130.3	132.8	133.8	134.2	139.1	139.3	143.8	137.2
5 FCR/doz eggs	2.5	2.8	3.1	2.8	2.7	3	2.8	2.9	2.4	2.8
6 FCR/kg eggs	3.6	4	4.1	3.9	3.8	4.3	4	3.9	3.6	3.9
7 EW (g)	58.5^{d}	60.4^{b}	61.5^{a}	58.8^{d}	59.9^{bc}	59.9^{bc}	59.7^{c}	60.1^{bc}	57.3^{c}	59.6
9 Shell %	10	9.6	9.8	9.9	9.7	10	10.1	9.7	10.1	9.9
8 Shell thickness (mm)	0.54	0.53	0.55	0.54	0.54	0.55	0.54	0.53	0.55	0.54
At 40th week										
10 Serum Ca (mg/dl)	15.9	14.2	15.1	14.8	15.4	15	17	16.4	15	15.4
11 Serum P (mg/dl)	3.3	3.1	3.4	3.4	3.4	3.2	2.8	2.5	3.4	3.2
12 Tibia Ash %	60.2	59.9	60.8	60	60.1	63.1	58.9	59.8	63.1	60.7
13 Tibia Ash Ca %	19.6^{bc}	18.7^{c}	20.2^{b}	19.9^{bc}	20.1^{b}	19.9^{bc}	19.9^{bc}	20.2^{b}	21.9^{a}	20
14 Tibia Ash P %	4.7^{a}	4.0^{bc}	4.0^{bc}	4.5^{ab}	5.0^{a}	3.5^{c}	4.7^{a}	4.5^{ab}	4.5^{ab}	4.4

References

REFERENCES

Andrews, C.V., Vengopalan, C.K., Unni, A.K.K. and Ramakrishnan, A. 1984. Comparative performace of Desi ducks reared under two systems of housing. *Kerala J. Vet. Sci.* **15**(2): 140-145.

Anon, 1994. Indian poultry industry year book 1997. S.P. Gupta, A.25, Priyadarshini Vihar, New Delhi. 10th edn. p.713

Anon, 1999. Watt poultry statistical year book 1999. *Poult. Int.* **38**(9): 12

Anon, 2001. Farm Guide, Information Bureau Government of Kerala. pp.33

Anon, 2002. Annual Report (2001-2002) NATP on "Productivity Enhancement of Ducks" Kerala Agricultural University p.70

AOAC. 1990. Association of official analytical chemist. Official methods of analysis of the association of official analytic chemist Iled, Washington, DC. p.642

Applegate, T.J., Harper, D. and Lilburn, M.S. 1998. Effect of hen production age on egg composition and embryo development in commercial Pekin ducks. *Poult. Sci.* 77: 1608-1612.

Avens, J.S., Athearn, R.M., and McNeal, J.H. 1980. Egg production and efficiency of food conversion of Khaki Campbell ducks under different Management Systems. *Brit. Poult.Sci.* **21**: 333-337.

Bandyopadhyay, U.K., and Sikdar, A. (2000). Duck farming Neglected but potential sector. *Indian poult. Rev.* **32**(4): 37-46.

Baruah, R.K. Sharma, P.K. and Bora, N.N. 1991. Egg production of indigenous, Khaki Campbell ducks and their crosses. *Indian J. Poult. Sci.* **26**(4): 193-197.

BIS. 1992. Bureau of Indian Standards. Indian standard specification of poultry feeds (revised) IS 1374-1992. Manak Bhavan, 9, Bahadur Shah Zafar Marg, New Delhi.

Bolton, W. and Blair, R. 1977. Poultry Nutrition 4th edn. Bulletin 174. Published by Her Majesty's Stationary Office, London. p.134.

Bulbule, V.D. 1982. Duck raising. *Poult. Advisor* **15**(9): 41-43

Bulbule, V.D. 1992. Feeding practices in duck. *Indian Poult. Rev.* **23**(12): 25-33

*Chavez, E.R. and Lasmini, A. 1978. Comparative performance of native Indonesian egg laying ducks. *Anim. Breed. Abstr.* **48**(4): 2210

Chen, B.J. 1992. Nutritional requirement of laying brown Tsaiya ducks *poult. Abstr.* **21**(2): 46-47.

Das, G.C., Goswami, N., Das, D. and Goswami, R.N. 2000. Comparative studies on age at sexual maturity and egg production at different ages of Khaki Campbell, Desi ducks and their crosses under field condition. *Indian J. poult. Sci.* **35**(3): 240-242.

Davis, G.S., Parkhurst, C.R. and Brake, J. 1993. Light intensity and sex ratio effect on egg production, egg quality characteristics and fertility in breeder Pekin ducks. *Poult Sci.* **72**: 23-29

Dutta, K.Kr., Pathak, J.N. Dutta, K.K. and Goswami, R.N. 1993. Body weight of Khaki Campbell ducks at different ages under three managemental systems. *Indian poult. Rev.* **24**(8): 41-43.

Eswaran, K.R., Ramakrishnan, A., Venugopalan, C.K. and Nair, G.R. 1985. Comparative performance of Khaki Campbell and Desi ducks, 2. egg production, feed efficiency and egg quality. *Indian J. poult. Sci.* **20**(1): 42-45.

Gajendran, K. Kothandaraman, P. and Sheriff, F.R. 1990. Performance of Khaki Campbell and Desi ducks under intensive system of rearing in Maritime monsoon type of climate. *Cheiron.* **19**(5) 213-219.

Hamid, M.A., Chowdhury, S.M.R.K. and Chowdhury, S.D. 1988. A comparative study on the performance of growing ducklings of Khaki Campbell, Indian Runner and Indigenous ducks under farm conditions. *Indian J. Poult. Sci.* **23**(2): 118-121.

Hengmin, C. and Lingping, L. 1997. Phosphorus deficiency heavily affects ducking. *World Poult.* **13**(4): 18-19

*Hutt, F.B. 1953. The Jansen Khaki Campbell duck *Anim. Bred. Abstr.* **21**(2): 1449.

Kalango, I.O. and Ademosun, A.A. 1973. Effect of Calcium and Phosphorus levels on the performance of layers in Nigeria II. Bone ash, Calcium and Phosphorus retention. *Poult. Sci.* **52**: 1393-1398

Keshavarz, K. 1985. The effect of high dietary levels of calcium with different dietary levels of Phosphorus on performance and retention of these nutrients by the laying hens. *Poult. Sci.* (Suppl.1), **64**: 127

Ketaren, P.P. 1998. Feed and Feeding of ducks in Indonesia. *Indonesian Agri. Res. Dev. J.* **20**(3): 51-56.

*Konovalov, V. 1974. Restricted feeding of replacement ducks. *Nutr. Abstr. Rev.* (1975) **45**: 9414

Mahanta, J.D. 1997. Characterisation and evaluation of indigenous ducks of Kerala. Ph.D thesis, Kerala Agricultural University, Trichur. p.140

Mahanta, J.D., Dutta, D.J. and Rahman, H. 1993. Physical quality characteristics of indigenous and Khaki Campbell duck eggs. *Indian J. Poult. Sci.* **28**(2): 147-149.

Mostageer, A., Kamar, G.A.R. and Goher, N.E. 1971. The effect of crossing on the productivity of ducks. III. On egg production. *Anim. Bred. Abstr.* **39**(4): 5205.

*Narahari, D. and Sundararasu, V. 1988. Relative performance of ducks on wet and dry mash feeding. *Indian poult.Rev.* 19(7): 49

*Narahari, D. and Sundararasu, V. 1996. Studies on different rearing system and roof insulation on the laying performance of Khaki Campbell ducks. *Indian poult. Rev.* 17(12): 26.

*Nesbitt, B.F., Kelly, J.O. and Sargent, K.S.A. 1962. Feeding practices in ducks. *Nature*. **195**: 1062-1063.

NRC. 1994. Nutrient Requirement of Poultry 9th edn. Published by National Academy press, Washington, D.C. pp.20

Panda, A.K., Ramarao, S.V., Raju, M.V.L.N. and Shyamsunder, G. 2002. Performance of commercial broilers fed diet with different levels of non phytin phosphorus. *Indian J. Poult. Sci.* 37(1): 45-48.

Patra, U.K., Samanta, A. and Dey, A. 1989. Some aspects of duck nutrition. *Indian Poult. Rev.* 20(11): 33-35.

Portsmouth, J. 1985. Needs for calcium phosphorus, sodium, manganese, chloride and vitamin D_3. *Indian Poult. Rev.* 16(19): 17-21.

Ramakrishnan, A. 1996. Ducks production scenario in India. Scope for improvement. Proceedings of xxth world's poultry congress, New Delhi, India, Sept 2-5 Vol.I. pp. 589-596.

Rao, B.S. 1981. Suggested nutrient for different age groups and rations composition for laying type of ducks. *Indian poult. Rev.* 23(12): 25-33.

Rashid, N., Barua, A. and Bulbul, S.M. 1995. A study of the performance of Khaki Campbell, Desi and Khaki Campbell, x desi ducks with and without extra feeding under rural conditions of Bangladesh. *Asian-Australacian J. Anim. Sci.* 8(4): 375-378.

Reddy, M. K., Rao, P.V. and Reddy, V.R. 1981. A study on the protein and energy requirements of Khaki Campbell layer ducks. *Indian J. Poult. Sci.* **16**: 132-137.

Reddy, P.M. and Reddy, V.R. 1979. Studies on growth rate and feed efficiency in Khaki Campbell ducklings. *Indian J. Poult. Sci.* **14**:48-49

Sarma, N.K., Barurah, K.K., Pathak, J.N. and Bora, N.N. 1986. Age at sexual maturity of Khaki Campbell ducks as affected by different levels of protein. *Indian Poult. Rev.* **17**(24): 27-29.

Scott, M.L. and Heuser, G.F. 1952. Studies in ducks nutrition. Bowed legs in ducks causes niacin deficiency *Poult. Sci.* **31**(4): 752-754.

Shrivastava, A.K. and Panda, B. 1982. Raise ducks-earn more. *Farmers J.* **2**(5): 27-36.

Singh, R.A. and Pal, R.N. 1978. Effect of levels of dietary protein on mortality, growth and reproduction of White Pekin ducks. *Indian Vet. J.* **55**: 390-393

Snedecor, G.W. and Cochran, W.G. 1980. Statistical Methods. 7th edn., Oxford and IBH Publishing Co., Calcutta. P. 564.

Tian-Fwu C., Yu-Tsai L. and Chin-Moo P. 1998. Calcium Requirements of Cage-Feeding laying Tsaiya ducks. *J. Taiwan Livestock Res.* **31**(1): 27-33.

*Zakaria, A. 1994. Feeding and managing ducks. *Indian Poult. Rev.* **25**(10): 45.

* *Original not seen*

Appendices

APPENDICES

Appendix 1 Week-wise Duck Housed Number (DHN) in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

Age in weeks	calcium (%)			available phosphorus (%)		
	3	3.5	4	0.4	0.5	0.6
21	0	0	0	0	0	0
22	0.03	0	0.17	0	0.03	0.17
23	0.47	0.23	1.0	0.2	0.6	0.90
24	1.7	0.9	2.1	1.0	2.2	1.4
25	3.1	1.6	3.3	1.9	3.9	2.2
26	3.5	2.5	3.8	2.7	4.0	3.2
27	4.2	3.8	4.3	4.0	4.6	3.7
28	4.7	5.1	5.2	5.3	4.5	5.3
29	4.0	4.7	4.5	4.6	4.4	4.2
30	4.8	4.6	4.6	5.0	4.0	4.9
31	4.5	4.5	4.1	4.1	4.4	4.6
32	4.7	4.4	4.6	5.0	3.7	5.0
33	3.7	4.6	4.6	4.3	3.9	4.7
34	4.8	4.5	4.2	5.1	4.5	3.9
35	4.6	4.0	4.6	4.4	4.3	4.5
36	5.0	4.9	5.1	5.6	4.7	4.7
37	3.7	3.4	4.5	4.0	3.6	3.9
38	4.2	5.2	5.3	4.6	5.2	4.9
39	3.8	3.6	4.9	4.6	4.0	3.7
40	3.6	3.9	4.4	4.0	3.9	3.9
Cumulative	68.9	66.4	75.7	70.2	70.2	70.6

Appendix 2 Duck housed egg number (DHN) in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

Ca (%)	3			3.5			4.0		
AP (%)	0.4	0.5	0.6	0.4	0.5	0.6	0.4	0.5	0.6
Diet No.	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
I	1.0	3.3	2.2	1.4	1.9	-	1.2	3.3	5.2
II	15.6	17.3	13.8	15.5	14.1	9.4	10.3	19.4	19.9
III	19.4	17.2	17.2	16.3	18.0	20.3	20.3	14.3	18.9
IV	20.4	17.8	15.9	16.5	18.0	19.5	21.0	16.2	20.2
V	17.3	16.7	11.7	16.1	16.5	15.6	18.3	17.0	21.9
Cumulative egg number (21 to 40 weeks)	73.7	72.3	60.8	65.8	68.5	64.8	71.1	70.2	86.1
Overall mean 25-40 week	18.0^{ab}	17.3^{abc}	14.7^{c}	16.1^{bc}	16.7^{bc}	16.2^{bc}	17.5^{abc}	16.7^{bc}	20.2^{a}

Overall Mean
2.4
15.0
18.0
18.4
16.8

Note: *The interaction was significant ($P<0.05$) and the means bearing same superscripts did not differ significant*

Appendix 3 Week-wise per cent production in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

Age in weeks	calcium (%)			available phosphorus (%)			
	3	3.5	4	0.4	0:5	0.6	Overall Mean
21	0	0	0	0	0	0	0
22	0.47	0	2.4	0	0.47	2.4	1.4
23	6.7	3.3	14.2	2.8	9.1	12.3	8.1
24	23.8	12.4	29.5	14.3	31.0	20.5	21.9
25	43.8	22.9	46.7	26.7	55.7	30.9	37.8
26	50.5	35.7	53.8	38.1	56.7	45.3	46.7
27	60.5	53.8	61.4	57.2	65.7	52.9	58.6
28	67.6	73.3	74.3	75.2	63.8	76.2	71.7
29	57.2	67.1	64.3	65.2	62.9	60.5	62.9
30	68.1	65.2	65.7	71.4	57.1	70.5	66.3
31	64.3	64.3	58.6	58.1	63.3	65.7	62.4
32	66.7	63.4	66.2	71.9	52.4	71.9	65.4
33	52.4	65.7	65.7	60.9	55.2	67.6	61.3
34	68.6	63.8	69.5	72.4	63.8	65.7	67.3
35	65.2	57.6	65.3	62.4	61.0	64.8	62.7
36	71.4	70.0	72.9	80.0	67.6	66.7	71.4
37	52.4	48.1	63.8	57.6	51.4	55.2	54.8
38	60.0	74.8	75.2	65.2	74.8	70.0	70.0
39	54.3	55.7	70.5	65.7	56.7	53.3	58.6
40	51.0	55.7	62.9	57.6	56.2	55.7	56.5
Overall Mean 25-40	59.4	58.0	64.6	61.5	60.0	60.6	60.7

Appendix 4 Period wise egg production (per cent) in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

Ca (%)		3			3.5			4.0		
AP (%)	0.4	0.5	0.6	0.4	0.5	0.6	0.4	0.5	0.6	Overall Mean
Diet No.	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	
I	3.57	11.8	7.9	5	6.8	-	4.3	8.2	18.6	8.27
II	55.7	61.8	49.3	55.4	50.4	33.6	36.8	69.3	71.1	53.70
III	68.1	61.4	60.2	58.2	63.1	72.5	72.5	49.9	66.3	63.6
IV	72.9	63.6	56.8	58.9	64.3	69.64	75.0	57.9	72.1	65.7
V	61.8	59.6	41.8	57.5	56.5	55.7	65.4	60.7	78.2	59.7
Overall mean 25-40 week	64.6^{ab}	61.6^{abc}	52.0^{c}	57.5^{bc}	58.6^{bc}	57.9^{bc}	62.4^{abc}	59.4^{bc}	71.9^{a}	60.7

Note: *The interaction was significant ($P<0.05$) and the means bearing same superscripts did not differ significant*

Appendix 5 Period wise mean daily feed consumption in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

Ca (%)		3			3.5			4.0		
AP (%)	0.4	0.5	0.6	0.4	0.5	0.6	0.4	0.5	0.6	Overall Mean
Diet No.	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	
I	101	101	96	95.6	102	105	108.5	107	102.8	102.1
II	111.5	122.3	107.8	112.8	114	112.3	112.5	123.3	124	115.6
III	137.8	149.5	128.8	128	130.5	131	135.3	135.5	139	135
IV	148.5	159.3	144.8	147.5	147.5	146.5	159	154.5	161.8	152.2
V	147.3	149	139.8	143	143.3	146.8	149.5	143.8	150.5	145.9
Overall mean 25-40 week	136.3	145.0	130.3	132.8	133.8	134.2	139.1	139.3	143.8	137.2

Appendix 6 Week-wise Feed Conversion Ratio (FCR) per Dozen Egg in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

Ca (%)	3			3.5			4.0		
AP (%)	0.4	0.5	0.6	0.4	0.5	0.6	0.4	0.5	0.6
Diet No.	T1	T2	T3	T4	T5	T6	T7	T8	T9
21	-	-	-	-	-	-	-	-	-
22	-	70.2	-	-	-	-	-	-	15.4
23	-	11.9	12.1	64.4	14.7	-	17.7	14.4	4.7
24	9.8	3.5	4.9	5.7	6.9	0	13.5	3.7	3.0
25	3.3	1.8	3.4	3.4	3.7	61.7	8.2	1.9	2.0
26	2.8	2.8	3.1	3.3	3.6	6.2	7.6	2.0	2.2
27	2.2	2.1	2.6	2.0	2.2	4.8	3.7	2.1	2.0
28	1.9	3.0	2.0	1.9	2.2	1.9	1.9	2.5	2.1
29	2.5	3.0	3.3	2.6	2.2	1.9	2.2	2.6	3.0
30	1.9	2.8	2.3	2.0	2.3	2.1	2.2	2.8	1.9
31	2.9	2.9	2.2	3.2	2.3	2.3	2.5	3.3	3.1
32	2.3	3.1	2.5	2.9	3.0	2.3	2.0	4.4	2.2
33	3.3	5.2	2.9	3.2	2.8	2.4	3.0	3.4	3.2
34	2.3	2.2	3.8	2.8	2.8	2.6	2.5	3.4	2.4
35	2.2	3.3	3.0	3.6	3.0	2.9	3.0	3.1	2.6
36	2.2	2.5	2.7	2.6	2.4	2.3	1.9	3.0	2.5
37	2.6	3.5	4.3	3.2	3.8	3.7	3.6	2.9	2.1
38	2.8	2.3	3.4	2.8	2.0	2.1	2.1	2.5	2.1
39	2.9	3.3	3.7	2.8	3.8	3.9	2.5	2.6	2.7
40	3.2	3.0	4.6	3.1	2.9	3.7	3.2	3.7	2.4
Overall Mean 25-40	2.5	2.8	3.1	2.8	2.7	-	-	2.9	2.4

Appendix 7 Period wise mean Feed Conversion Ratio (FCR)/ dozen egg in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

Ca (%)		3			3.5			4.0		
AP (%)	0.4	0.5	0.6	0.4	0.5	0.6	0.4	0.5	0.6	Overall Mean
Diet No.	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	
I	34.2	10.3	14.7	23.0	18.0	-	28.7	10.9	6.6	19.5
II	2.4	2.4	2.6	2.4	2.7	4.0	3.7	2.1	2.10	2.7
III	2.3	2.9	2.5	2.7	2.4	2.2	2.2	3.2	2.5	2.6
IV	2.5	3.00	3.1	3.00	2.8	2.5	2.5	3.2	2.7	2.8
V	2.9	3.00	4.00	3.0	2.9	3.27	2.8	2.8	2.3	3.0
Overall mean 25-40 week	2.5	2.8	3.1	2.8	2.7	3.0	2.8	2.9	2.4	2.8

Appendix 8 Week-wise Feed Conversion Ratio (FCR) per kg egg mass in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

Ca (%)	3			3.5			4.0		
AP (%)	0.4	0.5	0.6	0.4	0.5	0.6	0.4	0.5	0.6
Diet No.	T1	T2	T3	T4	T5	T6	T7	T8	T9
21	0	0	0	0	0	0	0	0	0
22	0	125.3	0	0	0	0	0	0	24.3
23	0	18.7	20.5	149.7	21.3	0	27.8	23.9	7.0
24	14.8	5.3	8.3	9.2	10.3	0	21.7	6.0	4.9
25	5.3	3.0	4.8	5.7	5.3	109.5	12.7	3.0	3.6
26	4.3	4.2	4.5	5.5	5.9	8.7	12.5	3.4	3.7
27	3.5	3.2	4.0	3.1	3.3	7.2	5.6	3.3	3.1
28	2.8	4.6	3.0	3.1	3.1	2.9	2.9	3.6	3.4
29	4.0	4.5	4.9	4.2	3.4	2.8	3.2	3.9	4.8
30	2.9	4.1	3.5	3.0	3.5	3.5	3.3	4.0	3.0
31	4.1	4.0	3.2	4.6	3.3	3.2	3.9	4.6	4.4
32	3.1	4.0	3.5	3.7	4.4	3.5	3.1	6.1	3.2
33	4.7	7.2	3.8	4.4	4.1	3.5	4.3	4.5	4.5
34	3.0	2.9	4.8	3.8	3.8	3.6	3.3	4.4	3.3
35	3.0	4.5	3.9	4.5	4.0	3.8	3.8	4.1	3.9
36	2.9	3.3	3.3	3.4	3.2	2.9	2.5	3.7	3.5
37	3.4	4.8	5.1	4.1	4.7	4.9	4.8	3.6	2.8
38	3.7	3.2	4.0	3.6	2.5	2.7	2.8	3.2	2.8
39	3.8	4.2	4.6	3.8	5.0	5.0	3.2	3.4	3.7
40	4.7	3.7	5.8	4.0	3.6	4.5	3.7	5.0	3.3
Overall Mean 25-40	3.6	4.0	4.1	3.9	3.8	-	4.0	3.9	3.6

Appendix 9 Period wise Feed Conversion Ratio (FCR)/ kg egg mass in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

Ca (%)		3			3.5			4.0		
AP (%)	0.4	0.5	0.6	0.4	0.5	0.6	0.4	0.5	0.6	Overall Mean
Diet No.	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	
I	53.3	17.1	26.60	39.6	27.9	-	51.8	18.42	11.5	30.63
II	3.7	3.7	3.9	4.0	4.00	6.1	5.6	3.4	3.4	2.6
III	3.4	4.2	3.7	3.7	3.6	3.3	3.3	4.3	3.8	3.7
IV	3.3	4.0	3.9	4.0	3.8	3.5	3.4	4.2	3.8	3.8
V	3.8	3.9	4.8	3.9	3.7	4.0	3.5	3.7	3.1	3.8
Overall mean 25-40 week	3.6	4.0	4.1	3.9	3.8	4.3	4.0	3.9	3.6	3.9

Appendix 10 Week-wise Total Egg Mass in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

Ca (%)	3			3.5			4.0		
AP (%)	0.4	0.5	0.6	0.4	0.5	0.6	0.4	0.5	0.6
Diet No.	T1	T2	T3	T4	T5	T6	T7	T8	T9
21	0	0	0	0	0	0	0	0	0
22	0	0.051	0	0	0	0	0	0	0.267
23	-	0.382	0.355	0.047	0.344	0	0.267	0.302	1.068
24	0.528	1.386	0.765	0.684	0.738	0	0.374	1.439	1.418
25	1.241	2.407	1.277	1.127	1.383	0.056	0.482	2.360	2.018
26	1.893	2.206	1.726	1.601	1.412	0.933	0.664	2.586	2.459
27	2.328	2.476	2.002	2.528	2.346	1.183	1.528	2.586	2.742
28	2.898	2.163	2.814	2.664	2.764	3.021	2.950	2.727	2.942
29	2.222	2.425	1.868	2.130	2.442	3.068	3.065	2.334	2.051
30	2.986	2.344	2.570	2.696	2.389	2.379	2.750	2.113	2.793
31	2.629	2.692	2.675	1.953	2.883	3.009	2.399	2.220	2.439
32	3.375	2.622	2.716	2.678	2.373	2.863	3.137	1.657	3.127
33	2.320	1.650	2.807	2.396	2.683	2.913	2.798	2.562	2.874
34	3.278	3.610	2.291	2.656	2.672	2.849	3.554	2.159	3.299
35	3.350	2.520	2.621	2.289	2.613	2.758	2.706	2.744	2.916
36	3.710	3.247	2.711	2.943	3.034	3.337	3.958	2.879	2.936
37	3.056	2.235	1.834	2.425	2.067	2.138	2.252	2.725	3.542
38	2.697	3.134	2.260	2.689	3.889	3.718	3.373	3.051	3.738
39	2.720	2.583	2.194	2.665	2.079	2.100	3.332	3.016	2.866
40	2.288	2.754	1.794	2.609	2.925	2.281	2.000	2.087	3.405
Cumulat.	43.53	42.67	37.12	38.96	40.95	38.45	42.59	41.89	48.46

Appendix 11 Mean Egg Weight (week wise) in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

Ca (%)	3			3.5			4.0		
AP (%)	0.4	0.5	0.6	0.4	0.5	0.6	0.4	0.5	0.6
Diet No.	T1	T2	T3	T4	T5	T6	T7	T8	T9
21	0	0	0	0	0	0	0	0	0
22	0	50.6	0	0	0	0	0	0	53.3
23	0	54.5	44.3	47.3	57.4	0	53.4	50.3	56.2
24	52.8	55.4	47.8	52.6	56.8	0	53.4	53.3	50.6
25	51.7	53.5	55.5	53.6	55.3	56.3	53.5	52.4	51.7
26	54.1	55.1	55.7	51.7	54.3	58.3	51.1	52.8	52.3
27	54.1	55.0	57.2	53.8	54.6	56.3	56.6	53.9	52.7
28	53.7	56.9	56.3	53.3	56.4	56.0	56.7	54.5	53.5
29	54.2	57.7	56.6	53.3	55.5	55.8	57.8	58.4	54.0
30	54.3	58.6	57.1	56.2	55.6	55.3	55.0	57.1	53.7
31	58.4	61.2	60.8	57.4	56.5	59.0	57.1	58.4	56.7
32	60.3	62.4	61.7	60.9	56.5	58.4	57.0	61.4	57.9
33	59.5	61.1	62.4	59.9	58.3	58.3	58.3	62.5	58.7
34	63.0	63.3	63.6	60.4	60.7	59.3	63.5	63.5	61.1
35	59.8	63.0	62.4	63.6	62.2	64.1	64.4	62.4	60.8
36	61.8	63.7	64.6	65.4	63.2	64.2	60.9	65.4	62.5
37	63.7	63.9	65.5	65.5	66.7	66.8	64.3	64.9	63.3
38	62.7	66.7	66.5	65.6	65.5	65.2	64.9	63.6	62.3
39	63.3	66.2	68.6	62.0	65.0	65.6	64.1	62.8	61.0
40	61.8	67.2	66.4	65.2	66.5	67.1	65.2	63.2	60.8
Overall Mean 25-40	58.5	60.4	61.5	58.8	59.9	59.9	59.7	60.1	57.3

Appendix 12 Mean egg weight in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

Ca (%)		3			3.5			4.0		
AP (%)	0.4	0.5	0.6	0.4	0.5	0.6	0.4	0.5	0.6	Overall Mean
Diet No.	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	
I	53.2	50.0	46.0	48.4	53.7	-	48.9	49.3	48.1	49.7
II	53.6	53.5	56.7	51.1	56.6	55.0	54.6	53.2	52.1	54.0
III	56.9	59.7	58.6	57.3	56.0	56.7	56.8	60.9	55.4	57.6
IV	60.6	62.3	63.2	62.3	61.1	61.8	63.2	62.7	59.7	61.9
V	62.9	66.1	67.3	64.5	65.9	66.0	64.3	63.6	61.9	64.7
Overall mean 25-40 week	58.5^{d}	60.4^{b}	61.5^{a}	58.8^{d}	59.9^{bc}	59.9^{bc}	59.7^{c}	60.1^{bc}	57.3^{e}	59.6

Note: *The interaction was significant ($P<0.05$) and the means bearing same superscripts did not differ significant*

Appendix 13 Shell thickness (mm) in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

Ca (%)		3			3.5			4.0		
AP (%)	0.4	0.5	0.6	0.4	0.5	0.6	0.4	0.5	0.6	Overall Mean
Diet No.	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	
I	0.53	0.52	0.54	0.54	0.54	-	0.54	0.52	0.52	0.53
II	0.54	0.53	0.55	0.55	0.54	0.53	0.53	0.55	0.54	0.54
III	0.53	0.52	0.54	0.51	0.53	0.54	0.53	0.52	0.56	0.53
IV	0.56	0.54	0.55	0.54	0.54	0.56	0.56	0.55	0.54	0.55
V	0.54	0.51	0.54	0.54	0.54	0.56	0.52	0.51	0.55	0.53
Overall mean 25-40 week	0.54	0.53	0.55	0.54	0.54	0.55	0.54	0.53	0.55	0.54

Appendix 14 Shell weight (per cent) in indigenous layer ducks as influenced by varying levels of calcium and available phosphorus in the diet

Ca (%)		3			3.5			4.0		
AP (%)	0.4	0.5	0.6	0.4	0.5	0.6	0.4	0.5	0.6	Overall Mean
Diet No.	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	
I	10.2	9.4	10.2	10.2	9.9	-	10.4	9.8	10.0	10.0
II	10.3	9.8	9.9	10.3	9.6	9.6	9.9	10.0	10.3	10.0
III	9.8	9.7	9.8	9.8	10.1	10.3	10.5	9.8	10.5	10.0
IV	10.0	9.9	9.9	9.9	9.5	10.0	10.1	9.5	9.7	9.8
V	10.0	9.1	9.7	9.5	9.4	10.1	9.8	9.5	9.9	9.7
Overall mean 25-40 week	10.0	9.6	9.8	9.9	9.7	10.0	10.10	9.7	10.1	9.9

Appendix 15 The calcium and phosphorus content in the serum and tibia ash as influenced by experimental diets

Ca (%)		3			3.5			4.0		
AP (%)	0.4	0.5	0.6	0.4	0.5	0.6	0.4	0.5	0.6	Overall Mean
Diet No.	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	
Serum calcium (mg/dl)	15.9	14.2	15.1	14.8	15.4	15.0	17.0	16.4	15.0	15.4
Serum phosphorus (mg/dl)	3.3	3.1	3.4	3.4	3.4	3.2	2.8	2.5	3.4	3.2
Tibial Ash %	60.2	59.9	60.8	60.0	60.1	63.1	58.9	59.8	63.1	60.7
Tibial Ash Ca %	19.6^{bc}	18.7^{c}	20.2^{b}	19.9^{bc}	20.1^{b}	19.9^{bc}	19.9^{bc}	20.2^{b}	21.9^{a}	20.0
Tibial Ash P %	4.7^{a}	4.0^{bc}	4.0^{bc}	4.5^{ab}	5.0^{a}	3.5^{c}	4.7^{a}	4.5^{ab}	4.5^{ab}	4.4

Note: *The interaction was significant ($P<0.05$) and the means bearing same superscripts did not differ significant*

CALCIUM AND PHOSPHORUS REQUIREMENTS OF INDIGENOUS LAYER DUCKS (*Anas platyrhynchos*)

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ABSTRACT OF A THESIS

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ABSTRACT

A 3 x 3 factorial experiment was carried out at the Department of Poultry Science, Kerala Agricultural University during the period from February to July 2002 to establish the optimum requirements of calcium (Ca) and available phosphorus (AP) in the diets for indigenous layer ducks under cage system of rearing.

The Kuttanad varieties of indigenous ducklings of Kerala were maintained on deep litter system of rearing until 18 weeks of age at the University poultry farm, Mannuthy. From this flock, Ninety (90) female ducks were housed in 45 California type cages at the rate of two ducks per cage and they were weighed individually at 20 weeks of age. The dimension of each cage was 60 x 45 x 40 cm and the floor area of 1350 cm^2 per duck was provided in the cage. The experimental diets were fed from 21 to 40 weeks of age and the observations were recorded in five periods of 28 days each. Nine experimental diets containing three levels of Ca viz., 3.0, 3.5 and 4.0 per cent with three levels of AP viz., 0.40, 0.50 and 0.60 per cent were formulated and were fed to nine treatments consisting of five replicates of two ducks per cage in each treatment in a 3x3 factorial design.

The mean body weight of ducks at 20 weeks of age was uniform in all groups ranging from 1400±9.11 to 1465±53.24 g with an overall mean of 1431±9.96 g. The Ca and AP levels did not influence significantly the 40^{th} week body weight, which ranged from 1473±18.10 to 1579±58.28 g with an overall mean of 1544±13.76g. The age at first egg in the flock with 3.0, 3.5 and 4.0 per cent Ca levels were 154, 158 and 148 days respectively and with AP levels 0.4, 0.5 and 0.6 per cent the same were 161, 154 and 148 days respectively.

The period wise mean duck housed number (DHN) from 25-40 weeks of age (18.1eggs) was significantly higher with ducks fed 4.0 per cent Ca ($P<0.05$). The interaction effect was significant ($P<0.05$) for the dietary combination of 4.0 per cent Ca and 0.6 per cent AP with 20.2 eggs. The cumulative egg number (EN) of 75.7 eggs from 21 to 40 weeks of age was also higher with the Ca level 4.0 per cent and the 71.9 per cent production with diet T9 was superior by interaction effect ($P<0.05$). The duck housed per cent (DHP) production from 25 to 40 weeks of age averaged 64.6±1.92 per cent with 4.0 per cent Ca level.

The Ca and AP levels in the diet did not influence the mean daily feed consumption, feed conversion ratio (FCR), egg mass and shell thickness. The overall mean daily feed consumption was 137.2±1.49 g per duck. The FCR per dozen eggs was 2.8±0.078 and that per kg egg was 3.9±0.099 for the period from 25 to 40 weeks of age. The mean egg weight (EW) and per cent shell were highly significant and the EW of 60.1±0.575 g averaged with 3.0 per cent Ca and 0.5 per cent AP level as well were high ($P<0.01$). The interaction effect with the above combination was also significant ($P<0.01$). The 9.7±0.081 per cent shell recorded with 0.5 per cent AP was significantly lower in comparison with other AP levels ($P<0.05$).

At 40 weeks of age, the overall mean serum Ca was 15.42±0.35 mg/dl and serum P was 3.18±0.081 mg/dl. The mean serum inorganic P value of 2.92±0.164 mg/dl recorded with dietary Ca level 4.0 per cent was significantly lower than that of 3.5 per cent Ca level ($P<0.05$). The tibia ash (62.34±0.512 per cent) was significantly higher with 0.6 per cent dietary AP level ($P<0.05$) and the tibia ash Ca with 4.0 per cent dietary Ca level was significantly higher and the interaction effect with 0.6 per cent AP level was also significant. With this AP level, the tibia P was reduced significantly, but

the interaction showed that the tibia P was high with diet T9. The liveability was excellent in ducks reared in cages (100 per cent) and there was no mortality during the period from 21 to 40 weeks of age.

In the present study, the production traits used for evaluating the Ca and AP requirements of caged layer ducks were EN, EW, egg mass, feed consumption and FCR. The study revealed that 4.0 per cent Ca in the diet was superior over other Ca levels in the diet. The dietary Ca and AP levels did not influence the mean daily feed consumption and feed conversion ratios significantly. On the other hand, dietary AP levels influenced the mean EW, per cent shell, tibia ash weight and tibia ash Ca and P. Though the mean EW of 60.1±0.566 g recorded with 0.5 per cent AP was significantly higher, the significant interaction on egg number with the 0.6 per cent AP with 4.0 per cent Ca was found superior. Therefore it will be logical to set the requirements of AP at 0.6 per cent level.

Thus, the overall results of the present study revealed that the 4.0 per cent Ca and 0.6 per cent AP levels with 18 per cent Crude Protein and 2650 Kcal ME/kg was optimum for egg production in indigenous layer ducks under cage system of rearing.