Production Performance of Improved Indigenous Poultry Breeds under Different Management Regimes

A thesis submitted to the

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in

ANIMAL HUSBANDRY

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CERTIFICATE

This is to certify that the thesis entitled, "**Production Performance of Improved Indigenous Poultry Breeds under Different Management Regimes"** submitted to faculty of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri, Maharashtra State, in partial fulfillment of the requirements for the degree of Doctor of Philosophy (Agriculture) in Animal Husbandry embodies the results of a piece of *bona-fide* research carried out by **Mr. Shalu Kumar** under my guidance and supervision and that no part of this thesis has been submitted for any other degree or diploma. All the assistance and help received during the course of investigation and the sources of literature have been duly acknowledged by him.

Place: DBSKKV, Dapoli

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APPENDIX – I

ABBREVIATIONS USED

AOAC	:	Association of Official Analytical chemists
e.g.	:	For example
Temp	:	Temperature
Kg	:	Kilogram
FRBD	:	Factorial Randomized Block Design
%	:	Per cent
/	:	Per
<	:	Less than
>	:	Greater than
^0C	:	Degree Celsius
@	:	At the rate of
C.D.	:	Critical difference
etc.	:	Etcetera (and other things)
Fig.	:	Figure
G	:	Gram
hr	:	Hour(s)
i.e.	:	Id est (that is)
Dm	:	Dry matter
CoA	:	oenzyme A
CP	:	Crude Protein
dl	:	Decilitre
mm	:	Milimeter
HDL	:	High density lipoprotein
HDLC	:	High density lipoprotein cholesterol
LDL	:	Low density lipoprotein
LDLC	:	Low density lipoprotein cholesterol

FCR	:	Feed Conversion Ratio
PRS	:	Poultry Research Station
NFE	:	Nitrogen free extract
nm	:	Nanometer
NS	:	Non-significant
ppm	:	Parts per million
rpm	:	Revolution per minute
mg	:	Miligram
km	:	Kilometer
m	:	Molar
KOH	:	Potassium hydroxide
Rs.	:	Rupees
Avg.	:	Average
DLS	:	Deep litter system
BCS	:	Battery cage system
SIS	:	Semi intensive system
Wt.	:	Weight
RD	:	Rain day
R.T.	:	Rectal temperature
Res	:	Respiration rate

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(Shalu K. Rana)

CHAPTER - I
INTRODUCTION

Poultry (*Gallus domesticus* L.) production is one of the areas in livestock withsignificant contribution to human food. Poultry products in recent years become important and popular food for the 68 per cent of non-vegetarian population. Chickens
are widely reared in India and total population of chicken in India is estimated to be about 729.21 million (Anonymous, 2012a) with 133.79 million improved layer bird population (Birthal, *et al.* 2012) regarding breed, 70.50 per cent (514.13 million),18.34 per cent (133.79 million) and 11.14 per cent (81.28 million) of the total poultry were reported to be hybrid and exotic, improved layer and indigenous birds, respectively. The estimate of total number of eggs produced during the year is about74.75 billion tons (Anonymous, 2012b). Chickens are important farm animal species in almost all countries in the world. They are an important source of animal protein and can be kept in situations with limited feed and housing resources. Chickens produce eggs and meat which are next to milk as a contributor to the output from livestock sector in recent years
(Rajendran and Samarendu, 2003) and chickens are also waste converters; theyconvert scavenged feed resource base into animal protein if kept under semi-intensive and extensive system.Today India is the third largest in egg and fifth largest in broiler production in the world. Indian poultry industry is growing at the rate of 8 to 10 per cent for eggs and 15 to 20 per cent for broiler production due to improved poultrystrain/variety (Jha *et al.,* 2013a). Per capita annual availability of poultry products has increased to 62
eggs and 2.20 kg of meat (Anonymous, 2015a) still below the recommended levels of 180 eggs and 11 kg of meat per person by Indian Council of Medical Research, New Delhi (Niranjan *et al.*, 2008). The poultry sector in India can be characterized into three major production systems based on some selected parameters such as breed, flock size, housing, feed, ealth, technology and bio-security. These are large commercial, small scale commercial and backyard poultry production system. These production systems have their own specificchicken breeds, inputs and production properties. Each can2 sustainably co-exists and contribute to solve the socio-economic problems of different

targeted societies (Tadelle *et al.,* 2003). From the total population of chicken in India,34 per cent are raised under the traditional back yard system of management, while 66per cent are under intensive and semi-intensive management system (Prabakaran, 2003). The traditional poultry production system is characterized by small flock sizes,low input and output and periodic devastation of the flock by diseases (Demeke, 2007)and it also contributes nearly 30 per cent to the national egg production. The Indian improved indigenous chickens are characterized by rapid growth rate, early maturity and better production performance. The mean annual egg production of improved indigenous chickens is estimated at 160-220 eggs with thick shells and a deep yellow yolk colour (Anonymous, 2014). The egg laying period and number of eggs laid perperiod are to some extent higher in urban than in rural areas (Anonymous, 2003). The leading poultry producing states in different regions are Andhra Pradeshand Tamil Nadu in Southern Region, West Bengal and Bihar in Eastern Region,

Maharashtra in Western Region and Punjab in Northern Region. Productivity of "*desi*" (local) and improved birds, *i.e.,* eggs produced/year, also varies in different regions. The egg productivity of "*desi*" and improved birds is found to be 15 to 91 and 204 to241 eggs/year, respectively (Vetrivel and Chandrakumarmangalam, 2013). Out of 29 states, only three state *viz.* Andhra Pradesh (20.1 billion), Tamil Nadu (11.5 billion) and Maharashtra (4.2 billion) states are producing 70 per cent of the country's egg production (Karthikeyan and Nedunchezhian 2014).Maharashtra has a total geographical area of 3.08 *lakhs* km2 spread over*Vidharbha*, *Marathwada*, *West Maharashtra* and *Konkan* regions. The State is divided into 35 districts and total population of the State is 9.69 crore, of which 57.6 per cent are living in rural areas. Animal husbandry is an important agriculture related activity of Maharashtra. The State's share in livestock and poultry population in India is about 7 per cent and 10 per cent, respectively, (Anonymous, 2012b). The contribution of thelivestock sector to Gross Domestic Product (GDP) from Agriculture sector during 2006-07 was about 25 per cent (Anonymous, 2009). Maharashtra is one of the progressive states in poultry farming during last twodecade. Maharashtra ranked third in the egg production and second in the broiler production (378.8 mt). Poultry population of Maharashtra is 227.401 *lakhs* of the 3 India's poultry population (729.21 million), producing approximately 507 crores eggs (47%) out of total egg production (74.75 billion) of the country (Anonymous, 2015b). Out of (507 crores eggs) about 20.91 per cent contribution comes from desi layers and79.09 per cent from improved layers (Anonymous, 2012a). The performance of improved indigenous per ecotype in this region is better, they have produced about 150 to 180 eggs/year and 1.5 to 2.10 kg body weight at 6 to 12 weeks (Bharambe and Garud 2012; Jadhao, 2014 and Anonymous, 2015c). Majority of birds are improved (30 %) in which growth and production potential is significantly higher as compared to "*desi*" as well as *non-descript*. Therefore, average per capita availability of eggs in Maharashtra is 38 to 40 **(**Anonymous, 2014), which is very less as compared to national average (62 eggs) and much lower than eggs recommended by Nutritional Advisory Committee of ICMR (180 eggs per capita/year). Hence, because of the short fall in egg production of the country, there is the need to fill in gap between production and requirement. Hence, a few genetic stocks have been developed recently for promoting rural poultry production and marketed under the names of Giriraja, Vanaraja, Gramapriya,Gramlakshmi, Srinidhi, Krishipriya, Krishna-J, Yamuna, Nandanum, CARI Shyam and Kroiler *etc*. (Anonymous, 2016). They have given encouraging results under traditional backyard and semi-intensive system of poultry production with an improved productivity, adaptability and disease resistance. Nevertheless, the insufficient provision of feed/ingredients to such birds under rural house holdings,appear to limit the exploitation of full production potential. Hence, in semi-scavenging system, birds are let out into the field for scavenging during the day time and balanced supplementary feed of about 25- 30g/bird/day is provided during night hours. *Konkan* region is one of the meliorative and penitentiary divisions of Maharashtra state in poultry farming with rapid growth potential. It comprises the five district *viz.*, *Sindhudurg*, *Ratnagiri*, *Raigad*, *Thane* and *Palghar*. Poultry population of *Ratnagiri* district is 2.268 *lakhs desi* and 0.68 *lakhs* improved birds, of the *Konkan's* region (14.96 *lakhs*), producing 205.042 *lakhs* eggs from "*desi* and

192.82 *lakhs* fromimproved layers. The total eggs production of *Konkan* region is 1722.192 *lakhs* during 2013-14. *Ratnagiri* district share 23.102 per cent in total egg production of *Konkan*4 region. The egg production of *desi* and improved layers in Ratnagiri are 205.042 *lakhs* and 192.82 *lakhs*, respectively (Anonymous, 2015d). Blood haematological and biochemical parameter plays an important role in the transportation of nutrients, physiological state of individuals, metabolic waste products and gases around the body (Zhou *et al.*, 1999). Moreover, blood represents ameans of assessing clinical, nutritional health status and the general condition of animals (Schmidt *et al.*, 2007 and Kececi and Col, 2010). Blood biochemistry in combination with haematology is a pre-requisite of the medical diagnosis of organ dysfunction and disease in avian species (Mbassa, 1991, Jain, 1993, Ritchie *et al.*,1994 and Kececi and Col, 2010). The need for clinical chemistry is underlined by the fact that clinical signs of illness in birds are frequently subtle (Simaraks *et al.*, 2004, Schmidt *et al.*, 2007 and Nazifi *et al.*, 2012). Changes, which may be easily overlooked during physical examination, may be discovered by biochemical and haematological examination (Voslarova *et al.*, 2006a). The haemato-biochemical profiles are most commonly used in nutritional studies for chickens (Adeyemi *et al.*, 2000 and Rani, Prameela *et al.*, 2011) and other birds like pigeon (Pavlak *et al.*, 2005)and guinea fowl (Onyeanusi, 2007).Hen's eggs traditionally considered as an important source of nutrientscontaining all of the proteins, lipids, vitamins and minerals for humans (Mine andNolan, 2004 and Tolik *et al.*, 2014). They are also one of the least expensive single foodsources of complete protein (Watkins, 1995 and Nys and Sauveur, 2004). Egg.quality is important for consumer and the economic success of a producer depends on the total number of eggs sold. Egg quality includes several aspects related to theeggshell (external quality) and to the albumen and yolk (internal quality). Egg quality has a genetic basis and the parameters of egg quality vary between strains of hens (Pandey *et al.*, 1986 and Silversides *et al.*, 2006). These quality traits of the eggs are significant in the poultry breeding for their influence on the yield features of the future generation, breeding performance and quality chicks' growth (Altinel *et al.*, 1996).Therefore, the internal and external characteristics of egg changes increasessignificantly with age, while egg shell quality deteriorates, egg weight, yolk weightand albumen weight increase as the age increase in chickens (Hurnik *et al.,* 1997).Chicken meat a good source of protein and many nutrients and relatively lowin fat, especially when skin is removed. Chicken meat is also characterized byversatility in menu planning, ease of preparation, consistent quality and theavailability of a wide range of pre-packaged, branded, raw and ready to eat and serveproducts (Shedeed, 1999). Chicken cuts- up are good source of animal protein of highbiological value, which contains all the essential amino acids required for humannutrition. Amino acid content of chicken meat components as being a part of chickencuts- up can play a significant role in meat identification (Irina *et al.,* 2011). Besides that chicken meat, contain higher proportion of unsaturated fatty acids and less cholesterol.The chemical and nutritional compositions of chicken cuts-up varied from genotype to genotype (Lawrie, 1998).The poultry business in India depends on the economic production of poultry

meat and eggs. The profit in the poultry industry depends mainly on the cost benefit ratio. The cost involved in feeding and management plays pivotal role on performance in terms of growth, feed efficiency, carcass yield and nutritional composition, and overall economics of the enterprise. The cost of construction and recurrent expenditure are always higher for cage system, whereas, deep litter system of management is comparatively more affordable to the rural farmers (Buragohain *et al.,* 2009). The net economic merit of a laying flock depends not only on the total number of eggs produced but also on the egg weight and other egg quality traits (Padhi *et al.,* 1998 and Chatterjee *et al.,* 2005).The estimation of unit cost will help to determine the profits in poultry enterprises and at the same time useful to marketing agencies in fixing the product prices and to lending agencies in assessing the credit needs of borrowers. The higher cost is associated with smaller size units and lower cost is associated with larger sets Verma and Singh (1997). Keeping the above in view, an experiment entitled " Production Performance of Improved Indigenous Poultry Breeds under Different Management Regimes" was initiated with the following objectives.

1 To determine the effect of rearing pattern on the growth performance of improved indigenous poultry breeds 6

2 To determine the effect of management regimes on production performance of improved indigenous poultry ecotypes

3 To determine the Haemato-biochemical characteristics of improved poultry under different management regimes

4 To study the egg geometric traits of improved indigenous chicken

5 To work out the economics of raising the poultry breeds under different management regimes

CHAPTER II
REVIEW OF LITERATURE

Available relevant literature on the performance of improved indigenous poultry breeds under different management regimes has been reviewed and presented in this chapter under the following main heads of research.

2.1 Growth performance
2.2 Egg production performance
2.3 Egg quality parameters
2.3.1 External egg quality parameters
2.3.2 Internal egg quality parameters
2.4 Haemato-biochemical profile of blood
2.4.1 Hematological parameters
2.4.2. Biochemical parameters
2.5 Morbidity and mortality rate
2.6Cost of poultry production

2.1 Growth performance

Many factors that could impact growth performance are genotype, age, sex,diet, density, environment, exercise and feed intake. Body weights are the direct reflection of growth of birds. The significant effect of genetic group on body weight of chicken was reported by many researchers (Niranjan *et al.,* 2008).

2.1.1 Body weight

Niranjan *et al.* (2008) evaluated production performance of improved chicken varieties under backyard farming. They recorded significant ($p<0.05$) differences inbody weights at 40 weeks in all crosses, with highest body weight of 264.16±25.51 g in C_1 cross, followed by Vanaraja, C_2 and Gramapriya. The body weights (g) at 72 wks varied between 2866.31±22.31 (Vanaraja) and 2469.29±29.58 (Gramapriya). The body weights between C_1 and Vanaraja were not significantly different from each other. However, the body weight of C_2 cross at 72 wks of age was significantly higher than the Gramapriya.Haunshi *et al.* (2011) recorded significantly ($p<0.05$) higher body weightfrom day old (33.19 ± 0.20 g) to 40 wks of age (2,105.5± 44.9 g) in Aseel bird thanKadaknath (28.55±0.12 and 1,435.7±21.5 g) breed**.**Khawaja *et al.* (2012) studied the growth performance of Desi, Fayoumi and Rhode Island Red chicken. They revealed significantly ($p<0.05$) higher body weight in RIR (1640.00 g) during whole experimental period than the Desi (1180.63 g) and Fayoumi (1166.60 g). The higher body weight in RIR may be due to the average higher day old weight in RIR (31.30g), intermediate in Desi (25.9 g) and lowest in Fayoumi (20.90 g).Sharma *et al.* (2012) studied the performance of Kadaknath and Krishna-Jbirds reared in backyard system. They observed significantly higher body weight andbody weight gain in Krishna-J birds (1141.65±0.27 g and 170.93 g) as compared to Kadaknath birds (1011.43±0.91 g and 167.42 g) at 12 wks of age.Jha *et al.* (2013_a) conducted experiment on the production performance of Dahlem Red, Desi and their crosses under intensive condition. They recorded the mean weight of body at 0 day, 4_{th}, 6_{th}, 8_{th}, 12_{th}, 16_{th}, 20_{th} and 40_{th}wks of age as 33.24, 145.82, 369.48, 495.46, 812.75, 1243.46, 1546.31 and 1795 g, respectively in Dahlem Red and 32.67, 138.34, 346.38, 478.23, 785.36, 1138.27, 1468.52 and 1724.58 g,respectively in Dahlem Red × Desi crosses and 29.56, 114.83, 185.61, 263.75, 418.25, 627.36, 982.75, 1136.32 g, respectively in Desi birds. The body weights of crosses were significantly ($p<0.05$) higher than Desibirds and nearly similar to Dahlem Red birds at different period of age. Jha *et al.* (2013_b) studied the production performance of indigenous chicken in intensive farming system. Theyreported average body weight of *Hazra* birds at 0, 4,6, 8, 12, 16, 20 and 40 wks of age as 31.48±0.28, 162.45±2.48, 276.73±3.12,384.54±4.23, 614.83±5.39, 1056.82±6.31, 1294.38±7.35, 1472.85±9.76 g and 29.72±0.21, 127.43±1.28, 186.78±2.55, 273.72±3.52, 416.25±4.78, 678.37±5.36,

1038.72±6.73, 1326.45±8.75 g in *Aseel*, whereas, 28.54±0.33, 114.86±1.63,
9 152.42±2.87, 238.86±3.76, 372.98±4.85, 624.56±5.80, 957.45±6.84, 1248.12±9.31 g observed in Kadaknath birds. The body weight at all ages was significantly (p<0.05) higher in Aseel than Kadaknath and the body weight gain was also significantly (p<0.05) higher in Aseel than Kadaknath at all experimental periods.Jha and Prasad (2013) conducted experiment on improved varieties viz.Vanaraja, Gramapriya and indigenous Aseel birds. 214 day old Vanaraja, Gramapriyaand Aseel chicks were brooded upto 8^{th} weeks of age under deep litter system ofmanagement. They revealed that the live weight (g) of day old Vanaraja, Gramapriyaand Aseel chicks were ranged from 32 to 41, 31 to 37 and 28 to 34, respectively, bodyweight at 1^{st} egg laying of Vanaraja, Gramapriya and Aseel 2103.39±7.39,1574.31±6.87 and 1038.75±6.83 and body weight at 40^{th}wks 2467.83±11.36,1828.17±9.51 and 1156.41±8.79, respectively. Mean body weight at laying 1^{st} egg and40^{th} week age was significantly (p<0.01) higher in improved varieties birds than the Aseel birds Baba *et al.* (2014) studied the effect of some climatic parameters on theperformance of Vanaraja birds kept under intensive and backyard systems. They recorded 106.82±7.11, 134.62±3.99, 160.08±2.69, 183.12±5.77, 181.53±4.03, 192.64±6.32 and 254.09±7.11 g body weight with overall mean 173.27±6.78 g body weight in intensive system and 98.44±5.04, 135.93±6.10, 117.65±8.22, 161.65±6.01, 166.85±7.68, 245.43±5.01 and 269.95±6.45 g body weight with overall mean 170.84±5.21 g body weight gain in backyard system at 2^{nd}, 3^{rd}, 4^{th}, 5^{th}, 6^{th}, 7^{th} and 8^{th} weeks of age, respectively. It was concluded that overall performance of the Vanaraja birds more impressive/economical in backyard than intensive system. Islam *et al.* (2014) studied the performance of Vanaraja and Indigenous chicken under backyard system. They reported that the body weights at 8, 20, 40 and 52 wks of age was 768.23±6.43 g, 1693.52±11.13 g, 2976.61±18.08 g and 3491.87±21.32 g, respectively in Vanaraja and 365.12±2.74 g, 0.783.14±5.03 g, 1274.31±9.01 g and 1423.47±16.14 g, respectively in case of indigenous chicken. The body weight of Vanaraja was significantly (p<0.05) higher than the corresponding body weights of indigenous chicken.**10** Padhi *et al.* (2014_a) conducted the experiment on crossbred chicken rearedunder backyard. They reported that average body weights at 20 wks of age of male and female were 1671±65 g and 1371±28 g, respectively. Corresponding body weights at 40 and 72 wks of age were 2784±99 and 1978±68 g and 3309±307 g and 1827±62 g. The body weight of male was significantly higher than the female irrespective of age. Kundu *et al.* (2015) conducted the trial on the production performance of indigenous Nicobari fowls, Vanaraja and their various F_1 crosses under hot humid climate of Andaman and Nicobar Islands. They reported body weight of Vanaraja (Van), White Nicobari (WN), Black Nicobari (BN), Brown Nicobari (BrN) and six F_1 crosses of Vanaraja and Nicobari fowls *i.e.* Vanaraja male × White Nicobari female (Van × WN), White Nicobari male × Vanaraja female (WN×Van), Vanaraja male × Black Nicobari female (Van×BN), Black Nicobari male × Vanaraja female (BN × Van), Vanaraja male × Brown Nicobari female (Van× BrN), Brown Nicobari male × Vanaraja female as 3394.24±23.31, 1594.40±19.24, 1705.00±18.78, 1612.50±13.34, 1833.70±10.20, 1923.10±18.81, 1420.80±16.78, 1517.30±17.25, 1341.30±13.75 and 1083.90±12.23 g, respectively at 8^{th} weeks of age.

2.1.2 Feed consumption

Malik and Singh (2010) conducted an experiment on production performance of CARI Nirbheek in agro-climatic conditions of Tripura. They reported that the cumulative feed consumption of birds up to 6 weeks of age was 0.981 kg at farm condition. The feed consumption per day between 19 to 20 and 39 to 40 weeks of age were 99.0±0.68 g/bird and 160.22±0.68 g/bird, respectively under deep litter system. Podchalwar *et al.* (2013) studies on performance of three crossbred chickens *viz.* Australorp (A) x White Leghorn (IWP strain), Naked Neck (Na) x White Leghorn (IWP strain) and Rhode Island Red (RIR) x White Leghorn (IWP strain). They found non-significant difference in feed consumption at different ages. The RIR x IWP (15.231±0.019 kg/bird) crossbred had significantly (p<0.05) lower feed consumption as compared to A x IWP (15.529±0.019 kg/bird) and Na x IWP (15.405±0.028 kg/bird) during 29 to 40 weeks of age. Baba *et al.* (2014) studied the effect of some climatic parameters on the performance of Vanaraja birds reared under intensive and backyard systems. They recorded feed consumption at 2nd, 3rd, 4th, 5th, 6th, 7th and 8th weeks of age as 184.42±4.51, 280.34±7.80, 345.67±9.10, 377.64±8.02, 445.67±5.03, 553.27±4.05 and 599.10±7.35 g/bird/week with mean 398.02±5.66 g/bird/week in intensive system as well as 186.20±7.11, 294.50±6.98, 300.03±9.01, 330.11±5.11, 367.97±3.09, 404.25±5.27 and 412.25±9.09 g/bird/week with mean 327.90±7.11 g/bird/week in backyard system, respectively. It was concluded that overall performance of the Vanarajabirds was superior in backyard system. Kumar *et al.* (2014a) studied the performance of Rhode Island Red and Bovans White under intensive management in Mekelle, Ethiopia. They recorded that Bovans White bird had significantly (p<0.05) higher total feed intake (9.60±0.32 kg/bird) and daily feed intake (62.30±4.22 g/bird) compared to Rhode Island Red feed intake (8.75±0.21kg/bird) and daily feed consumption (56.75±4.32g/bird). Kundu *et al.* (2015) evaluated the performance of indigenous Nicobari fowl, Vanaraja and their various F_1 crosses under hot humid climate of Andaman and Nicobar Islands, India. Theyrecorded feed intake capacity of four pure varieties *viz.*Vanaraja, WN, BN, BrN and six F_1 crosses of Van and Nicobari fowls *i.e.* Van × WN, WN × Van, Van × BN, BN × Van, Van × BrN and BrN × Van upto 8 weeks of age as 2.60, 3.60, 3.90, 4.17, 3.20, 2.90, 3.80, 3.60, 4.10 and 3.90 kg/weeks, respectively.

2.1.3 Feed conversion ratio

Debata *et al.* (2012) conducted experiment for evaluation of growth performance and carcass traits of three breeds of chicken viz., Black Rock, Red Cornish, and Vanaraja reared in coastal climate of Odisha. They recorded feed conversion ratio (FCR) up to 6th week less than 2 and after restricted feeding from 8 weeks the FCR was 5.09±0.09, 4.57±0.18 and 4.99±0.88 in Black Rock, Red Cornish and Vanaraja. Throughout the experimental period, the Red Cornish had better FCR than Vanaraja and Black Rock and there was no-significant difference between Vanaraja and Black Rock for FCR. Khawaja *et al.* (2012) studied on growth performance of Desi, Fayoumi and Rhode Island Red chicken. They observed that the feed conversion of birds during the period of 9 to 20 wks was better in RIR (4.64±0.36) followed by Fayoumi (5.76±0.144) and *Desi* (6.30±0.66). Thutwa *et al.* (2012) conducted the trial on two normal feathered and Naked neck strains of Tswana chickens. They revealed that Naked neck birds utilized feed more efficiently than normal chickens. The males had significantly better feed efficiency than females in both strains. This reiterates that generally males grow faster than females. Jha and Prasad (2013) studied the performance of improved and indigenous breed of chicken. They revealed that the feed conversion ratio was 4.28, 3.85 and 5.47 in Vanaraja, Gramapriya and Aseel birds, respectively at 40 weeks of age under Jharkhand agro climatic condition. Baba *et al.* (2014) studied the performance of Vanaraja birds reared under intensive and backyard systems. They recordedfeed conversion ratio at 2nd, 3rd, 4th, 5th, 6th, 7th and 8th weeks of age as 1.72±0.05, 2.08±0.13, 2.16±0.13, 2.06±0.07, 2.45±0.24, 2.87±0.10 and 2.35±0.01 per cent with overall average 2.24±0.11 per cent in intensive system and 1.89±0.08, 2.17±0.08, 2.55±0.03, 2.04±0.01, 2.38±0.02, 1.64±0.04 and 1.52±0.10 per cent with overall average as 2.02±0.12 per cent in backyard system, respectively. It was concluded that overall feed conversion ratio of Vanaraja birds was better in backyard system than intensive system. Kundu *et al.* (2015) conducted an experiment on the production performance of indigenous Nicobari fowls, Vanaraja and their various F_1 crosses under hot humid climate of Andaman and Nicobar Islands. Theyfoundthat feed conversion ratio (FCR) of Vanaraja (Van), White Nicobari (WN), Black Nicobari (BN), Brown Nicobari (BrN) and six F_1 crosses of Vanaraja and Nicobari fowls i.e. Vanaraja male × White Nicobari female (Van×WN), White NicobariMale×Vanaraja female (WN×Van), Vanaraja male × Black Nicobari female (Van×BN), Black Nicobari male × Vanaraja female (BN×Van), Vanaraja male × Brown Nicobari female (Van×BrN), Brown Nicobari Male ×Vanaraja female (BrN×Van) was 2.6±0.25, 3.6±0.17, 3.9±0.20, 4.17±0.17, 3.2±0.21, 2.9±0.29, 3.8±0.14, 3.6±0.15, 4.1±0.28 and 3.9±0.18, respectively.

2.1.4 Age at first laying

Mohan *et al.* (2008) conducted an experiment on performance profile of Kadaknath hens. They observed that Kadaknath birds started laying at145 days of their age under normal rearing system. Biswas *et al.* (2010) evaluated the production performance and egg quality traits in Indian native Kadaknath hen. They recorded age of first egg lay of Kadaknath in a range of148.60±3.58 to 158.20±2.10 days. Haunshi *et al.* (2011) observed that the Kadaknath breed reached early age at first egg in the flock (175 days) as compared to Aseel (176 days) kept in deep litter system.Mondal *et al.* (2012) conducted the experiment on Vanaraja birds in Kargil.They observed age of first laying between 161 to 168 days under intensivemanagement condition.Khawaja *et al.* (2012) studied the growth performance of Desi, Fayoumi and RIR. They recorded that Fayoumi birds (135±3.51 days) laid earlier age at first egg than RIR (147±1.15 days) and Desi(204±1.53 days).Sharma *et al.* (2012) conducted experiment to know the performance of Kadaknath and Krishna-J Birds reared as backyard system. They observed significantly better age of first laying in Krishna-J birds (147±4.34 days) as compared to Kadaknath (154±3.78 days). Deka *et al.* (2014) studied the production performance of Vanaraja and indigenous birds under traditional system of rearing in Assam. They observed age of first laying of Vanaraja and indigenous chicken as 178.13±0.79 and 191.25 ± 1.46 days, respectively. Hajra *et al.* (2014) evaluated performance of Vanaraja, Gramapriya and Desi birds in the backyard system of rearing in Manipur. They recorded age of first egg significantly lower ($p<0.05$) in Gramapriya (173.00±1.35 day) in comparison to Vanaraja (181.53±1.29 days) and Desi birds (179.87±1.48 days). Gramapriya predominantly an egg producing variety developed at Project Directorate on Poultry,Hyderabad and thus lower age of sexual maturity was justifiable. Islam *et al.* (2014) recorded that age at first egg laying ranged from 180 to 191 days with overall mean of age at first egg laying as 187.45±1.02 days in case of Vanaraja and in indigenous chicken it was recorded as 201.31±2.03 days. There was also a significant ($p<0.05$) difference of age at first egg between Vanaraja and indigenous chicken, which might be due to the genetic difference between two groups of birds. Kumari and Subrahmanyeswari (2014) in their study recorded age at first egg as 165 days and 191.25 days in Rajasri and indigenous birds, respectively. Kumar *et al.* (2014_a) studied the performance of Rhode Island Red (RIR) and Bovans White (BW) under intensive management in Mekelle, Ethiopia. They recorded better age of first laying in BW (139.40±2.95 days) than RIR (154.55±3.45 days).Padhi *et al.* (2014_b) recorded age at first laying as 203 days in crossbred chicken developed using both exotic and indigenous breeds reared under backyard system. Tomar *et al.* (2015) evaluated the production performance of some economic traits in White leghorn birds. They found 149.77 days for AFE in WLH birds. There was a significant ($p<0.05$) change in AFE over the different generations and it showed an increasing trend over the successive generations.

2.1.5 Age at sexual maturity

Jilani *et al.* (2007) conducted the genetic studies on some economic traits of Rhode Island Red. They reported that RIR birds get age of sexual maturity at 146.16±0.33 days in North Indian condition. Kumar *et al.* (2005) evaluated the production performance of Vanaraja birds under traditional system of rearing in Manipur. They reported that average age at sexual maturity was 171 days in Vanaraja bird and Gramapriya bird get significantly early maturity at 160.89±0.63 days of age compared to Vanaraja (164.79±0.58 days) as revealed by Niranjan *et al.* (2008).Malik and Singh (2010) studied the performance of CARI Nirbheek in agroclimatic conditions of Tripura. They revealed that the age at sexual maturity was 187.16±0.35 and 198.04±1.70 days, respectively on farm and field conditions. Haunshi *et al.* (2011) revealed that the Kadaknath breed reached an early age sexual maturity at 200.61±1.37 days as compared to Aseel (213.25±0.54 days) kept in deep litter system. Kalita *et al.* (2012) conducted an experiment on the Vanaraja bird reared under intensive rearing system. They revealed that Vanaraja birds attempted sexual maturity at 147.50±5.46 days during study period.
Jha and Prasad (2013) studied the production performance of improved varieties and indigenous breed of chicken in Jharkhand. They observed lower age of sexual maturity in Gramapriya (155.32±1.76 days) as compared to Vanaraja (161.58±1.67 days) and Aseel (192.83±1.64 days). Jha *et al.* (2013a) studied the growth and production performance of 358 birds each of Dahlem Red, Desi and their crosses under intensive system of management. They observed that the Dahlem Red get early maturity at 143.65 days as compared to Desi bird (212.43 days) and their crosses (171.38 days). The early age of sexual maturity in crosses compared to Desi may be because of genetic inheritance of Dahlem Red birds prevailing in crosses. Podchalwar *et al.* (2013) studies on performance of three crossbred chickens *viz.* Australorp (A) x White Leghorn (IWP strain), Naked neck (Na) x White Leghorn (IWP strain) and Rhode Island Red (RIR) x White Leghorn (IWP strain). During study age at sexual maturity was observed lower in RIR x IWP (153.56±0.39 days) and Na x IWP (153.71±0.36 days) crossbreds than to A x IWP (157.68±0.65 days) crossbred. Das *et al.* (2014) revealed that the age of maturity of Rhode Island Red in backyard condition was 164.15±13.72, 169.75±15.89, 174.30±20.72, 152.74±19.60 and 163.66±16.38 days under Terai Alluvial, New Laterite, Red, Old and coastal agroclimatic zones of West Bengal, respectively.Debata *et al.* (2014) reportedsignificantly earlier sexual maturity (ASM) in Black Rock (144 days) and Vanaraja(147.20 days) than Red Cornish (157.35 days) under coastal climatic condition of Odisha.

2.2 Egg production
2.2.1 Daily hen day egg production

Singh *et al.* (2009) studied production performance and egg quality of four strains of laying hens kept in conventional cages and floor pens. They recorded hen day egg production as 93.4, 91.8, 93.5 and 82.4 per cent for Lohmann White, Lohmann Brown, H and N White and Rhode Island Red male × Barred Plymouth Rock cross, respectively in cages system and 90.4, 93.2, 54.9 and 86.9 per cent for Lohmann White, Lohmann Brown, H and N White and Rhode Island Red male×Barred Plymouth Rock cross, respectively also onfloor pens during 20 to 30week.Kucukyılmaz *et al.* (2012) recorded that egg production rate and hen day totalegg production were influenced by the hen genotype ($p<0.01$), while rearing system showed no significant effect on these parameters. The egg production rate of white hens was higher than that of brown hens under conditions in organic and conventional rearing systems. Regassa *et al.* (2013) investigated production performance of Fayoumi chicken breed under backyard management condition in Mid Rift valley of Ethiopia.

They observed 41.23±15.97 per cent hen day egg production. Tomar *et al.* (2015) evaluated the production performance of some economic traits in White leghorn birds. They observed that the egg number upto 40 wks of age (EN_{40}) ranged from 74.14 eggs to 90.09 eggs in different generations and the pooled mean for EN_{40} was 80.85 eggs. There was a significant ($P<0.05$) change in EN_{40} over the different generations.

2.2.2 Weekly hen egg production

Das *et al.* (2014) revealed that average weekly hen day egg production of Rhode Island Red in five agro-climatic zones of West Bengal, India *viz.*Terai **17** (3.24±0.24/hen/wks), New Alluvial (3.16±0.48/hen/wks), Red Laterite (3.13±0.66/h6en/wks), Old (3.24±0.45/hen/wks) and Coastal (3.45±0.35/hen/wks),respectively with overall mean (3.24±0.50/hen/week).

2.2.3 Annual hen egg production

Mohan *et al.* (2008) conducted an experiment on performance profile of Kadaknath, Desi hens. They recorded 105eggs/hen during 21-52 weeks under traditional management condition.Niranjan *et al.* (2008) evaluated production performance in improved chicken varieties for backyard farming. They revealed that the egg production at 40, 64 and 72 weeks ranged from 56.15±1.84 (Vanaraja) to 99.88±1.84 (C_1 cross) 131.84±3.84 (Vanaraja) to 204.85±3.15 (Gramapriya) and 149.47±4.46 (Vanaraja) and 237.35±3.70 (Gramapriya). The egg production of C_1 cross was significantly ($p<0.05$) higher than C_2 and Vanaraja at all ages but did not differed significantly with Gramapriya at 64 and 72 weeks of age. Malik and Singh (2010) conducted an experiment performance of CARI Nirbheek in agro-climatic conditions of Tripura. They recorded egg production upto 40 weeks of age was 37.32 and 26.31 eggs, respectively, at farm and field conditions. Haunshi *et al.* (2011) recorded significantly higher egg production (49.40) in Kadaknath than Aseel (36.23) at 40 wks of age. Podchalwar *et al.* (2013) studies on performance of three crossbred chickens *viz.* Australorp (A) x White Leghorn (IWP strain), Naked neck (Na) x White Leghorn and Rhode Island Red (RIR) x White Leghorn. They observed higher egg production in Na x IWP (103.54±1.26 eggs) and RIR x IWP (101.86±1.26 eggs) as compared to A x IWP (96.11±1.28 eggs) crossbreds. There was no significant difference in egg production between Na x IWP and RIR x IWP crossbreds. Regassa *et al.* (2013) recorded annual average egg production of Fayoumi chicken as 150.47±3.15eggs/hen/year managed under backyard management condition**.**

Deka *et al.* (2014) studied the production performance of Vanaraja bird under traditional system of rearing in Assam. They recorded significant difference in annual egg production of Vanaraja (145.75±1.44) and indigenous chicken (54.62±1.13). Das *et al.* (2014) revealed that the total egg production of Rhode Island Red was 146.76±31.43, 142.12± 34.20, 144.43±36.92, 159.75±28.02 and 160.56±23.12 eggs per birds per annum under Terai Alluvial, New Laterite, Red, Old and Coastal Agro-climatic zones of West Bengal, respectively reared in backyard condition. Islam *et al.* (2014) recorded mean egg production up to 32, 40 and 52 wks of age in Vanaraja as 33.13±0.11, 52.08±0.32 and 87.29±1.02, respectively and in case of indigenous chicken, the corresponding values were recorded as 10.21±0.03, 27.82±0.18 and 43.57±0.72, respectively. The mean egg production was also significantly ($p<0.05$) differed between two genetic groups, which might be due to different genetic makeup of two groups. Kumari and Subrahmanyeswari (2014) studied the productive performance of Rajasri and indigenous birds. They found average egg production/hen/year in Rajasrias 170 and indigenous birds as 54.62 maintained at backyard. Padhi *et al.* (2014_b) investigated performance of a crossbred chicken developed using both exotic and indigenous breeds under backyard system of rearing. They recorded 148 eggs production per bird upto 72 wks of age.

2.2.4 Feed consumption per egg

Podchalwar *et al.* (2013) studied performance of three crossbred chickens *viz.*Australorp (A) x White Leghorn (IWP strain), Naked neck (Na) x White Leghorn (IWP strain) and Rhode Island Red (RIR) x White Leghorn (IWP strain). They recorded that feed consumption per egg (FC/E) was significantly (P<0.05) higher in A x IWP (166.81±2.83 g/egg) crossbred as compared to RIR x IWP (153.71±2.34 g) and Na x IWP (152.96±2.26 g) crossbreds. However, there was no significant difference in FC/E between Na x IWP and RIR x IWP crossbreds.

2.2.5 Feed efficiency/dozen of eggs

Podchalwar *et al.* (2013) in their studies on performance of three crossbred chickens *viz.* Australorp (A) x White Leghorn (IWP strain), Naked neck (Na) x White Leghorn (IWP strain) and Rhode Island Red (RIR) x White Leghorn (IWP strain), recorded feed consumption per dozen eggs (FC/DE_{21-40}) was significantly (P<0.05) higher in A x IWP (1.93±0.02 Kg/dozen eggs) crossbred as compared to Na x IWP (1.78±0.02 Kg/dozen eggs) and RIR x IWP (1.79±0.01 Kg/dozen eggs) crossbreds. There was no significant difference in FC/DE_{21-40} between Na x IWP and RIR x IWP crossbreds.

2.2.6 Feed efficiency/kg of eggs

Singh *et al.* (2009) reported no significant interaction between environment and strain for feed consumption or feed efficiency. It was strain and not environment that influenced the daily feed consumption and feed efficiency. The HN hens eat less than LW, LB, and cross hens, but significantly less than all other strains only at 40 wk.They recorded feed efficiency as 1.42 and 2.13 gm of feed per gram of egg in cages and floor pen system, respectively.Podchalwar *et al.* (2013) studied performance of three crossbred chickens *viz.*Australorp (A) x White Leghorn (IWP strain), Naked neck (Na) x White Leghorn (IWP strain) and Rhode Island Red (RIR) x White Leghorn (IWP strain). They observed that feed consumption per kilogram egg (FC/KE_{25-28}) was significantly (p<0.05) higher (2.85±0.06 kg) in A x IWP crossbred as compared to Na x IWP (2.60±0.03 kg) and RIR x IWP (2.60±0.03 kg) crossbreds. The FC/KE_{21-40} was significantly (P<0.05) higher in A x IWP (3.18±0.04 kg) crossbred than Na x IWP (2.94±0.03 kg) and RIR x IWP (2.93±0.04 kg) crossbreds. The crossbreds of Na x IWP and RIR x IWP crossbreds had significantly (p<0.05) better feed efficiency ascompared to A x IWP crossbred.

2.3 Egg quality parameters

2.3.1 External egg quality parameters

2.3.1.1 Egg weight

Niranjan *et al.* (2008) recorded significantly higher egg weights 51.76±0.27, 54.37±0.29, 56.58±0.28, 57.43±0.27, 60.13±0.34 and 61.14±0.37 g at 28, 32, 36, 40, 64 and 72 wks in Gramapriyacompared to Vanaraja (44.86±0.26, 49.63±0.27, 52.64±0.24, 54.98±0.22, 57.06±0.27, 60.07±0.28 and 62.35±0.31 g), respectively. Biswas *et al.* (2010) evaluated the egg quality traits in Kadaknath. They recorded egg weight of Kadaknath in a range from 41.45±1.15 to 42.97±0.95 g. Haunshi *et al.* (2011) recorded significantly (p<0.01) higher egg weight at 28, 32 and 40 wks of age in Aseel (42.71±0.36, 45.80±0.49 and 49.28±0.53 g) as compared to Kadaknath (35.58±0.34, 39.92±0.38 and 41.39±0.37 g) kept under floor system. Lewko and Gornowicz (2011) recorded significant differences (P≤0.05) between egg weights in different system. They revealed that caged birds laid heaviest eggs (61.06±2.98 g) as compared to backyard system (57.93±3.36 g) and deep litter (56.35±5.06 g). Jha and Prasad (2013) found higher egg weight in Gramapriya (54.23±2.34 g) than Vanaraja (53.98±1.24 g) and Aseel (42.38±2.34 g) under cage system. Jha *et al.* (2013a) studied the egg quality traits of Dahlem Red and Desi crosses chicken reared under intensive management system. Egg weight of Dahlem Red, Desi and their crosses were 38.75±0.22, 34.94±0.37 and 30.82±0.58 g at pullet age and 55.87±2.24, 51.26±2.35 and 42.89±2.37 g at 40 wks of age, respectively.They observed significantly ($p<0.05$) increased egg weights as17.12, 12.07 and 15.42 g between first lay to 40 weeks of age.Padhi *et al.* (2013) conducted the study on Vanaraja birds for analyzing effect of age on eggs quality. It was recorded that egg weight at 28, 40, 52, 64 and 72 weeks of age in Vanaraja was 47.60±0.53, 55.19±0.6, 61.74±0.91, 60.42±0.72 and 61.07±0.84 g, respectively. The results indicated that the age of the birds significantly affect different parameters of egg. Deka *et al.* (2014) observed significantly higher egg weight of Vanaraja (51.08±0.36 and 59.06±0.42 g) as compared to indigenous chicken (36.12±0.62 and 41.07±0.48 g) at 40 and 72 wks of age, respectively.Debata *et al.* (2014) reported that the egg weight was 53.10, 58.3 and 55.3 g in BlackRock, RedCornish and Vanaraja breeds, respectively. The mean egg weight was significantly higher ($p<0.05$) in Red Cornish than Black Rock and no significant difference was seen between Vanaraja and Black Rock. Dorji and Phurba (2014) reported that overall average egg weight was 47.44±5.29 g with the lowest for Seim Red Jungle fowl (45.95±5.84 g) and highest for Phulom (50.35±4.48 g). Islam *et al.* (2014) recorded significantly($p<0.05$) higher egg weight in Vanaraja at 32 wks (48.32±0.21g), 40 wks (53.07±0.24 g) and 52 wks (58.17±0.26 g) than indigenous at 32 wks (27.85±0.04 g), 32 wks (32.06±0.07 g) and 52 wks (36.08±0.13 g). There was significant ($p<0.05$) difference between the values at different ages.Kumari and Subrahmanyeswari (2014) noticed average egg weight of Rajasri birds and indigenous as 48 g and 36.12 g at 40 wks and 52 g and 41.07 g at 72 wks of age, respectively.Padhi *et al.* (2014a) observed egg quality traits of 3 way cross (PD_1 x IWI x PD_3) at 32, 40, 52, 64 and 72 wks of age reared under backyard condition. They recorded higher (61.89±0.92g) egg weight at 52 wks than 64 wks (61.26±0.86 g), 72 wks (61.05±0.51 g), 40 wks (59.08±0.94 g) and 32 wks (56.38±0.77 g). Padhi *et al.* (2014b) conducted trial on crossbred chicken developed using both exotic and indigenous breeds (PD_1xPD_4).They recorded egg weight as 50.70±0.96 g at 40 wks of age under backyard system. Kumar *et al.* (2017) evaluated the egg geometric traits of Vanaraja and Giriraja birds under battery cage system. They recorded 57.08±0.98 g and 57.05±0.90 g egg weight in Vanaraja and Giriraja birds, respectively in Konkan condition.

2.3.1.2 Egg length

Kgwatalala *et al.* (2013) reported that the indigenous Tswana chickens eggs had significantly higher ($p<0.001$) egg length (5.68±0.04 cm) compared to commercial layer chickens (5.58±0.04 cm). Regassa *et al.* (2013) revealed that egg length of Fayoumi birds was 51.8 ± 1.71 mm reared in backyard condition.Kumar *et al.* (2017) studied the external and internal egg characteristics of improved poultry birds. They observed maximum egg length in Giriraja bird (5.71±0.04 cm) as compared to Vanaraja bird (5.69±0.07 cm) in Konkan Agroclimatic condition.

2.3.1.3 Egg width

Kgwatalala *et al.* (2013) reported non-significant difference between commercial layer chickens (4.43±0.03 cm) and indigenous Tswana chickens (4.23±0.03 cm) eggs.
Regassa *et al.* (2013) observed that the egg width in Fayoumi hen (3.93±0.01cm) managed under traditional system. Kumar *et al.* (2017) recorded significantly higher egg width in Giriraja bird (4.33±0.10cm) as compared to Vanaraja (4.17±0.09cm) at 52 weeks of age.

2.3.1.4 Egg shape index

Krawczyk *et al.* (2011) reported egg shape index as 74.5±2.40 in Greenleg Partridge layers kept at litter floor and semi-intensive system (72.3±3.00). However, egg shape index was almost same in Yellowleg Partridge layers managed under litter floor (74.4±3.70) and semi-intensive system (74.7±3.40). Haunshi *et al.* (2011) recorded non-significant differences in the egg shape index of Aseel (77.36±0.36) and Kadaknath (76.39±0.57) breed. Lewko and Gornowicz (2011) noted significantly ($p<0.05$) higher egg shape index of synthetic hen managed at backyard system (79.29±3.64) as compared to cage (77.86±2.12) and deep litter (79.00±2.52). Kgwatalala *et al.* (2013) reported significantly lower ($p<0.01$) egg shape index in indigenous Tswana chickens (74.74±0.51) than commercial layer chickens (79.51±0.49). Regassa *et al.* (2013) noticed shape index in Fayoumi birds as 75.95 ± 2.81 under backyard condition. Dorji and Phurba (2014) found 74.45±3.37, 75.82±4.64, 72.78±3.46, 74.50±2.98 and 76.68±2.07 egg shape index in Seim, Phulom, Yuebjha Narp, Khuilay, Hyline Brown strain of Bhutanese indigenous chicken, respectively. Padhi *et al.* (2014a) studied effect of age on egg quality traits in a 3-way cross egg type chicken developed for backyard poultry farming. There wasnosignificant ($p\leq0.05$) difference between the egg quality traits at 32 week (74.57±1.68), 40 week (74.88±0.57), 52 week (75.73±0.64), 64 week (73.89±0.71) and 72 week (74.66±0.57). Kumar *et al.* (2017) studied the egg shape index of improved poultry birds.They observed significantly higher egg shape index in Giriraja (76.03±1.88)as compared to Vanaraja (73.37±1.50).

2.3.1.5 Egg shell weight

Krawczyk *et al.* (2011) reported egg shall weight as 5.63±0.65 g, 4.77±0.61 g and 5.77±0.47 g, 5.30±0.37 g in Greenleg Partridge and Yellowleg Partridge layers managed under litter floor and litter floor with free range access (semi-intensive system), respectively. Haunshi *et al.* (2011) found that significantly ($p<0.01$) higher shell weight in Aseel (4.94±0.08 g) as compared to Kadaknath (4.34±0.04 g). Lewko and Gornowicz (2011) observed significantly highest shell weight in deep litter (5.76 ±0.71 g) followed by cage system (5.50±0.33 g) and semi-intensive system (4.93±0.51 g). Jain Archana (2012) reported that shell weight was 5.74±0.19 g in WLH at 24 weeks of age in Madhya Pradesh. Regassa *et al.* (2013) revealed shell weight as 5.63 ± 0.76 g in Fayoumi chickens managed under backyard condition.Kumar *et al.* (2017) studied the egg quality traits of improved poultry birds. They observed significantly higher egg shell weight in Vanaraja (5.67±0.16 g)as compared to Giriraja (5.49±0.09 g) under *Konkan* region.

2.3.1.6 Egg shell thickness

Biswas *et al.* (2010) evaluated the egg quality traits in Indian native Kadaknath hen. They recorded shell thickness (mm) of Kadaknath in a range from 0.30±0.02 to 0.31±0.08 mm. Lewko and Gornowicz (2011) found significantly (*p<0.05*) lower shell thickness in deep litter system (317.71 ± 36.08 μm) as compared to cage system (333.71±18.03μm) and free range system (360.14±36.14μm). Jain, Archana (2012) studied production performance of layers supplemented with dietary melatonin. She observed that egg shell thickness was 1.03±0.02 mm in WLH at 24 weeks of age in Madhya Pradesh. Jha and Prasad (2013) observed that the shell thickness ranged from 0.31 to 0.38 mm with an average of 0.35±0.007 mm in Vanaraja, 0.32±0.007 mm in Gramapriya and 0.36±0.008 mm in Aseel eggs. Kgwatalala *et al.* (2013) recorded non significant differences in egg shell thickness between eggs of indigenous Tswana chickens (4.29±0.08 cm) and commercial layer chickens (4.38±0.07 cm) reared under traditional management system and intensive management system.

Regassa *et al.* (2013) found the shell thickness as 3.60± 0.04 cm in Fayoumi chickens reared under free range condition. Padhi *et al.* (2014a) observed that the age of bird significantly ($p<0.05$) affected on shell thickness. The shell thickness was higher at 52 (0.3684±0.003 mm) and 72 wks (0.3548±0.005 mm) of age compared to 30 wks (0.3425±0.005 mm), 40 wks (0.3421±0.005 mm) and 64 wks (0.3463±0.005 mm) of age indicating that the shell quality was better towards the end of the experiment. Kumar *et al.* (2017) studied the egg quality traits of improved poultry birds. They did not observed any significant difference in egg shell thickness between Vanaraja and Giriraja birds.

2.3.1.7 Shell ratio

Lewko and Gornowicz (2011) recorded shell ratio as 8.77±0.90, 9.03±0.73 and 9.93±0.88 per cent, respectively in deep litter, cage and backyard system of management. Kgwatalala *et al.* (2013) observed no-significant differences between eggs shell ratio of indigenous Tswana chickens (15.36±0.47%) and commercial layer chickens (16.25±0.45%). Kumar *et al.* (2017) studied the egg quality traits of Vanaraja and Giriraja birds under Konkan region. They observedhigher egg shell ratio in Vanaraja (9.93±0.20) than Giriraja (9.65±0.16) birds.

2.3.1.8 Specific gravity

Haunshi *et al.* (2011) recorded that Kadaknath breed had a significantly ($p<0.05$) higher specific gravity (1.1038±0.08) as compared to Aseel (1.0096±0.12). Dorji and Phurba (2014) evaluated of egg quality parameters in Bhutanese indigenous chickens *vis-a-vis* exotic chicken. They reported 1.11±0.09, 1.09±0.07, 1.03±0.09, 1.17±0.09 and 1.12±0.03 g/cm^3 specific gravity in Seim (Red Jungle fowllike), Phulom (Frizzle), Yuebjha Narp (Black-feathered), Khuilay (Naked neck) and Hyline Brown strains of Bhutanese indigenous chickens, respectively. Kumar *et al.* (2017) studied the egg quality traits of Vanaraja and Giriraja birds under Konkan region. They did not observed significant difference in egg specific gravity between Vanaraja and Giriraja birds.

2.3.2 Internal egg quality parameters

2.3.2.1 Yolk weight

Biswas *et al.* (2010) revealed that the yolk weight of Kadaknath ranged from 14.19±0.12 to 15.20±0.15 g. Krawczyk *et al.* (2011) recorded higher yolk weight in Greenleg Partridge and Yellowleg Partridge layer breed raised under semi-intensive (15.0±0.96 g and 18.1±2.39 g) and litter flor system (14.9±0.75 g and 17.8±1.36 g), respectively. Haunshi *et al.* (2011) recorded significantly ($p<0.01$) higher yolk weight in Aseel (16.32±0.24 g) compared to Kadaknath (12.49±0.09 g). Lewko and Gornowicz (2011) found significantly higher yolk weight in cage system (18.20±0.94 g) than backyard system (16.95±0.99 g) and deep litter system (16.79±2.49 g). Kgwatalala *et al.* (2013a) observed significantly higher ($P<0.001$) yolk weight in IndigenousTswana chickens (16.24±0.37 g) than commercial layer chicken (14.61b±0.26 g). Regassa *et al.* (2013) recorded yolk weight in Fayoumi chickens as 14.54±1.36 g maintained under scavenging conditions. Deka *et al.* (2014) reported higher egg yolk weight in Vanaraja (18.70±0.56 g) as compared to indigenous (15.8±0.68 g) breed under North-East condition of India. Kumar *et al.* (2017) evaluated the egg quality traits of improved poultry breeds under Konkan region. They recorded yolk weight in Giriraja as 15.98±0.30 g and Vanaraja as 15.96±0.32 g.

2.3.2.2 Yolk height

Kumar *et al.* (2017) evaluated the egg quality traits of improved poultry breeds under Konkan region. They recorded higher yolk height in Giriraja (17.60±0.3mm) as compared to Vanaraja (16.5±0.3 mm) birds at 52 wks of age.

2.3.2.3 Yolk index

Biswas *et al.* (2010) found yolk index of Kadaknath in a range from 34.48±0.89 to 36.36±0.98 per cent. Haunshi *et al.* (2011) recorded significantly higher yolk index as 0.395±0.006 per cent in Aseel as compared to Kadaknath (0.367±0.008). Padhi *et al.* (2014_a) studied effect of age on egg quality traits in a 3-way cross egg type chicken. They observed that yolk index showed significant ($p<0.05$) difference between different ages of measurement. At 72 wks of age it decreased significantly compared to other age of measurement. However, yolk index was significantly (p<0.05) higher at 40 (0.4886±0.007) and 52 (0.4714±0.006) weeks of age compared to other ages of measurement. Kumar *et al.* (2017) studied the egg quality traits of improved poultry breeds under Konkan region. They recorded significantly higher yolk index in Giriraja (43.41±0.54) as compared to Vanaraja (41.83±0.98) birds at 52 wks of age.

2.3.2.4 Yolk ratio

Haunshi *et al.* (2011) noted significantly (p<0.01) higher percentage of yolk in Aseel (33.12±0.42 %) compared to Kadaknath (30.22±0.29 %). Lewko and Gornowicz (2011) found yolk content as 29.75±0.03, 29.89±2.24 and 29.31±1.69 per cent under deep litter, cage, backyard system of management,respectively. Kgwatalala *et al.* (2013) recorded significantly higher (p<0.01) values for yolk index in indigenous Tswana chickens (32.60±0.39%) compared to commercial layer chickens (26.53±0.37%) raised traditional and intensive system of management.Dorji and Phurba (2014) evaluated egg quality parameters in Bhutanese indigenous chickens *vis-a-vis* exotic chicken. They observed 42.96±6.73, 46.16±5.51, 44.58±6.99, 43.24±6.69 and 45.83±4.71 per cent yolk index in Seim (Red Jungle fowl), Phulom (Frizzle), Yuebjha Narp (Black-feathered), Khuilay (Naked neck) and Hyline Brown strains of Bhutanese indigenous chicken, respectively. Padhi *et al.* (2014_b) reported that percentage of yolk did not significantly (p≤0.05) differed between different age groups. They recorded yolk ratio as 27.00±0.35 per cent at 32 wks, 28.52±0.46 per cent at 40 wks, 29.21±0.26 per cent at 52 wks, 29.29±1.35 per cent at 64 wks and 29.53±0.51 per cent at 72 wks of age.

2.3.2.5 Albumen weight

Biswas *et al.*(2010) observed albumin weight ranging from 21.21±0.21 to 22.02±0.35 g in Kadaknath.Haunshi *et al.* (2011) recorded significantly (p<0.01) higher albumin weight in Aseel (28.97±0.59 g) compared to Kadaknath (26.29±0.49 g). Lewko and Gornowicz (2011) noted significantly (p<0.05) higher albumin weight in cage system (34.89±3.17 g) than free range system (32.54±2.19 g) and deep litter system (31.95±3.47 g). Kgwatalala *et al.* (2013) observed significantly higher (p<0.01) albumen weight in commercial layer chicken (31.40±0.42 g) compared to indigenous Tswana chickens (26.20±0.44 g). Regassa *et al.* (2013) revealed albumen weight as 24.61±2.67 g in Fayoumi hen reared under free range management system. Kumar *et al.* (2017) studied the egg quality traits of Vanaraja and Giriraja birds under Konkan region. They recorded higher albumin weight in Giriraja (35.69±0.54 g) as compared to Vanaraja (35.50±0.58 g) birds.

2.3.2.6 Albumen height

Krawczyk *et al.* (2011) reported higher albumin height in Yellowleg Partridge and Greenleg Partridge layer raised under semi-intensive (5.92±1.37 mm and 6.39±1.52 mm) than litter floor system (5.57±1.13 mm and 5.81±1.08 mm), respectively.Lewko and Gornowicz (2011) found 5.00±1.05, 4.49±0.81 and 4.07±1.57 mm albumin height in deep litter, cage and free range system of management, respectively.Dorji and Phurba (2014) studied the egg quality parameters in Bhutanese indigenous chickens *vis-a-vis* exotic chicken. They noted that the albumin height was 6.57±1.10, 6.93±1.09, 6.60±1.26, 5.98±1.06 and 11.21±1.21 mm in Seim (Red Jungle fowl-like), Phulom (Frizzle), Yuebjha Narp (Black-feathered), Khuilay (Naked neck) and Hyline Brown strains of Bhutanese indigenous, respectively. Kumar *et al.* (2017) evaluated the egg quality traits of improved poultry breeds under Konkan region. They recorded significantly higher albumin height in Giriraja (6.10±0.3 mm) as compared to Vanaraja (5.70±0.3 mm) birds.

2.3.2.7 Albumen index

Haunshi *et al.* (2011) recorded non significant differences between Kadaknath (0.072±0.002) and Aseel (0.076±0.002) indigenous poultry breeds for albumin index.
Jha and Prasad (2013) observed higher albumen index in Gramapriya (6.97±0.13) as compared to Vanaraja (6.81±0.14) and Aseel (6.25±0.14) at 40 wks. Padhi *et al.* (2014_a) observed that the albumen index was significantly ($p<0.05$) differed between different age and the lowest albumen index was observed at 72 wks (0.0918±0.005) of age indicating the poor quality of albumen at 72 wks of age. Kumar *et al.* (2017) evaluated the egg quality traits of improved poultry breeds under Konkan region. They recorded significantly higher albumin index in Giriraja (8.26±0.43) as compared to Vanaraja (8.00±0.46) birds.

2.3.2.8 Albumen ratio

Haunshi *et al.* (2011) recorded significantly ($p<0.01$) higher albumin ratio in Kadaknath (59.31±0.33 %) compared to Aseel (56.88±0.43 %) at 40 weeks of age. Lewko and Gornowicz (2011) found 56.74±4.10, 57.04±2.58 and 56.17±1.97 per cent in egg albumin under deep litter system, cage system and backyard system, respectively. Kgwatalala *et al.* (2013) observed significantly lower ($p<0.001$) values for albumin percentage in indigenous Tswana chickens (52.21a±0.47 %) compared to commercial layer chicken (57.23±0.45 %). Padhi *et al.* (2014_a) recorded albumin ratio at 32 week (64.80±0.31%), 40 week (63.33±0.48%), 52 week (61.30±0.26%), 64 week (61.68±1.67%) and 72 week (61.09±0.50 %). Kumar *et al.* (2017) evaluated the egg quality traits of improved poultry breeds under Konkan region. They recorded significantly higher albumin ratio in Giriraja (62.60±0.23 %) as compared to Vanaraja (62.21±0.21 %) birds.

2.3.2.9 Yolk-Albumen ratio

Dash *et al.* (2011) conducted an experiment on three poultry genotypes viz.,Kalinga Brown and CARI Shyama reared under backyard condition. They recorded that yolk to albumen ratio was significantly higher ($p<0.05$) in Black Rock (0.94±0.04) as compared to Kalinga Brown (0.81±0.09) and CARI Shyama (0.72±0.06). Haunshi *et al.* (2011) reported yolk-to-albumen ratio as 0.59±0.011 and 0.51±0.007 in Aseel and Kadaknath, respectively.Kumar *et al.* (2017) conducted an experiment on two improved ecotypes of chicken *viz.*Vanaraja and Giriraja bird in Konkan region. They recorded yolk-albumen ratio similar (0.45±0.00) in Vanaraja and Giriraja birds at 50 wks of age.

2.3.2.10 Haugh unit

Biswas *et al.* (2010) studied the egg quality traits in Indian native Kadaknath hen. They found that Haugh unit score of Kadaknath ranged 68.51±2.34 to 83.10±1.71 per cent.

Krawczyk *et al.* (2011) found higher haugh unit (75.6±8.70 and 78.9±12.87)in Yellowleg Partridge layer hen reared under litter flora and semi-intensive system as compared to Greenleg Partridge (75.1±8.74 and 78.8 ± 9.11), respectively. Lewko and Gornowicz (2011) found higher haugh unit in deep litter system (69.70±8.07) as compared to cage (62.80±7.99) and backyard system (58.64±13.43) of management.
Jha and Prasad (2013) observed higher haugh unit in Gramapriya (72.27±0.64) than to Vanaraja (71.26±0.65) and Aseel (69.94±0.68) at 40 wks.Padhi *et al.* (2014_a) recorded that the haugh unit was significantly ($p<0.05$)differed at different ages *i.e.* 32 wks (81.50±1.92), 40 wks (89.93±1.03), 52 wks (83.85±2.41) and 64 wks (86.30±1.42) and the lowest haugh unit (80.60±2.66) was obtained at 72 wks of age.Kumar *et al.* (2017) conducted an experiment on Vanaraja and Giriraja birdin Konkan region. The recorded higherhaugh unit (77.67±1.78) in Giriraja ascompared Vanaraja (75.09±1.95).

2.4 Haemato-biochemical profile

2.4.1. Haematological parameters

Simaraks *et al.* (2004) worked on hematological, electrolyte and serum biochemical values of the Thai indigenous chickens (*Gallus domestics*).The results revealed the following information: total red blood cell count, hemoglobin concentration, packed cell volume, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, total white blood cell count, lymphocyte, heterophil, monocyte, eosinophil, basophil, H:L ratio values of Thai native chickens were 2.26±0.29 ×10^6 cells/μl, 8.89±1.20 g/dl, 32.18±4.46 per cent, 144.63±18.61 fl, 39.69±4.96 pg, 27.86±3.37 g/dl, 2.04±0.45×10^4 cells/μl, 63.68±9.36 per cent, 23.70±7.21 per cent, 4.20±3.20 per cent, 5.83±3.53 per cent, 2.65±2.09 per cent and 0.40 ± 0.17, respectively. Hachesoo *et al.* (2011) evaluated haematological parameters *viz.* WBC counts, total white blood cell count (WBC) and packed cell volume (PCV) percentages of indigenous and Ross-308 broiler breeders. They revealed that differences among hematological parameter of Ross-308 and indigenous cocks and Ross-308 and indigenous hens were not significant except for PCV% of Ross-308 (32.60±2.32) and indigenous hens (35.50±2.22). Schumann *et al.* (2014) studied biochemical and haematological profile of pheasant hens during the laying period. They recorded haematocrit (l/l), haemoglobin (g/l), erythrocytes (T/l), leukocytes (G/l), heterophils (G/l), lymphocytes (G/l), eosinophils (G/l), basophils (G/l), monocytes (G/l) and heterophil to lymphocyte ratio as 0.39±0.01, 126.5±3.4, 3.91±0.19, 14.3±1.26, 2.48±0.61, 11.6±1.06, 0.07±0.01, 0.07±0.01, 0.08±0.01 and 0.27±0.08 at 01 day and 0.32±0.01, 129.8±2.1, 3.32±0.08, 32.9±2.86, 3.18±0.59, 29.2±2.33, 0.16±0.01, day 0.18±0.02, 0.16±0.01 and 0.10±0.01 at 84 days, respectively.

2.5.2. Serum biochemical parameters

Simaraks *et al.* (2004) analyzed hematological, electrolyte and serum biochemical values of the Thai indigenous chickens (*Gallus domestics*). They recorded potassium, sodium and chloride values of Thai native chickens as 5.3±0.8 mmol/l, 155.9±3.1 mmol/l and 116.9±2.7 mmol/l, respectively. Furthermore, serum biochemistry values of

Thai native chickens such as total protein, glucose, alkaline phosphatase, uric acid, calcium and cholesterol were 4.6±1.0 mg/dl, 190.2±29.8 mg/dl, 235.9±68.6 U/L, 5.0±1.9 mg/dl, 10.4±1.2 mg/dl and102.4±30.8 mg/dl, respectively. Hachesoo *et al.* (2011) studied the biochemical values namely; total protein, alkaline phosphatase, alkaline transferase, calcium, phosphorous, magnesium, glucose, triglyceride and cholesterol) of adult indigenous chickens compared with adult industrial broiler breeders (Ross 308). They noticedthat the comparison of biochemical parameters, showed significant differences only for cholesterol and glucose values between indigenous and Ross-308 hens. Glucose value in Ross-308 hens was higher than indigenous hens (274.50 ± 33.22 mg/dl and 245.60 ± 28.11 mg/dl, respectively). In addition, cholesterol value in Ross-308 hens was higher than indigenous hens (181.50 ± 33.22 mg/dl and 152.60 ± 28.11 mg/dl, respectively). No significant differences were observed between biochemical parameters values of Ross- 308 and indigenous cocks. Schumann *et al.* (2014) analyzed biochemical and haematological profile of pheasant hens during the laying period. They reported that total protein (g/l), albumin (g/l), cholesterol (mmol/l), glucose (mmol/l), uric acid (μmol/l), calcium (mmol/l) and phosphorus (mmol/l)was 49.6±1.34, 25.7±0.70, 5.61±0.57, 23.9±0.85, 194.4±19.4, 3.63±0.22 and 1.62±0.11 at 1 days and 29.2±3.85, 22.3±0.58, 8.93±0.65, 19.7±0.26, 268.2±14.5, 5.90±0.16 and 2.35±0.09 at 84 days, respectively.

2.6 Morbidity and mortality rate

Debata *et al.* (2012) observed that the mortality rate of the bird's upto 24 weeks of age ranged from 3-5 per cent in Black Rock, Red Cornish and Vanaraja breeds, which did not differed significantly. Khawaja *et al.* (2012) revealed that crossbred chickens had significantly ($p<0.05$) lowest mortality than pure bred chickens. The highest mortality was recorded in RIR followed by Fayoumi chickens. In this study, the mortality during the rearing period was higher than growing period in all types of chickens. Jha and Prasad (2013) studied the production performance of improved varieties and indigenous breed of chicken in Jharkhand. They reported mortality rate in Vanaraja, Gramapriya and Aseel as 14.57, 11.62 and 9.46 per cent, respectively upto 72 weeks period. Deka *et al.* (2014) conducted the experiment on Vanaraja bird under traditional system of rearing in Assam. They noticed 4.55±0.38 and 4.85±0.51 per cent mortality in Vanaraja and indigenous birds, respectively during the study period. Islam *et al.* (2014) found that there was significant ($p<0.05$) difference in mortality rate between Vanaraja (11.23±1.62 %) and indigenous chicken (7.04±0.86 %) during 0 to 5 wks of age. Later on the mortality rate decreased with the advancement of age in both the cases and there was no significant difference in mortality rate between Vanaraja (1.04±0.03 %) and Indigenous (3.61±0.43 %) breed during 6 to 30 wks. It was1.03±0.02 per cent and 1.06±0.53 per cent in Vanaraja and Indigenous during 31 to 52 wks of age. Kumari and Subrahmanyeswari (2014) studied the productive performance of Rajasri bird at farmer's backyard. They noted average mortality of the birds between 3 to 6 per cent. Padhi *et al.* (2014) recorded 4.41 per centmortality rate in crossbred chicken developed using both exotic and indigenous breeds during brooding period.

2.7 Cost of poultry production

Podchalwar *et al.* (2013) studied performance of three crossbred chickens *viz.*Australorp (A) x White Leghorn (IWP strain), Naked neck (Na) x White Leghorn (IWP strain) and Rhode Island Red (RIR) x White Leghorn (IWP strain). Thereturn over feed cost from 21-40 weeks of age ($ROFC_{21-40}$) was found to be 0.14±0.04, 0.29±0.03 and 0.28±0.03 in A x IWP, Na x IWP and RIR x IWP crossbreds, respectively. The ROFC was significantly ($P<0.05$) higher in Na x IWP and RIR x IWP crossbreds as compared to A x IWP crossbred. This was because of their better feed efficiency. However, there was no significant difference in ROFC between Na x IWP and RIR x IWP crossbreds. Deka *et al.* (2014) revealed that the benefit cost ratio of Vanaraja (3.47) was recorded significantly higher in comparison to indigenous chicken (2.42) under Assam condition. Better ratio might be due to better productive and reproductive performance of the dual purpose Vanaraja as compared to the indigenous chicken. Das *et al.* (2014) evaluated the benefit-cost analysis of Rhode Island Red chicken reared in backyard on the basis of egg production performance. The study was conducted on 60000 chicken covering five different agro-climatic zones in the state West Bengal, India. They observed 2.38, 1.98, 2.30, 2.38 and 2.30 benefit-cost analysis (B:C) for production cost for an egg under Terai Alluvial, New Laterite, Red, Old and coastal agro-climatic zones of West Bengal, respectively. Kumari and Subrahmanyeswari (2014) studied the productive performance of Rajasribird at farmer's backyard. They recorded net income/annum/bird as Rs.2545.10 and net profit /annum /bird as Rs. 2489.24 from Rajasri bird. Padhi *et al.* (2014) conducted an experiment on performance of a crossbred chicken developed using both exotic and indigenous breeds under backyard system of rearing. They reported that farmer earned a net profit of Rs. 8195/- from the backyard poultry using 20 number of PD_1 x PD_4chicks from 6 to 72 wks of age.

CHAPTER IV

RESULTS AND DISCUSSION

The present investigation was conducted as per the objectives of the data pertaining to production performance of improved poultry breeds under different management regimes at Poultry Unit, Livestock Instructional Farm, College of Agriculture, Dr. BSKKV, Dapoli, Dist. Ratnagiri, Maharashtra state.After of statistical analysis of data, the findings of the present experiment are presented and discussed in this chapter under the following heads.

4.1 Growth performance

4.1.1 Daily feed consumption (g/bird)

4.1.2 Total feed consumption (g/bird)

4.1.3 Body weight gain (g)

4.1.4Age at first laying (days)

4.2 Egg production performance

4.2.1 Hen day egg production (%)

4.2.2 Hen egg production per week (no/per bird)

4.2.3 Hen egg production per year (no/per bird)

4.2.4 Feed conversion efficiency/dozen of eggs

4.2.5 Feed conversion efficiency/kg of eggs

4.3 Egg quality parameters

4.3.1 External egg quality parameters

4.3.1.1 Egg weight (g)

4.3.1.2 Egg width (mm)

4.3.1.3 Egg length (mm)

4.3.1.4 Egg shape index

4.3.1.5 Egg shell weight (g)

4.3.1.6 Egg shell thickness

4.3.1.7 Egg specific gravity

4.3.2 Internal egg quality parameters

4.3.2.1 Yolk weight (g)

4.3.2.2 Yolk width (mm)

4.3.2.3 Yolk height (mm)

4.3.2.4 Albumen length (mm)

4.3.2.5 Albumin width (mm)

4.3.2.6 Albumen height (mm)

4.3.2.7 Albumen weight (g)

4.4 Physiological parameters

4.5.1 Rectal temperature

4.5.2 Respiration rate

4.5 Morbidity and mortality

4.6 Cost of poultry production

4.1 Growth performance

4.1.1 Daily feed consumption

4.1.1.1 Daily feed consumption during brooding period

The observations on average daily feed consumption (g/bird) during chick period (1 day - 8 wks) under brooding condition are presented in Table 4.1 and graphically shown in Fig 4.1. The average daily feed consumption (g) was maximum in Srinidhi (54.01 /bird) followed by Vanaraja (50.48 g/bird), Gramapriya (34.06 g/bird) and Desi (27.32/bird). The results of this experiment showed significant ($p<0.05$) differences in feed sumption between different poultry ecotype during brooding stage. These results were in line ith those of Chatterjee *et al*. (2005) who indicated that cross of ILI 80 male× White icobari female showed significantly higher feed intake (42.76g/bird) than White obari male ith ILI 80 female birds (40.39 g/bird) at 8 weeks of age. Similar findings were also ecorded by Jatoi *et al.* (2014) on an overall basis, daily feed intake per bird was recorded as 5.0g/bird for Mianwali Aseel and Chatterjee *et al.* (2005) for White Nicobari as 40.39 g/bird and ILI -80 as 42.76 g/bird.

4.1.1.2Daily feed consumption during growing period
4.1.1.2.1 Effect of breed on daily feed intake during growing period

The data of the daily feed consumption per bird are shown in Table 4.1 and graphically presented in Fig. 4.1. Breedwise significantly higher daily feed intake was recorded for Vanaraja (96.32 g/bird) followed by Srinidhi (95.57 64 g/bird), Gramapriya (86.68 g/bird) and Desi (69.68 g/bird). The findings of study were comparable with Hassen *et al.* (2006) who recorded daily feed intake of indigenous chickens of Ethiopia *viz.* Tilili, Gellilia, Debre, Ellias, Mello, Hamusit, Gassay, Guangua, Mechaand RIR as 89.6,98.5, 87.3, 86.0, 89.7, 86.7, 91.6 and 83.3 g/bird/day, respectively. However, Awad *et al.* (2014) recorded non-significant differences in feed intake for experimental birds.

4.1.1.2.2 Effect of management system on daily feed intake during growing Phase

The Table 4.1 and graphically in Fig 4.2 clearly showed the effect of rearing system on daily feed consumption. The results revealed that significantly maximum daily feed intake (103.38 g/bird) in deep litter system as compared to battery cage system (99.41 g/bird) and semi intensive system (58.41 g/bird). The findings of this experiment were close comparable with Gerzilov *et al.* (2012). They recoded average feed consumption per day as 118.8, 121.1 and 120.7 g for the layers reared in conventional cages, enriched cages and in floor/litter system. However, similar result was recorded by Bahouh *et al.* (2012) that birds raised on floor system consumed significantly ($p<0.05$) more feed than the birds in cages.

4.1.1.2.3 Effect interaction between breeds and management systems on daily feed intake during growing phase

The results of effect interactions between breeds and systems on daily feed intake during growing phase (g/bird) are presented Table 4.1. The overall means demonstrated significant ($p<0.05$) difference in daily feed consumption with respect to different rearing systems, poultry genotypes and their interaction. This interaction significantly ($p<0.05$) affected daily feed intake. The result of experiment showed significantly higher feed intake in Vanaraja when raised on deep litter system (114.20 g/bird) followed by Srinidhi kept in battery cage system (112.97 g/bird), Vanaraja in battery cage system (112.95 g/bird), Srinidhi on deep litter (111.92 g/bird), Gramapriya on deep litter (102.14g/bird), Gramapriya in battery cage (96.09g/bird), Desi on deep litter (85.26g/bird), Desi in battery cage (75.62 g/bird), Vanaraja, Gramapriya and Srinidhi in semi intensive system (61.82 g/bird) and Desi in semi intensive system (48.18g/bird).
Because birds of semi-intensive system were offered only 50 per cent fed. The results of study were in agreement with Yakubu *et al.* (2007) who recorded that the birds raised on deep litter consumed more feed than those in cages. Similar results were also recorded by Hameed *et al.* (2012). They observed higher feed intake from 0-24 weeks under open housing system than controlled housing.

4.1.1.3 Effect of breed on daily feed consumption (g/bird) in laying period

The data of overall means of daily feed consumption are presented in Table 4.1 and depicted graphically in Fig 4.1.The results, revealed that the daily feed consumption per bird of different poultry breed was maximum for Vanaraja (103.87±1.29 g/bird) followed by Srinidhi (100.79±1.29 g/bird), Gramapriya (99.43±1.29 g/bird) and Desi (87.31±1.29 g/bird). The difference in feed intake of chicken was due to interplay of multiply genes and it could be improved through genetic selection (Chambers, 1990). These differences in feed intake could also be attributed to the environmental conditions such as season, temperature, humidity and management. However, higher feed consumption per day was recorded by Bharambe and Garud (2012) for Vanaraja (117.14 g/bird), Delham Red (115.28 g/bird), Malik and Singh (2010) as 129.62±80 g/bird for CARI Nirbheek and Anonymous (2008) for CARI Shyama. Feed consumption of indigenous birds were generally lower than commercial poultry birds (Islam and Nishibori 2010). In present study also, the feed consumption of Desi birds were low (87.31±1.29g). However, no significant differences were observed between the different genotypes of poultry for daily feed intake per bird per day (Hassen *et al.*, 2006). Lower feed consumption was recorded for the indigenous lines compared to the RIR chickens. This could be related to the pronounced selective feeding and feed scratching behaviour that could have lead to an over estimation of the feed intake during the rearing period.

Table 4.1 Average daily feed consumption (g/bird) of improved indigenous poultry breeds under different management regimes
Treatments/Phases Chick stage
(1 day -8 wks.)
Growing
(9 - 18 wks.)
Early laying
(19 - 33 wks.)
Mid laying
(34 - 44 wks.)
Late laying

(45 - 62 wks.)
Avg. Daily FC
(19-62 wks.)
Breeds
Vanaraja (B_1) 50.48_{ab} 96.32_{a} 105.11_{a} 107.17_{a} 105.50_{a} **103.87_{a}**
Gramapriya (B_2) 34.06_{c} 86.68_{b} 100.06_{b} 104.37_{ab} 103.71_{a} **99.43_{b}**
Srinidhi (B_3) 54.01_{a} 95.57_{a} 101.57_{ab} 99.90_{b} 103.93_{a} **100.79_{ab}**
Desi (B_4) 27.32_{d} 69.68_{c} 90.33_{c} 92.99_{c} 92.25_{b} **87.31_{c}**
S.E. 2.56 1.09 1.34 1.63 1.86 1.29
C.D. ($p<0.001$) 7.98 3.21 3.93 4.79 5.46 3.79
Systems
DLS (M_1) -- 103.38_{a} 115.85_{a} 113.04_{a} 111.54_{a} **111.30_{a}**
BCS (M_2) -- 99.41_{b} 109.86_{b} 109.99_{a} 108.19_{a} **107.20_{b}**
SIS (M_3) -- 58.41_{c} 72.09_{c} 80.30_{b} 84.31_{b} **75.05_{c}**
S.E. -- 0.95 1.16 1.41 1.61 1.12
C.D. ($p<0.001$) -- 2.781 3.40 4.15 4.73 3.28
Breeds × Systems
Vanaraja
DLS -- 114.20_{a} 122.69_{a} 119.01_{a} 116.06_{a} **118.00_{a}**
BCS -- 112.95_{a} 116.03_{ab} 116.84_{ab} 114.51_{a} **115.06_{ab}**
SIS -- 61.82_{f} 76.63_{d} 85.65_{f} 85.92_{cd} **78.54_{e}**
Gramapriya
DLS -- 102.14_{b} 113.90_{b} 118.63_{a} 113.96_{a} **112.49_{ab}**
BCS -- 96.09_{c} 110.93_{b} 113.69_{abc} 114.20_{a} **109.56_{b}**
SIS -- 61.82_{f} 75.36_{d} 80.80_{fg} 82.96_{d} **76.24_{e}**
Srinidhi
DLS -- 111.92_{a} 115.38_{b} 109.60_{bcd} 115.84_{a} **113.65_{ab}**
BCS -- 112.97_{a} 113.97_{b} 108.49_{cde} 110.69_{a} **111.55_{ab}**
SIS -- 61.82_{f} 75.36_{d} 81.61_{f} 85.26_{cd} **77.17_{e}**
Desi
DLS -- 85.26_{d} 111.43_{b} 104.92_{de} 100.28_{b} **101.06_{c}**
BCS -- 75.62_{e} 98.54_{c} 100.94_{e} 93.37_{bc} **92.63_{d}**
SIS -- 48.18_{g} 61.03 73.12_{g} 83.10_{d} **68.23_{f}**
S.E. 1.89 2.32 2.83 3.22 2.24
C.D. ($p<0.001$) 5.55 6.79 8.29 9.44 6.55
$_{abcdef}$Means under each class in the same column with different superscripts differed significantly

.4.1.1.4. Effect of management system on daily feed consumption (g/bird) in laying period

The data of daily feed consumption per bird with different management systems are presented in Table 4.1 and graphically shown in Fig 4.2. The effect of management system on feed consumption during laying period was significant ($p<0.05$). According to system significantly higher average daily feed consumption was recorded when birds were reared on deep litter system (111.30 g/bird) than battery cage system (107.20 g/bird) and semi-intensive system (75.05 g/bird). Lower mean daily feed intake per bird (83.3 g/bird) was reported for RIR by Halima *et al.* (2006), Khawaja *et al.* (2012) as 49.48 g for RIR, Kumar *et al.* (2014) as 62.30±4.22 and 56.75±4.32 g/bird for Bovans White and RIR under intensive management. However, Li *et al.* (2017) recorded higher feed intake in cage system as compared to free range system. The previous researchers raised poultry birds under different management systems and found non-significant effect of different managements on daily feed consumption (Ahmad *et al.,* 2010; Siopes, 1984).

4.1.1.5 Effect of interaction between breed and system on daily feed consumption (g/bird) in laying period

The feed intakes of the different poultry breeds in each of the three raising systems are shown in Table 4.1. The interaction between the breeds and rearing systems significantly influenced the feed consumption per bird. The Vanaraja birds consumed maximum feed when reared on the deep litter system (118.00 g/bird) and battery cage system (115.05 g/bird) followed by Srinidhi on deep litter system (113.65 g/bird), Gramapriya on deep litter system (112.49 g/bird), Srinidhi in battery cage system (111.55 g/bird), Gramapriya in battery cage system (109.56 g/bird), Desi on deep litter and battery cage system (101.06 and 92.63 g/bird), Vanaraja, Gramapriya and Desi on semi-intensive system (78.54, 76.24 and68.23g/bird), respectively. The birds in semi-intensive system had the lowest feed intake as compared to deep litter and battery cage system. These differences in feed intakes under different rearing systems may be explained by the inherent variability in free-range raising systems; free-range birds are exposed to some factors that are inherently variable, such as light intensity, photoperiod, and temperature. Furthermore, birds raised in a free-range system had access to the various forages, insects, and worms found on pasture. These may contribute some dietary nutrients and thus interfere with their normal intake of commercial feed (Li *et al.,* 2017).

4.1.2 Total feed consumption
4.1.2.1 Total feed consumption during brooding period

The observations on average total feed consumption (kg/bird) during chick period (1 day - 8 wks) under brooding condition are presented in Table 4.2 and graphically depicted in Fig 4.3. The average total feed consumption (kg) was maximum for Srinidhi (3.02kg/bird) followed by Vanaraja (2.82 kg/bird), Gramapriya (1.90 kg/bird) and Desi (1.56 kg/bird) from 1st week to 8th weeks. All poultry genotypes had significant ($p<0.05$) differences in total feed consumption during chick stage. These results were in line with those of Krishna *et al*. (2012) who recorded 1.55 kg/bird feed intake in Rajasree birds. The results of this study showed variation in feed intake among different varieties of breeds were in agreement with Joya *et al.* (1979), Proudfoot and Hulan (1987), Leeson *et al*. (1997) and Jatoi (2012) who reported significant strain variation on feed intake in chicken and Japanese quail.

4.1.2.2Total feed consumption during growing period
4.1.2.2.1 Effect of breed on total feed consumption during growing period

The breedwise average total feed consumption of experiment birds are presented in Table 4.2 and graphically shown in Fig. 4.3. The total feed consumption (kg/bird) was recorded significantly higher for Vanaraja (7.41 kg/bird) and Srinidhi (7.35 kg/bird) than Gramapriya (6.68 kg/bird) and Desi (5.36 kg/bird) birds. The present results were in accordance with the findings of Kumar *et al.* (2014) who reported higher feed intake/bird (kg) for Bovans White chicken (9.60±0.32 kg/bird) as compared to RIR (8.75±0.21kg/bird) upto 22 wks. Similar results were also recorded by Hassen *et al.* (2006). They recorded total feed intake of indigenous chicken of Northwest Ethiopia *viz.* Tilili, Gellilia, Debre, Ellias, Mello, Hamusit, Gassay, Guangua, Mecha and RIR as 15.2, 13.5,13.3, 13.8, 13.4, 14.1 and 12.8 kg/bird, respectively during growing stage.

4.1.2.2.2 Effect of management system on total feed consumption during growing period

The average total feed consumption of experiment birds with different systems are presented in Table 4.2 and graphically depicted in Fig. 4.4. In case of rearing systems significantly more feed intake was found in deep litter system (5.78 kg/bird) than battery cage system (5.56 kg/bird) and semi intensive system (3.27 kg/bird). Results of present study were in consonance with of the earlier investigation that birds in deep litter consumed more feed as compared to control housing system (Hameed *et al.*, 2012).

4.1.2.3 Effect of breed on total feed consumption during laying period

The breedwise data of total feed consumption per bird during laying period (19 to 62 wks) are presented in Table 4.2 and graphically depicted in Fig 4.3. The finding revealed significant ($p<0.05$) influence of breed on total feed intake during laying period. The total feed consumption of Vanaraja was significant higher than Srinidhi, Gramapriya and Desi as 31.82, 30.86, 30.74 and 27.60 kg/bird, respectively. The results were in agreement with Scheideler *et al.* (1998) found significant differences in feed intake among Dekalb Delta, Babcock B-300 and Hy-Line W-36. Similarly, Gunawardana *et al.* (2009) also found significant differences in seven commercial leghorn strains and Singh *et al.* (2009) found significant difference in Lohmann White, H&N White, Lohmann Brown and non-commercial cross between RIR and Barred Plymouth Rock. However, Hassen *et al.* (2006) observed non-significant differences in total feed consumption amongst the tested chicken lines. But, higher levels of feed consumption were recorded for the indigenous lines compared to the RIR chickens.

4.1.2.4 Effect of management system on total feed consumption during laying period

The average data of the effect of systems on total feed consumption laying period are presented in Table 4.2 and graphically showed in Fig. 4.4. The systemwise average total feed consumption (kg) of present experiment was 34.12, 32.85 and 23.80 kg/bird recorded in deep litter, battery cage and semi intensive system, respectively. The results of present study were in consonance with some of the earlier investigations that birds consumed more feed in deep litter system as compared to cage system and semi intensive system (Yakubu *et al.*, 2007; Hameed *et al.*, 2012 and Castilho *et al.*, 2013). However, present results disagreed with Hetland *et al.* (2004) who reported that hens kept in enriched cages consumed more feed compared to hens reared in conventional cages system.

4.1.2.5 Effect of interaction between breed and management system on total feed consumption during laying period

The interaction effect of rearing system and genotype on feed consumption of improved indigenous birds (Table 4.2) was significant ($p>0.05$). The finding of present study revealed that birds on deep litter system consumed more feed than those reared on battery cage system and semi intensive system. In the interaction, the maximum ($p<0.05$) feed intake of 35.83 kg/bird was obtained for Vanaraja on deep litter system followed by Vanaraja in battery cage system (34.77), Gramapriya on deep litter system (34.60 kg/bird), Srinidhi on deep litter system (34.37 kg/bird), Gramapriya in battery cage system (33.97 kg/bird), Srinidhi in battery cage system (33.49 kg/bird) Desi on deep litter system (31.67 kg/bird), Desi in battery cage system (29.16 kg/bird), Vanaraja in semi intensive system (24.85 kg/bird), Srinidhi in semi intensive system (24.34 kg/bird) Gramapriya in semi intensive system (23.92 kg/bird) and Desi in semi intensive (21.98 kg/bird). These findings were close to Olaniyi *et al.* (2012). They recorded that birds reared on deep litter system consumed more feed than those reared on free range. This could be related to the pronounced selective feeding and feed scratching behaviour that could have lead to an overestimation of the feed intakeduring the rearing period.

4.1.3 Live body weight (g/bird)

4.1.3.1 Average live body weight during brooding period

The observations on average live body weight (g/bird) of birds during their brooding period are presented in Table 4.3 and graphically shown in Fig 4.5. The average live body weight upto 8thwks was significantly ($p<0.05$) higher by Vanaraja (1035.62 g) than Srinidhi (905.59 g), Gramapriya (799.77 g) and Desi (593.49 g). These findings of present experiment revealed that all improved poultry genotypes *i.e.*, Vanaraja, Srinidhi and Gramapriya gained significantly higher live body weight (g/bird) than Desi birds. This may be due to highest average body weight of day old chick of Vanaraja (35.09 g) followed by Srinidhi (33.91 g), Gramapriya (31.17 g) and Desi (28.96 g). The results of present experiment were agreement with Islam *et al.* (2014), who recorded significantly higher body weight for Vanaraja (768.23±6.43 g/bird) as compared to Indigenous bird (365.12±2.74 g/bird) and Deka *et al.* (2014) recorded weight for Vanaraja and indigenous as 861.96±44.66 and 301.96 ± 17.36 g/bird, respectively at 8 wks of age.

4.1.3.2 Average live body weight during growing period

The results of live body weight during growing period (9 to 18 wks) are presented in Table 4.3 and graphically shown in 4.5. During growing phase, significantly more live body weight was recorded in Vanaraja, than Gramapriya, Srinidhi and Desi as 1741.42, 1348.81, 1232.19 and 980.10d g/bird, respectively. Similar, results were observed by Islam *et al.* (2014), who recorded significantly higher body weight for Vanaraja (1693.52±11.1 g/bird) than Indigenous bird (783.14±5.03g/bird) and Deka *et al*. (2014) for Vanaraja (1443.70±46.76g/bird) and indigenous (639.57± 23.00 g/bird) at 20 wks of age. In contrast to the present results, Niranjan *et al.* (2008) and Ramana *et al.* (2010) recorded higher body weight of Vanaraja birds at different ages as compared to other poultry genotypes.

Table 4.2 Total feed consumption (kg/bird) of improved indigenous poultry breeds under different management regimes

Treatments/Phases	Chick stage (1 day -8 wks.)	Growing (9 - 18 wks.)	Early laying (19 - 33 wks.)	Mid laying (34 - 44 wks.)	Late laying (45 - 62 wks.)	Total FC (19-62 wks.)
Breeds						
Vanaraja(B_1)	2.82^{ab}	7.41^{a}	11.03^{a}	7.50^{a}	13.29^{a}	**31.82^{a}**
Gramapriya (B_2)	1.90^{c}	6.68^{b}	10.50^{b}	7.30^{ab}	13.06^{a}	**30.86^{b}**

Srinidhi (B3)	3.02^{a}	7.35^{a}	10.66^{ab}	6.99^{b}	13.09^{a}	**30.74^{ab}**
Desi (B4)	1.56^{d}	5.36^{c}	9.48^{c}	6.50^{c}	11.62^{b}	**27.60^{c}**
S.E.	1.43	0.83	1.08	1.63	2.34	**5.05**
C.D. (p<0.001)	4.46	2.47	4.12	4.79	6.87	**15.78**
Systems						
DLS (M1)	--	5.78^{a}	12.16^{a}	7.91^{a}	14.05^{a}	**34.12^{a}**
BCS (M2)	--	5.56^{b}	11.53^{b}	7.69^{a}	13.63^{a}	**32.85^{b}**
SIS (M3)	--	3.27^{c}	7.56^{c}	5.62^{b}	10.62^{b}	**23.80^{c}**
S.E.	--	**0.53**	**1.21**	**0.98**	**2.02**	**4.21**
C.D. (p<0.001)	--	**1.55**	**3.57**	**2.90**	**5.95**	**12.42**
Breeds × Systems						
Vanaraja						
DLS	--	6.39^{a}	12.88^{a}	8.33^{a}	14.62^{a}	**35.83^{a}**
BCS	--	6.32^{a}	12.18^{ab}	8.17^{ab}	14.42^{a}	**34.77^{ab}**
SIS	--	3.46^{f}	8.04^{d}	5.99^{f}	10.82^{cd}	**24.85^{e}**
Gramapriya						
DLS	--	5.71^{b}	11.95^{b}	8.30^{a}	14.35^{a}	**34.60^{ab}**
BCS	--	5.38^{c}	11.64^{b}	7.95^{abc}	14.38^{a}	**33.97^{b}**
SIS	--	3.46^{f}	7.91^{d}	5.65^{fg}	10.45^{d}	**23.92^{e}**
Srinidhi						
DLS	--	6.26^{a}	12.11^{b}	7.67^{bcd}	14.59^{a}	**34.37^{b}**
BCS	--	6.32^{a}	11.96^{b}	7.59^{cde}	13.94^{a}	**33.49^{ab}**
SIS	--	3.46^{f}	7.91^{d}	5.71^{f}	10.72^{cd}	**24.34^{e}**
Desi						
DLS	--	4.77^{d}	11.70^{b}	7.34^{de}	12.63^{b}	**31.67^{c}**
BCS	--	4.23^{e}	10.34^{c}	7.06^{e}	11.76^{bc}	**29.16^{d}**
SIS	--	2.69^{g}	6.40	5.11^{g}	10.47^{d}	**21.98^{f}**
S.E.		**1.05**	**2.43**	**1.98**	**4.05**	**8.46**
C.D. (p<0.001)		**3.10**	**7.12**	**5.80**	**11.89**	**24.81**

^{abcdef}Means under each class in the same column with different superscripts differed significantly

4.1.3.3 Effect of breed on live body weight

The live body weights (g/bird) of different breeds are presented in Table 4.3 and graphically depicted Fig. 4.5. The average live body weights of Vanaraja, Gramapriya, Srinidhi and Desi from early laying phase to late laying phase (19 to 62 wks) are presented in Table 4.3. There were significant ($p<0.05$) differences in live body weights of the four breeds (Vanaraja *vs* Gramapriya *vs* Srinidhi *vs* Desi) from day old. The Vanaraja had significantly higher live body weight than Gramapriya, Srinidhi and Desi from early laying phase to late laying phase. On the basis of breeds with overall mean live body weight during 19 to 62 wks was significantly higher in Vanaraja bird (2527.88 g/bird) as compared to Srinidhi (2295.00 g/bird), Gramapriya (2211.74 g/bird) and Desi (1486.54 g/bird). The results indicated that the improved breeds have significantly higher body weights than the Desi ecotype chicken from brooding stage to late laying stage. The body weights of Vanaraja were significantly ($p<0.05$) higher than the corresponding body weights of Gramapriya, Srinidhi and Desi chicken, which might be due to utilization of exotic germplasm for the development of Vanaraja (Islam *et al.*, 2001)

4.1.3.4 Effect of management system on live body weight

The average live body weights (g/bird) of birds in different systems are presented in Table 4.3 and graphically shown in Fig. 4.6. According to system significantly higher live body weight was recorded in battery cage system (2272.26g/bird) and deep litter system (2253.79 g/bird) than semi-intensive system (2064.69 g/bird).Overall means demonstrated significant ($p<0.05$) difference (Table 4.3) in live body weight with respect to different rearing systems. Birds kept under cage system and deep litter rearing systems exhibited enhanced live body weight than those reared under semi intensive system. Minimum activity or exercise in confinement rearing system or cage rearing system might be the factor behind enhanced live body weight (Rehman *et al.,* 2016).

Table 4.3 Average live body weight gain (g/bird) of improved indigenous poultry breeds under different management regimes

Treatments/Phases	**Chick period (1 day – 8 wks)**	**Growing period (9 – 18 wks)**	**Early laying (19 - 33 wks)**	**Mid laying (34 - 44 wks)**	**Late laying (45 - 62 wks)**	**Avg. Live BW (19 - 62 wks)**
Breeds						
Vanaraja(B$_1$)	1035.62$_{a}$	1741.42$_{a}$	2479.92$_{a}$	2893.11$_{a}$	2997.08$_{a}$	**2527.88$_{a}$**
Gramapriya (B$_2$)	799.77$_{c}$	1348.81$_{b}$	2010.45$_{c}$	2274.48$_{c}$	2350.31$_{c}$	**2211.74$_{c}$**
Srinidhi (B$_3$)	905.59$_{b}$	1232.19$_{c}$	2088.20$_{b}$	2333.80$_{b}$	2463.01$_{b}$	**2295.00$_{b}$**
Desi (B$_4$)	593.49$_{d}$	980.10$_{d}$	1352.64$_{d}$	1512.44$_{d}$	1594.54$_{d}$	**1486.54$_{d}$**
S.E.	**5.47**	**8.18**	**30.48**	**29.89**	**29.71**	**30.02**
C.D. ($p<0.001$)	**15.82**	**23.95**	**89.23**	**87.49**	**86.99**	**87.90**
Systems						
DLS (M$_1$)	--	1325.97$_{b}$	2055.32$_{a}$	2351.12$_{a}$	2354.95$_{b}$	**2253.79$_{a}$**
BCS (M$_2$)	--	1428.48$_{a}$	2075.12$_{a}$	2280.03$_{b}$	2461.63$_{a}$	**2272.26$_{a}$**
SIS (M$_3$)	--	1222.44$_{c}$	1833.85$_{a}$	2127.10$_{c}$	2233.14$_{c}$	**2064.69$_{b}$**
S.E.	**--**	**7.08**	**7.30**	**39.85**	**39.62**	**28.92**
C.D. ($p<0.001$)	**--**	**20.745**	**21.39**	**116.65**	**115.98**	**84.67**
Breeds × Systems						
Vanaraja						
DLS	--	1706.73$_{b}$	2589.3$_{a}$	2939.4$_{b}$	3046.1$_{b}$	**2858.26$_{a}$**
BCS	--	1900.31$_{a}$	2623.1$_{a}$	3063.2$_{a}$	3130.4$_{a}$	**2938.90$_{a}$**
SIS	--	1617.20$_{c}$	2227.4$_{b}$	2660.6$_{c}$	2802.3$_{c}$	**2563.43$_{ab}$**
Gramapriya						
DLS	--	1326.08$_{e}$	2129.9$_{c}$	2367.0$_{d}$	2432.9$_{ef}$	**2309.93$_{cd}$**
BCS	--	1445.80$_{d}$	1980.1$_{d}$	2310.1$_{de}$	2461.0$_{def}$	**2250.40$_{cd}$**
SIS	--	1274.55$_{f}$	1921.4$_{e}$	2142.2$_{f}$	2153.3$_{g}$	**2072.30$_{e}$**
Srinidhi						
DLS	--	1287.47$_{ef}$	2146.1$_{c}$	2351.0$_{de}$	2403.8$_{f}$	**2300.00$_{cd}$**
BCS	--	1300.50$_{ef}$	2160.0$_{c}$	2352.0$_{de}$	2512.8$_{d}$	**2341.60$_{c}$**

SIS -- 1108.60$_{g}$ 1958.5$_{d}$ 2299.0$_{e}$ 2472.0$_{de}$ **2243.16$_{cd}$**
Desi
DLS -- 983.62$_{h}$ 1332.7$_{g}$ 1459.7$_{h}$ 1534.3$_{i}$ **1442.23$_{g}$**
BCS -- 1067.29$_{g}$ 1518.6$_{f}$ 1655.1$_{g}$ 1717.6$_{h}$ **1630.43$_{f}$**
SIS -- 889.40$_{i}$ 1206.6$_{h}$ 1422.5$_{h}$ 1531.7$_{i}$ **1386.93$_{h}$**
S.E. -- 47.16 47.16 74.67 74.52 65.87
C.D. ($p<0.001$) -- 138.06 138.06 218.57 218.13 192.82
$_{abcdefg}$Means under each class in the same column with different superscripts differed significantly

4.1.3.5 Effect of interaction between breed and system on live body weight

The data of interactions between breeds and systems on live body weight are presented in Table 4.3. The average live body weight (19 to 62 wks) was significantly higher in Vanaraja with battery cage, deep litter and semi intensive system (2938.90, 2858.26 and 2563.43 g/bird), respectively as compared to Srinidhi in battery cage system (2341.60 g/bird), Gramapriya in battery cage system (2309.93 g/bird), Srinidhi on deep litter system (2300.00 g/bird), Gramapriya on deep litter(2250.40 g/bird), Srinidhi in semi intensive system (2243.16 g/bird) and Desi in battery cage, deep litter and semi intensive system (1630.43, 1442.23 and 1386.93 g/bird), respectively. The interaction of rearing systems with breeds depicted maximum live body weight in birds of Vanaraja breed under battery cage system (2938.90 g/bird) whereas, Desi breed manifested the lowest BW under semi intensive system (1386.93 b/bird). The synergistic effect of the genetic potential for higher body weight of Vanaraja and battery cage rearing system might be the possible reason behind enhanced body weight. These findings were in agreement with values reported by some other studies conducted on rearing systems showed and body weight. Therefore, results of present experiment agreed with Castellini *et al.,* (2002) and Wang *et al. (*2009$_{b}$), who reported that birds raised in indoor as well as under conventional treatments had higher growth rate as compared to free range system.

4.1.4 Age at first laying (days)

The results of present experiment revealed that the age at first egg laying was found significantly superior in Srinidhi when reared on deep litter system (128 days), followed by Desi in battery cage system (129 days), Gramapriya in battery cage system (131 days), Gramapriya on deep litter system (141 days), Vanaraja in battery cage system (142 days) Desi on deep litter system (143 days), Srinidhi in semi intensive system (147 days), Desi in semi intensive system (148 days), Gramapriya in semi intensive system (149 days), Vanaraja on deep litter system (157 days)and Vanaraja in semi intensive system (162 days), respectively. Age at first egg laying of birds in the present experiment were comparable with those reported in Dahlem Red by Jha *et al.* (2013$_{a}$), who recorded age at first egg laying as 143.65±1.76 days. The results of study agreed with Padhi *et al.* (2004) and Kundu *et al.* (2015). The early age of sexual maturity in crosses compared to Desi may be because of genetic inheritance of improved genotype birdsprevailing in crosses.

4.2 Egg production performance

4.2.1 Hen day egg production (HDEP %)

4.2.1.1 Effect of breed on hen day egg production

Table 4.4 represented the breedwise data of the average hen day egg production graphically presented in Fig 4.7. The results revealed that the average hen day egg production was significantly higher in Gramapriya (61.19 %) than Srinidhi (58.60%), Vanaraja (56.27 %) and Desi (42.48 %) breed. Highest peak daily egg production

(HDEP %) was observed at mid laying phase by Srinidhi (69.98 %) followed by Gramapriya (69.74%), Vanaraja (66.69%) and Desi (58.37 %) breed. The higher egg production recorded in Srinidhi during initial period was perhaps due to significantly early age at sexual maturity observed in Srinidhi as compared to Gramapriya, Vanaraja and Desi breeds. Overall relatively higher egg production up to 62 weeks was observed in Gramapriya as compared to Srinidhi, Vanaraja and Desi breeds. The results of the present study were in agreement with those of Haunshi *et al.* (2013). Likewise, a study was also conducted to determine the hen day egg production of crossbred chicken by Omeje and Nwosu., 1983.They observed that cross bred (GLxLC) and the reciprocal cross (LCxGL) had higher egg production than the local chickens. In present study, relatively higher egg production was recorded in all improved breeds *viz.* Gramapriya, Srinidhi and Vanaraja than Desi as compared to earlier reports (Thakur *et al.,* 2009 and Haunshi *et al*., 2011). Higher egg production in the present study might be due to early age at sexual maturity (Haunshi *et al.*, 2013).

Table 4.4 Average hen day egg production (%) of improved indigenous poultry breeds under different management regimes

Treatments/Phases	**Early laying (19 - 33 wks.)**	**Mid laying (34 - 44 wks.)**	**Late laying (45 - 62 wks.)**	**Avg. HDEP (%) (19 - 62 wks.)**
Breeds				
Vanaraja (B$_1$)	52.19^{b}	66.69^{b}	49.93^{b}	**56.27^{c}**
Gramapriya (B$_2$)	59.91^{a}	69.74^{ab}	53.92^{a}	**61.19^{a}**
Srinidhi (B$_3$)	58.44^{a}	69.98^{a}	47.40^{c}	**58.60^{b}**
Desi (B$_4$)	42.19^{c}	58.37^{c}	26.89^{d}	**42.48^{d}**
S.E.	**1.013**	**1.04**	**0.78**	**0.94**
C.D. ($p<0.001$)	**2.96**	**3.06**	**2.30**	**2.77**
Systems				
DLS (M$_1$)	53.57^{b}	67.65^{b}	44.63^{b}	**55.28^{b}**
BCS (M$_2$)	57.57^{a}	70.79^{a}	48.52^{a}	**58.96^{a}**
SIS (M$_3$)	48.42^{c}	60.14^{c}	40.46^{c}	**49.67^{c}**
S.E.	**0.877**	**0.90**	**0.68**	**0.81**
C.D. ($p<0.001$)	**2.569**	**2.65**	**1.99**	**2.4**
Breeds × Systems				
Vanaraja				
DLS	48.77^{de}	67.10^{bc}	50.77^{cd}	**55.54^{bc}**
BCS	56.10^{abc}	70.03^{ab}	55.57^{ab}	**60.56^{ab}**
SIS	51.70^{cd}	62.93^{cd}	43.47^{e}	**52.70^{cd}**
Gramapriya				
DLS	60.53^{a}	71.97^{ab}	53.17^{bc}	**61.89^{ab}**
BCS	61.00^{a}	75.20^{a}	58.70^{a}	**64.96^{a}**
SIS	58.20^{ab}	62.07^{cd}	49.90^{cd}	**56.72^{cd}**
Srinidhi				
DLS	58.50^{ab}	71.23^{ab}	47.00^{de}	**58.91^{de}**
BCS	59.00^{ab}	75.00^{a}	51.20^{c}	**61.73^{ac}**
SIS	57.83^{ab}	63.70^{cd}	44.00^{e}	**55.17^{cd}**
Desi				

DLS 46.47^{e} 60.30^{d} 27.60^{fg} **44.79^{fg}**
BCS 54.17^{bc} 62.93^{cd} 28.60^{f} **48.56^{f}**
SIS 25.93^{f} 51.87^{e} 24.47^{g} **34.09^{g}**
S.E. 1.75 1.81 1.36 1.64
C.D. (p<0.001) 5.12 5.30 3.99 4.80

^{abcdefg}Means under each class in the same column with different superscripts differed significantly

4.2.1.2 Effect of management system on hen day egg production

The hen day egg production under different management systems are shown in Table 4.4 and the data are graphically presented in Fig 4.8. The perusal of Table 4.4 revealed that hen produced significantly higher number of eggs in battery cage system than deep litter system and semi-intensive system as 58.96, 55.28 and 49.67 per cent, respectively. However, when birds were reared under semi-intensive system the birds produced lower eggs as compared to intensive management system. The results of the present study corroborated with the findings of Sartika *et al.* (2005) who recorded significantly higher hen day egg production under intensive system compared to semi intensive and extensive system. Similar results also were observed by Valavan *et al.* (2012) who recorded hen day production as 50.60±1.52 in Gramapriya under intensive system. Singh *et al.* (2009) also observed higher hen day egg production under cage system (86.70±0.1%) than floor pen (85.0±0.1%) system.

4.2.1.2 Effect of interaction between breed and system on hen day egg production

The data describing the effects of rearing system and hen genotype on egg production characteristics are presented in Table 4.4. Significant effect of rearing systems by genotype interaction (B×S) on hen egg day production was significance (p<0.01) level. This implies that hen genotypes significantly differed in their response to different management procedures. The results presented in Table 4.3 revealed that the average hen day egg production was significantly higher in Gramapriya in battery cage system (64.97%) followed by Gramapriya on deep litter system (61.89%), Srinidhi in battery cage system (61.73%), Vanaraja in battery cage system (60.57%), Srinidhi on deep litter system (58.91%), Gramapriya in semi intensive system (56.72%), Vanaraja on deep litter system (55.55%), Srinidhi in semi intensive system (55.18%), Vanaraja in semi intensive system (52.70%), Desi in battery cage system (48.57%), Desi on deep litter system (44.79%) and Desi in semi intensive system (34.09%). The results of present investigation were close to Matthews and Sumner (2015) who recorded maximum hen day egg production in aviary and enriched housing system as compared to conventional housing system.

4.2.2 Hen egg production per week

4.2.2.1 Effect of breed on weekly egg production per bird

The results of average weekly egg production (per bird) of different breeds are presented in Table 4.5 and graphically drawn in Fig 4.9. Among different breeds, Gramapriya (4.28 no/bird) breed showed significantly (p>0.05) higher weekly egg production that those of three breeds *viz.* Srinidhi (4.08 no/bird), Vanaraja (4.02 no/bird) and Desi (2.96 no/bird). Sameway, other studies on Dahlem Red (4.20 no/bird) support the claim of variation in egg production (Jha *et al.*, 2013$_{a}$). Difference in genotype of all these varieties may be the cause of variation in their egg production as disparity in egg production due to different genetic make-up (Akhtar *et al.,* 2007) or strains (Hanan, 2010) or breed (Ipek and Sahan, 2004) has been clearly illustrated in earlier studies.

4.2.2.2 Effect of management system on weekly egg production per bird

The data of systemwise average weekly egg production per bird (no.) are presented in Table 4.5 and graphically shown Fig 4.10. The results showed significantly ($p>0.005$) higher weekly egg production per bird (no.) in battery cage system (4.14 no/bird) than deep litter system (3.87 no/bird) and semiintensive system (3.50no/bird). Overall means revealed difference ($p<0.05$) in egg production with respect to rearing systems. Corroborating these findings, Krawczyk and Gornowicz (2010) reported better egg production in birds under confinement rearing system than those under free range system. Higher egg production has already been reported in confinement rearing system than free range system (Pavlovski *et al.*, 1992) establishing the positive relationship between confinement rearing system or cage system and egg production (Voslarova *et al.*, 2006). The findings of present experiment were in consonance with Giri and Sahoo (2012) who reported maximum egg production when Gramapriya birds reared under intensive system than extensive system of management. This may be attributed to the balanced diet with better intake in battery cage system as compared with free range rearing system where the birds were on natural scavenging with 25 per cent feed allowance only (Rehman *et al.,* 2016).

4.2.2.3 Effect of interaction between breed and management system on weekly egg production/bird

The average weekly egg production per bird is presented in Table 4.5. The findings of present experiment revealed that interaction of breeds with rearing systems demonstrated significantly higher weekly egg production Gramapriya (4.54 no/bird) in battery cage system followed by Gramapriya on deep litter system (4.32 no/bird), Srinidhi in battery cage system (4.31 no/bird) Vanaraja also in battery cage system (4.30 no/bird), Srinidhi on deep litter system (4.12 no/bird), Gramapriya in semi intensive system (3.96 no/bird), Srinidhi in semi intensive system (3.85 no/bird), Vanaraja in semi intensive system (3.84 no/bird), Desi in battery cage, deep litter, semi intensive (3.39, 3.13 and 2.35 no/bird), respectively. The results showed that all improved poultry breeds produced higher weekly egg production as compared to Desi indigenous breed. Niranjan *et al.* (2008) evaluated the production performance of improved chicken varieties and they recorded higher egg produced by Gramapriya (4.56±0.13 no/bird) as compared to crossbred (4.27±0.43 no/bird) and Vanaraja (2.93±0.18 no/bird) under backyard condition. The higher egg production by Gramapriya may be because of the same exotic female line utilized for developing them (Niranjan *et al.,* 2008). There was significant ($p<0.05$) difference between the values at different overall mean laying stages.

Table 4.5 Average weekly egg production (per bird) of improved indigenous poultry breeds under different management regimes

Treatments/Phases Early laying
(19 - 33 wks.)
Mid laying
(34 - 44 wks.)
Late laying
(45 - 62 wks.)
Avg. weekly egg Prod.
(19 - 62 wks.)

Breeds				
Vanaraja (B$_1$)	3.79^{b}	4.68^{a}	3.60^{b}	**4.02^{bc}**
Gramapriya (B$_2$)	4.19^{a}	4.88^{a}	3.77^{a}	**4.28^{a}**
Srinidhi (B$_3$)	4.09^{a}	4.89^{a}	3.31^{c}	**4.09^{b}**
Desi (B$_4$)	2.97^{c}	4.05^{b}	1.88^{d}	**2.96^{d}**
S.E.	**0.06**	**0.07**	**0.05**	**0.05**
C.D. ($p<0.001$)	**0.19**	**0.21**	**0.16**	**0.18**
Systems				
DLS (M$_1$)	3.75^{b}	4.73^{b}	3.15^{b}	**3.87^{b}**
BCS (M$_2$)	4.05^{a}	4.95^{a}	3.42^{a}	**4.14^{a}**
SIS (M$_3$)	3.47^{c}	4.20^{c}	2.85^{c}	**3.50^{c}**
S.E.	**0.05**	**0.06**	**0.05**	**0.05**
C.D. ($p<0.001$)	**0.17**	**0.18**	**0.14**	**0.16**
Breeds × Systems				
Vanaraja				
DLS	3.41^{c}	4.69^{c}	3.67^{c}	**3.92^{c}**
BCS	4.04^{ab}	4.90^{ab}	3.98^{ab}	**4.30^{ab}**
SIS	3.93^{ab}	4.46^{cd}	3.15^{e}	**3.84^{e}**
Gramapriya				
DLS	4.23^{a}	5.03^{ab}	3.72^{bc}	**4.32^{bc}**
BCS	4.26^{a}	5.26^{a}	4.11^{a}	**4.54^{a}**
SIS	4.07^{ab}	4.34^{cd}	3.49^{dc}	**3.96^{cd}**
Srinidhi				
DLS	4.10^{ab}	4.98^{ab}	3.28^{de}	**4.12^{de}**
BCS	4.13^{ab}	5.23^{a}	3.58^{c}	**4.31^{c}**
SIS	4.03^{ab}	4.45^{cd}	3.07^{e}	**3.85^{e}**
Desi				
DLS	3.25^{c}	4.22^{d}	1.93^{f}	**3.13^{f}**
BCS	3.79^{b}	4.40^{cd}	2.00^{f}	**3.39^{f}**
SIS	1.80^{d}	3.54^{e}	1.71^{f}	**2.35^{f}**
S.E.	**0.11**	**0.12**	**0.09**	**0.10**
C.D. ($p<0.001$)	**0.34**	**0.37**	**0.29**	**0.33**

^{abcdef}Means under each class in the same column with different superscripts differed significantly

4.2.3 Hen egg production per year

4.2.3.1 Effect of breed on annual egg production

Egg productions determine the success of the poultry enterprise. The breedwise data of annual egg production per bird are presented in Table 4.6 and graphically shown in Fig 4.11. The results showed that Gramapriya birds yielded significantly higher egg production (184.33 no/bird) as compared to Srinidhi (174.72 no/bird), Vanaraja (173.13 no/bird) and Desi (122.94 no/bird) breeds. However, the difference in egg between Srinidhi and Vanaraja birds was at par to each other. The finding of experiment were in agreement with Niranjan *et al.* (2008) who recorded significantly differed egg production ($p<0.05$) among the four varieties *viz.* Gramapriya (237.35±3.70) followed by C_1 cross (227.41±4.68), C_2 cross (209.08±4.68) and Vanaraja (149.47±4.46) upto 72 wks. The present estimates were comparable to the reports of Saikia *et al.* (2017) who recorded significant ($p<0.05$) difference between the values at different age in Vanaraja and Desi as 181.12±1.53 and 76.27±0.85no/bird, respectively. Ogbu *et al*. (2015) also recorded significant variation for egg production in different genotypes of layers *viz.* Heavy body weight genotype than Light body weight genotype as 140.06±0.63 and

126.22±2.13 no/bird, respectively. The egg production from 24$_{th}$ week to 40$_{th}$ week (16wks period) of Black Rock, Red Cornish and Vanaraja was 69.00, 57.26 and 71.03, respectively showing significant difference ($p < 0.05$) between Vanaraja and Black Rock observed by Debata *et al.* (2014). However, Singh *et al.* (2018) recorded higher annual egg production in Srinidhi (195 no/bird) as compared to Vanaraja (140 no/bird).The higher production in three crosses breeds may be because of the parental lines utilized in developing the crosses (Niranjan *et al.,* 2008). Difference in genotype of all these varieties may be the cause of variation in their egg production as disparity in egg production due to different genetic make-up (Akhtar *et al.*, 2007) or strains (Hanan, 2010) or breed (Ipek and Sahan, 2004) has been clearly illustrated in earlier studies.

Table 4.6 Annual egg production (per bird) of improved indigenous poultry breeds under different management regimes

Treatments/Phases	Early laying (19 - 33 wks.)	Mid laying (34 - 44 wks.)	Late laying (45 - 62 wks.)	Annual Egg Prod. (19 - 62 wks.)
Breeds				
Vanaraja (B_1)	56.85_{b}	51.48_{a}	64.80_{b}	**173.13_{bc}**
Gramapriya (B_2)	62.85_{a}	53.68_{a}	67.86_{a}	**184.33_{a}**
Srinidhi (B_3)	61.35_{a}	53.79_{a}	59.58_{c}	**174.72_{b}**
Desi (B_4)	44.55_{c}	44.55_{b}	33.84_{d}	**122.94_{d}**
S.E.	**0.90**	**0.77**	**0.90**	**2.57**
C.D. ($p<0.001$)	**2.85**	**2.31**	**2.88**	**8.04**
Systems				
DLS (M_1)	56.25_{b}	52.03_{b}	56.70_{b}	**164.98_{b}**
BCS (M_2)	60.75_{a}	54.45_{a}	61.56_{a}	**176.76_{a}**
SIS (M_3)	52.05_{c}	46.20_{c}	51.30_{c}	**149.55_{c}**
S.E.	**0.75**	**0.66**	**0.90**	**2.31**
C.D. ($p<0.001$)	**2.55**	**1.98**	**2.52**	**7.05**
Breeds × Systems				
Vanaraja				
DLS	51.15_{c}	51.59_{c}	66.06_{c}	**168.80_{c}**
BCS	60.60_{ab}	53.90_{ab}	71.64_{ab}	**186.14_{ab}**
SIS	58.95_{ab}	49.06_{cd}	56.70_{e}	**164.71_{e}**
Gramapriya				
DLS	63.90_{a}	55.33_{ab}	66.96_{bc}	**186.19_{bc}**
BCS	63.93_{a}	57.86_{a}	73.98_{a}	**196.77_{a}**
SIS	61.05_{ab}	47.74_{cd}	62.82_{dc}	**171.61_{cd}**
Srinidhi				
DLS	61.50_{ab}	54.78_{ab}	59.04_{de}	**175.32_{de}**
BCS	61.95_{ab}	57.53_{a}	64.44_{c}	**183.92_{c}**
SIS	60.45_{ab}	48.95_{cd}	55.26_{e}	**164.66_{e}**
Desi				
DLS	48.75_{c}	46.42_{d}	34.74_{f}	**129.91_{f}**
BCS	56.85_{b}	48.40_{cd}	36.00_{f}	**141.25_{f}**
SIS	27.00_{d}	38.94_{e}	30.78_{f}	**96.72_{f}**
S.E.	**1.65**	**1.32**	**1.62**	**4.59**
C.D. ($p<0.001$)	**5.10**	**4.07**	**5.22**	**14.36**

Abcdef Means under each class in the same column with different superscripts differed significantly

4.2.3.2Effect of management system on annual egg production

The results of system wise annual egg production per bird (no/bird) are shown in Table 4.6 and graphically depicted in Fig 4.12. According to rearing pattern, significantly higher numbers of egg were yielded in battery cage system (176.76 no/bird) than deep litter system (164.98 no/bird) and semi intensive system (149.55 no/bird). Overall means revealed difference (p<0.05) in egg production with respect to rearing systems. Higher egg production was observed in birds reared under both battery cage (176.76 no/bird) and deep litter (164.98 no/bird) rearing systems than those reared under semi intensive system (149.55 no/bird). This may be attributed to the balanced diet with better intake in both systems as compared with free range where the birds were on natural scavenging with 25 per cent feed allowance only (Rehman *et al.*, 2016).Corroborating these findings, Krawczyk and Gornowicz (2010) reported higher egg production in birds under control farming than those under free range. Better similar, egg production has already been reported in control farming system than free range (Pavlovski *et al.*, 1992) establishing the positive relationship between control farming or cage system and egg production (Voslarova *et al.*, 2006).

4.2.3.3 Effect of interaction between breed and management system on annually egg production

The overall means of interactions between is breeds × systems revealed difference (p<0.05) in annually egg production per bird is shown in Table 4.6. The results of interaction between rearing systems and breeds demonstrated maximum annually egg production in Gramapriya birds under battery cage system (196.77 no/bird) followed by Gramapriya in deep litter system (186.19 no/bird), Vanaraja in battery cage system (186.14 no/bird), Srinidhi in battery cage system (183.92 no/bird), Srinidhi in deep litter system (175.32 no/bird), Gramapriya in semi intensive system (171..61 no/bird), Vanaraja in semi intensive system (164.71 no/bird), Srinidhi in semi intensive system (164.66 no/bird), Desi in battery cage system (141.25 no/bird), Desi in deep litter system (129.91 no/bird) and Desi in semi intensive system (96.72 no/bird). In this study Gramapriya birds showed that they are suitable in all the three system of management *viz.* battery cage system, deep litter system and semi intensive system. The results of present experiment were in agreement with Patel *et al.* (2013), who found that total number of egg laid in 40 weeks were higher in deep litter than semi intensive and backyard farming. However, The total eggs produced at 40 weeks in present study was lower than the report of Giri and Sahoo (2012), who reported 93.25 eggs in intensive system and 78.0 eggs in extensive system of management. Similar, finding of the current experiment was also recorded by Gerzilov *et al.* (2012). The difference in results might be due to difference in management systems and other environmental factors Patel *et al.* (2013).

4.2.4 Feed conversion efficiency/dozen eggs

4.2.4.1 Effect of breed on the feed conversion efficiency/dozen eggs

The average breedwise feed conversion efficiency values per dozen of eggs during experimental period are illustrated in Table 4.7 and graphically shown in Fig 4.13. It was observed that the feed consumption per dozen of eggs was significantly lower in Gramapriya (2.04) followed by Srinidhi (2.10), Vanaraja (2.47) and Desi (5.10) with significant (p<0.05) difference among all four breed groups. The present findings were in close conformity with findings of Nage (2011) who recorded feed efficiency/dozen eggs as 2.587±0.59, 3.30±1.05 and 3.61±0.78 in Australorp, New Hampshire and Broiler, respectively. The same observations were recorded in other breeds by Galal *et al.* (2007) in Dahlem Red and Bekele *et al.* (2009) in Fayoumi and RIR.

4.2.4.2 Effect of breed on feed efficiency/dozen eggs

The system wise average feed conversion efficiency values per dozen of eggs are illustrated in Table 4.7 and graphically presented in Fig 4.14. The findings showed significantly better feed efficiency/dozen eggs were found in battery cage system (2.31) as compared to deep litter system (2.74) and semiintensive system (3.75). Results of current study were close agreement with Ahmand *et al*. (2010). They recorded the mean FCR values per dozen of eggs in groups A (fluorescent), B (compact fluorescent), and C (incandescent) were 1.22 ± 0.009, 1.21 ± 0.008 and 1.19 ±0.009, respectively. However, Lewis and Morris (1998) observed non-significant difference in the FCR of egg laying birds under different management systems. This contradiction may be due to different sources and intensities of light used in these studies.

4.2.4.3 Effect of interaction between breed and management system on feed conversion efficiency /dozen eggs

The overall average feed conversion efficiency per dozen of eggs during experimental period are illustrated in Table 4.7. From the results showed that feed utilization in Desi birds raised in semi intensive system was significantly inferior (9.67) than Desi breed raised on deep litter system (3.31), Vanaraja on deep litter system (2.92), Desi in battery cage system (2.61), Vanaraja in battery cage system (2.49), Gramapriya in battery cage system (2.45), Srinidhi on deep litter system (2.33), Srinidhi in battery cage system (2.22), Vanaraja in semi intensive system (2.02), Gramapriya in battery cage system (1.98), Srinidhi (1.77) and Gramapriya in semi intensive system (1.70). The interaction effect between breeds and systems on feed conversion efficiency was significant. The results of present study were close comparable with Bharambe and Garud (2012) who recorded feed conversion ratio calculated on the basis of dozen egg produced was significantly different ($p<0.05$) between crossbreds and purebreds. During early laying period purebred utilized their feed more efficiently than the crossbreds. However, during peak laying period crossbreds utilized their feed more efficiently. Similar, results were also recorded by Rao (1977) who observed feed efficiency/dozen of eggs highest in indigenous breeds (2.97 kg) as compared to White Leghorn (2.8 kg) and Rhode Island Red (2.9 kg). The feed conversion efficiency ratio based on per kg egg produced was significantly ($p<0.05$) higher in crossbred during early and peak laying period than the purebred.

Table 4.7 Average feed conversion efficiency/dozen eggs of improved indigenous poultry breeds under different management regimes

Treatments/Phases	**Early laying (19 - 33 wks.)**	**Mid laying (34 - 44 wks.)**	**Late laying (45 - 62 wks.)**	**Avg. FCR/ dozen eggs (19 - 62 wks.)**
Breeds				
Vanaraja(B$_{1}$)	2.49$_{b}$	2.22$_{a}$	2.70$_{b}$	**2.47$_{c}$**
Gramapriya (B$_{2}$)	2.07$_{b}$	1.81$_{c}$	2.24$_{c}$	**2.04$_{a}$**

Srinidhi (B_3)	1.79^{b}	2.01^{b}	2.50^{c}	**2.10^{b}**
Desi(B_4)	8.94^{a}	1.79^{c}	4.83^{a}	**5.10^{d}**
S.E.	**0.47**	**0.06**	**0.11**	**0.21**
C.D. ($p<0.001$)	**1.39**	**0.17**	**0.33**	**0.63**
Systems				
DLS (M_1)	2.75^{b}	2.12^{a}	3.37^{a}	**2.74^{b}**
BCS (M_2)	1.97^{b}	2.12^{a}	2.86^{b}	**2.31^{a}**
SIS (M_3)	6.75^{a}	1.62^{b}	2.98^{b}	**3.75^{c}**
S.E.	**0.41**	**0.05**	**0.10**	**0.18**
C.D. ($p<0.001$)	**1.20**	**0.15**	**0.29**	**0.54**
Breeds × Systems				
Vanaraja				
DLS	3.21^{b}	2.44^{ab}	3.09^{c}	**2.91^{c}**
BCS	2.46^{b}	2.56^{a}	2.42^{de}	**2.48^{b}**
SIS	1.81^{b}	1.65^{fgh}	2.58^{cd}	**2.01^{b}**
Gramapriya				
DLS	2.82^{b}	1.89^{def}	2.62^{cd}	**2.44^{b}**
BCS	1.95^{b}	1.73^{efgh}	2.25^{de}	**1.97^{b}**
SIS	1.43^{b}	1.81^{efg}	1.86^{e}	**1.7^{e}**
Srinidhi				
DLS	2.10^{b}	2.15^{bcd}	2.73^{cd}	**2.32^{b}**
BCS	1.92^{b}	2.30^{abc}	2.43^{de}	**2.21^{cd}**
SIS	1.36^{b}	1.58^{hg}	2.34^{de}	**1.76^{e}**
Desi				
DLS	2.86^{b}	2.01^{cde}	5.03^{a}	**3.30^{b}**
BCS	1.57^{b}	1.90^{def}	4.34^{b}	**2.60^{c}**
SIS	22.40^{a}	1.47^{h}	5.13^{a}	**9.66^{a}**
S.E.	**0.82**	**0.10**	**0.20**	**0.37**
C.D. ($p<0.001$)	**2.41**	**0.30**	**0.58**	**1.09**

^{abcdefg}Means under each class in the same column with different superscripts differed significantly

4.2.5 Feed conversion efficiency/Kg eggs

4.2.5.1 Effect of breed on the feed conversion efficiency/Kg eggs

The average feed conversion efficiency values per kg eggs of different breeds during experimental period are illustrated in Table 4.8 and graphically shown in Fig 4.15. It was observed that the feed utilization per kg egg was superior in Gramapriya (3.01) followed by Srinidhi (3.15), Vanaraja (3.28) and Desi (4.79) with significant ($p<0.05$) differences. The present findings were in close conformity with findings of Kamil *et al.* (2012) who recorded superior feed efficiency/kg eggs for white chicken bird (1.871) than brown chicken bird (2.232).

4.2.5.2 Effect of management system on the feed efficiency/Kg eggs

The average feed conversion efficiency per kg eggs produced by different breeds during experimental period are illustrated in Table 4.8 and graphically depicted in Fig 4.16. It was observed that the feed consumption per kg eggs was superior in semi intensive system followed by battery cage system and deep litter system as 3.35, 3.39 and 3.93 with significant ($p<0.05$) difference among all four breed groups. The present findings were agreement with Kamil *et al.* (2012) who recorded better feed conversion efficiency/kg eggs under conventional rearing system as compared to organic rearing system.

4.2.5.3 Effect of interaction between breed and management system on feed conversion efficiency/Kg eggs

The overall average feed conversion efficiency per dozen of eggs during experimental period are illustrated in Table 4.8. The results showed that feed utilization for production of per kg eggs by Gramapriya birds raised in semi intensive system was superior (2.54) followed by Srinidhi raised in semi intensive system (2.79), Vanaraja in semi intensive system (2.92), Gramapriya in battery cage system (3.02), Srinidhi in battery cage system (3.16), Vanaraja in battery cage system (3.29), Gramapriya on deep litter system (3.47), Srinidhi on deep litter system (3.49), Vanaraja on deep litter system (3.72),

Table 4.8 Average feed conversion efficiency/Kg egg of improved indigenous poultry breeds under different management regimes

Treatments/Phases	**Early laying (19-33 wks.)**	**Mid laying (34- 44 wks.)**	**Late laying (45 - 62 wks.)**	**Avg. FCR/Kg Eggs (19 - 62 wks.)**
Breeds				
Vanaraja (B_1)	3.86^{b}	2.63^{bc}	3.56^{b}	**3.28^{b}**
Gramapriya (B_2)	3.47^{c}	2.77^{b}	3.56^{c}	**3.01^{c}**
Srinidhi (B_3)	3.63^{bc}	2.48^{c}	3.67^{b}	**3.15^{bc}**
Desi (B_4)	5.69^{a}	3.20^{a}	6.50^{a}	**4.79^{a}**
S.E.	**0.11**	**0.06**	**0.10**	**0.06**
C.D. ($p<0.001$)	**0.33**	**0.20**	**0.30**	**0.19**
Systems				
DLS (M_1)	4.76^{a}	2.98^{a}	4.51^{a}	**3.93^{a}**
BCS (M_2)	3.72^{b}	2.77^{b}	4.05^{b}	**3.39^{b}**
SIS (M_3)	4.00^{b}	2.56^{c}	3.95^{c}	**3.35^{c}**
S.E.	**0.09**	**0.06**	**0.09**	**0.05**
C.D. ($p<0.001$)	**0.29**	**0.17**	**0.26**	**0.17**
Breeds × Systems				
Vanaraja				
DLS	4.76^{c}	2.86^{bc}	3.89^{cd}	**3.72^{c}**
BCS	3.95^{def}	2.65^{cde}	3.49^{def}	**3.29^{de}**
SIS	2.87^{h}	2.37^{de}	3.31^{efg}	**2.83^{fgh}**
Gramapriya				
DLS	4.11^{d}	3.06^{ab}	3.41^{defg}	**3.47^{cd}**
BCS	3.37^{fgh}	2.84^{bc}	2.96^{gh}	**3.02^{efg}**
SIS	2.92^{h}	2.42^{de}	2.48^{h}	**2.54^{h}**
Srinidhi				
DLS	4.22^{cd}	2.70^{dc}	4.05^{c}	**3.49^{cd}**
BCS	3.52^{efg}	2.43^{de}	3.79^{cde}	**3.16^{def}**
SIS	3.16^{gh}	2.33^{e}	3.17^{fg}	**2.79^{gh}**
Desi				
DLS	5.97^{b}	3.32^{a}	6.71^{a}	**5.02^{a}**
BCS	4.05^{de}	3.16^{ab}	5.95^{b}	**4.11^{b}**
SIS	7.05^{a}	3.12^{ab}	6.84^{a}	**5.24^{a}**
S.E.	**0.19**	**0.11**	**0.17**	**0.11**

C.D. (p<0.001) 0.58 0.35 0.52 0.34

[abcdefg]Means under each class in the same column with different superscripts differed significantly Desi breed in battery cage system (4.11), Desi on deep litter system (5.02) and Desi in semi intensive system (5.24). The interaction effect between breeds and systems was significant ($p<0.05$) on feed efficiency. The results of present experiment were close to Kamil *et al.* (2012). They recorded feed efficiency/kg eggs significantly ($p<0.05$) different between rearing system and breeds. This determination is consistent with reports from Lampkin (1997) and Castellini *et al.* (2002) who reported that laying hen raised in organic system had higher feed efficiency. Also, these results were parallel with those of Mugani *et al.* (2009).

4.3 Egg quality parameters

4.3.1 External egg quality parameters

4.3.1.1 Egg weight (g)

Egg weight is the most important physical characteristic of hen’s eggs perceived by the consumer. It is also the basic quality characteristic included in egg marketing regulations, which classify eggs into four weight categories (Commission Regulation (EC) No 589/2008). For the reasons stated above, egg weight is the essential selection trait in layer breeding and one of the most important trait in the breeding of general-purpose hens. The observations on egg weight of the different poultry ecotypes are given in Table 4.9.

4.3.1.1.1 Effect of breed on the egg weight

The data of average egg weight of different breeds are presented in Table 4.9 and graphically depicted in Fig. 4.17. Egg weight showed significant difference between the breeds ($p<0.01$). In present experiment average egg weight was recorded as 58.16 g for Gramapriya, 58.01 g for Vanaraja, 56.94 g for Srinidhi and 49.34 g for Desi. These egg weights were lower than the 64.35 and 61.46 g reported by Rayan *et al.* (2013) for Brown and W-36 strains. In present study lowest egg weight was produced by Desi. The results were in agreement for Desi with Hussain *et al.* (2013) who recorded that the indigenous eggs are mostly small in size with less weight when compared with other types of chicken eggs. Other pervious scientists recorded significant effect of genotype on egg weight (Bonekamp *et al.*, 2010 and Haunshi *et al.*, 2011). Choudhuri *et al.* (2016) also recorded similar finding. They observed that egg weight of Nicorock (56.79±0.77 g) was significantly ($p<0.05$) higher in comparison to Nicobari (53.20±0.34) and Nishibari (48.98±0.22). Significant genetic variation for egg weight in different breeds/genetic groups was reported by other workers (Washburn, 1990; Padhi *et al.*, 1998 and Chatterjee *et al.*, 2005). This might be due to the utilization of exotic germplasm for the development of these cross varieties (Sharma and Chatterjee 2006). Islam *et al.* (2001) reported significant differences in egg weight of indigenous Naked Neck and indigenous full feathered birds which were consistent with the results of the present study.

4.3.1.1.2 Effect of management system on the egg weight

The results obtained in respect of effect of systems on the egg weight (g) are presented in Table 4.9. The data are shown graphically in Fig. 4.18. From the Table 4.9, significantly higher egg weight was recorded in battery cage system than deep litter system and semi intensive system as 56.56, 55.97 and 54.26 g, respectively. There was a significant ($p<0.01$) influence of management system on egg weight of birds. These findings were close agreement with Lewko and Gornowicz (2011). They recorded heaviest eggs (61.06 g) in caged system.Voslarova *et al.* (2006) found that markedly heavier eggs were produced by caged layers (53.40 g). Using the same study material, Dukic-Stojcic *et al.* (2009) compared the quality of eggs from caged layers and those from restricted and free-range layers and found that heavier eggs (66.74 g) were laid by caged hens. However, the present findings did not agreed with Singh *et al.* (2009), Ojedapo, (2013) and Ogbu *et al.* (2015) who recorded higher egg weight in the deep litter system than cage system.

4.3.1.1.3 Effect of interaction between breed and management system on egg weight

Data of the effect of interactions between breeds and systems on egg weight are presented in Table 4.9. There were significant differences for ecotypes when reared in different housing systems. It could be seen from the Table 4.9,

Table 4.9 Average egg weight (g) of improved indigenous poultry breeds under different management regimes

Treatments/Phases	**Early laying (19-33 wks.)**	**Mid laying (34- 44 wks.)**	**Late laying (45 - 62 wks.)**	**Avg. Egg weight (19 - 62 wks.)**
Breeds				
Vanaraja (B_1)	52.04^{a}	59.09^{a}	61.39^{a}	**58.01^{a}**
Gramapriya (B_2)	52.82^{a}	59.88^{a}	60.46^{b}	**58.16^{a}**
Srinidhi (B_3)	51.96^{a}	57.25^{b}	60.35^{b}	**56.94^{b}**
Desi (B_4)	43.53^{b}	49.84^{c}	53.19^{c}	**49.34^{c}**
S.E.	**0.424**	**0.426**	**0.293**	**0.218**
C.D. ($p<0.001$)	**1.1911**	**1.196**	**0.825**	**0.6143**
Systems				
DLS (M_1)	50.28^{b}	57. 340^{a}	58.88^{a}	**55.97^{b}**
BCS (M_2)	51.81^{a}	57.595^{a}	59.18^{a}	**56.56^{a}**
SIS (M_3)	48.17^{c}	54.611^{b}	58.49^{a}	**54.26^{c}**
S.E.	**0.367**	**0.368**	**0.293**	**0.189**
C.D. ($p<0.001$)	**1.031**	**1.035**	**0.825**	**0.532**
Breeds × Systems				
Vanaraja				
DLS	52.19^{bcd}	60.02^{ab}	61.13^{a}	**58.28^{ab}**
BCS	52.54^{bc}	61. 03^{a}	61.54^{a}	**58.89^{a}**
SIS	51.39^{cde}	56.24^{d}	61.54^{a}	**56.84^{cd}**
Gramapriya				
DLS	53.68^{ab}	59.87^{ab}	58.11^{b}	**57.54^{bc}**
BCS	54.06^{ab}	58.78^{bc}	61.78^{a}	**58.57^{ab}**
SIS	50.72^{cde}	60.99^{a}	61.51^{a}	**58.37^{ab}**
Srinidhi				
DLS	50.06^{e}	57.07^{cd}	61.15^{a}	**56.02^{d}**
BCS	55.67^{a}	59.68^{ab}	58.48^{b}	**58.14^{ab}**
SIS	50.16^{de}	55.03^{d}	61.43^{a}	**56.63^{cd}**
Desi				
DLS	45.21^{f}	52.45^{e}	55.13^{c}	**51.44^{e}**
BCS	44.99^{f}	50.91^{e}	54.96^{c}	**50.76^{e}**
SIS	40.39^{g}	46.19^{f}	49.49^{c}	**45.81^{f}**

S.E.	**0.608**	**0.610**	**0.440**	**0.313**
C.D. (p<0.001)	**1.70**	**1.713**	**1.237**	**0.880**

^{abcdefg}Means under each class in the same column with different superscripts differed significantly that the highest egg weight was obtained by Vanaraja birds (58.89 g) reared in battery cage system followed by Gramapriya in battery cage system (58.57 g), Gramapriya in semi intensive system (58.37 g), Vanaraja on deep litter system (58.28 g), Srinidhi in battery cage system (58.14 g), Gramapriya in deep litter system (57.54 g), Vanaraja on deep litter system (56.84 g), Srinidhi in semi intensive system (56.63 g), Srinidhi on deep litter system (56.02 g) and Desi in three systems i.e. deep litter, battery cage and semi intensive as 51.44, 50.76 and 45.81g, respectively. These results were agreed with Kucukymaz *et al.* (2012) who observed significant effect of rearing system ($p<0.05$) and interactions of breed and housing significantly affected egg weight. In accordance with the findings Clerici *et al.* (2006) reported that an organic rearing system led to an increase in egg weight as compared to the conventional system ($p<0.01$). Eggs from white laying hens were heavier than those of brown layer hens ($p<0.01$) from both rearing systems. In contrast to present findings, Mugnai *et al.* (2009) showed that the rearing system did not significantly affected egg weight.

4.3.1.2 Egg length

4.3.1.2.1 Effect of breed on the egg length

The results of the breedwise egg length (mm) are presented in Table 4.10 and graphically depicted in Fig. 4.19. According to breeds, there were nonsignificant differences for egg length. The average maximum egg length was recorded for Gramapriya followed by Vanaraja, Srinidhi and Desi as 59.56, 57.19, 56.50 and 54.05 mm, respectively. The results of experiment were comparable with Bekele *et al.* (2009) who recorded non-significant difference among egg length for Fayoumi (F) × Naked neck (N) and Rhode Island Red (R) × Local Netch (W) as 51.7±0.3 and 52.7±0.7 cm, respectively. However, Kumar *et al.* (2014) recorded significantly higher length of egg for RIR as 5.65±0.17 cm as compared to Bovans White as 4.38±0.11 cm. Singh *et al*. (2010) also revealed significant differences in egg length for RIR (5.41±0.01 cm) than WLH (5.58±0.02 cm).

Table 4.10 Average egg length (mm) of improved indigenous poultry breeds under different management regimes

Treatments/Phases	Early laying (19-33 wks.)	Mid laying (34- 44 wks.)	Late laying (45 - 62 wks.)	Avg. Egg Length (19 - 62 wks.)
Breeds				
Vanaraja (B_1)	54.87^{a}	57.87^{a}	58.25^{a}	**57.19^{a}**
Gramapriya (B_2)	59.06^{a}	58.06^{a}	57.94^{a}	**59.56^{a}**
Srinidhi (B_3)	54.61^{a}	56.62^{b}	57.79^{a}	**56.50^{a}**
Desi (B_4)	51.80^{a}	53.45^{c}	56.35^{b}	**54.05^{a}**
S.E.	**0.250**	**0.225**	**0.289**	**0.255**
C.D. (p<0.001)	**0.703**	**0.633**	**0.812**	**0.716**
Systems				
DLS (M_1)	54.51^{a}	56.13^{b}	57.90^{a}	**56.14^{a}**
BCS (M_2)	54.81^{a}	53.45^{a}	57.43^{a}	**56.55^{a}**

SIS (M_3) 53.81^{a} 56.39^{b} 57.42^{a} **77.29^{a}**
S.E. 0.225 0.195 0.250 0.223
C.D. ($p<0.001$) 0.633 0.548 0.703 0.628
Breeds × Systems
Vanaraja
DLS 54.39^{b} 57.42^{bcd} 58.53^{ab} **56.99^{b}**
BCS 55.48^{b} 58.98^{a} 58.08^{ab} **57.70^{b}**
SIS 54.72^{b} 57.20^{cd} 58.15^{ab} **56.86^{b}**
Gramapriya
DLS 55.12^{b} 57.75^{bcd} 56.38^{cd} **57.60^{b}**
BCS 55.35^{b} 58.44^{ab} 58.47^{ab} **61.54^{a}**
SIS 66.72^{a} 57.97^{abc} 58.98^{a} **56.53^{b}**
Srinidhi
DLS 54.28^{b} 55.99^{e} 58.89^{a} **56.58^{b}**
BCS 55.78^{b} 57.19^{cd} 55.67^{d} **56.25^{b}**
SIS 53.77^{b} 56.67^{de} 58.81^{ab} **56.66^{b}**
Desi
DLS 51.45^{b} 53.35^{f} 57.80^{ab} **54.45^{b}**
BCS 52.63^{b} 53.27^{f} 57.46^{bc} **54.62^{b}**
SIS 51.34^{b} 53.71^{f} 53.77^{e} **53.08^{b}**
S.E. 0.363 0.323 0.414 0.367
C.D. ($p<0.001$) 1.020 0.907 1.1642 1.030
^{abcdefg}Means under each class in the same column with different superscripts differed significantly

4.3.1.2.2 Effect of management system on the egg length

The results of the systemwise egg length (mm) are presented in Table 4.10 and graphically depicted in Fig**.** 4.20. The results revealed highest egg length in battery cage system (56.55 mm) followed by deep litter system (56.14 mm) and semi intensive system (47.29).These results were comparable with Raji *et al.* (2009). They recorded non-significant differences between eggs length when stored at different room temperatures.

4.3.1.2.3 Effect of interaction between breeds and management systems on egg length

The data of interaction between breeds and systems on egg length (mm) are presented in Table 4.9. The results revealed highest egg length for Gramapriya in battery cage system (61.54 mm) followed by Vanaraja in battery cage system (57.70 mm), Gramapriya on deep litter system (57.60 mm), Vanaraja on deep litter system (56.99 mm), Vanaraja in semi intensive system (56.86 mm) Srinidhi in semi intensive system (56.66 mm), Srinidhi on deep litter system (56.58 mm), Gramapriya in semi intensive system (56.53 mm), Srinidhi in battery cage system (56.25 mm), Desi in battery cage system (54.62 mm), Desi on deep litter system (54.45 mm) and Desi in semi intensive system (53.08 mm). The egg length did not showed significant difference (Table 4.10) due to management regimes. Similarly, non-significant differences were observed of egg lengths between three genotypes of naked-neck chicken under tropical climate from India (Rajkumar *et al.*, 2009) under intensive system. The results of present experiment were in agreement with Choudhuri *et al.* (2016). They recorded that under intensive system, egg length of Nicorock (56.94±0.79 mm) was found significantly ($p<0.05$) higher in comparison to Nicobari (55.71±0.08 mm) and Nishibari (56.94±0.79 mm) as compared to backyard system as Nicorock (54.59±0.48mm), Nishibari (52.01±0.77 mm) and Nicobari (51.38±0.69 mm).

4.3.1.3 Egg width

4.3.1.3.1 Effect of breed on the egg width

The results obtained in respect of effect of breeds on egg width (mm) are presented in Table 4.11 and graphically shown in Fig. 4.21. The result of present experiment revealed highest egg width as 33.27 mm for Srinidhi followed by Vanaraja (33.26 mm), Gramapriya (33.12 mm) and Desi (31.52 mm). However, there were non-significant differences in egg widths between Srinidhi, Vanaraja and Gramapriya. Similarly, non-significant differences were observed between egg widths of three genotypes of naked-neck chicken under tropical climate of India (Rajkummar *et al.,* 2009). However, Bekele *et al.* (2009) recorded significant differences between egg width of two poultry genotypes *i.e.* Fayoumi (F) and Rhode Island Red (R) as 38.6±0.2 and 43.4±0.2 mm, respectively.

4.3.1.3.2 Effect of management system on the egg width

The data obtained with regards of effect of breed on the egg width (mm) are presented in Table 4.11 and graphically shown in Fig.4.22.There was significant ($p<0.05$) effect of housing types on egg width. The significantly higher egg width was recorded in battery cage system than deep litter system and semi intensive system as 33.11, 32.85 and 32.43 mm, respectively. The present findings were in agreement with Rath *et al.* (2015) they recorded egg width (mm) as 39.92±0.07 for White Leghorns under intensive system. However, Ojedapo (2013), recorded higher egg breadth as 3.59±0.10 cm for deep litter housing type over its counterpart in cage housing system. While, Tumora *et al.* (2011) disagreed for egg widths that were reported to be favoured in deep litter housing. Therefore, no significant differences were noticed between these housing systems.

4.3.1.3.3 Effect of interaction between breeds and management systems on egg width

The results of interaction between breeds and systems on egg width (mm) are presented in Table 4.11. The findings of present investigation showed highest egg width for Gramapriya (33.54 mm) for battery cage system followed by Srinidhi in battery cage system (33.48 mm), Vanaraja in battery cage system (33.39 mm), Vanaraja on deep litter system (33.38 mm), Srinidhi in semi intensive system (33.21 mm), Srinidhi on deep litter system (33.13 mm), Vanaraja in semi intensive system (33.02 mm), Gramapriya on deep litter system (32.97 mm), Gramapriya in semi intensive system (32.84 mm), Desi in battery cage system (32.01 mm), Desi on deep litter system (31.89 mm) and Desi in semi intensive system (30.66g mm) management system. Present results were comparable with Rath *et al.* (2015) who recorded egg width (mm) as 39.92±0.07 for White Leghorns under intensive system. However, significantly higher egg width was found in Naked-neck genotype as compared with the normal feathered Nigerian indigenous chickens in cage system (Yakubu *et al.,* 2007). A comparison of heavy and light ecotypes of Nigerian local chickens and their F_1 crosses also revealed significant difference in egg width (Momoh *et al.,* 2010). Significantly higher values of egg width had been found in Naked-neck genotype as compared with the normal feathered Nigerian indigenous chickens (Yakubu *etal.,* 2007).

4.3.1.4 Egg shape index

4.3.1.4.1 Effect of breed on the egg shape index

The data of the egg shape index of different chicken are shown in Table 4.12 and graphically given in Fig.4.23. The egg shape index showed significant difference among four poultry breeds. The higher ($p<0.01$) shape index was 58.80 of Vanaraja and lower ($p<0.01$) was observed in Gramapriya (57.97). Shape Index was 58.54 for Srinidhi and 58.34 for Desi (Fig. 4.23). This may be due to different genotypes of poultry breeds. However, higher egg shape index was observed by Rayan *et al.* (2013) as 75.99 and 74.34 for Brown and W-36 chickens.

Table 4.11 Average egg width (mm) of improved indigenous poultry breeds under different management regimes

Treatments/Phases	Early laying (19-33 wks.)	Mid laying (34- 44 wks.)	Late laying (45 - 62 wks.)	Avg. Egg Length (19 - 62 wks.)
Breeds				
Vanaraja (B_1)	32.64^{a}	33.21^{b}	33.78^{b}	**33.26^{a}**
Gramapriya (B_2)	32.26^{a}	33.56^{a}	33.30^{c}	**33.12^{a}**
Srinidhi (B_3)	32.27^{a}	33.01^{b}	34.29^{a}	**33.27^{a}**
Desi (B_4)	30.12^{b}	31.46^{c}	32.63^{d}	**31.52^{b}**
S.E.	**0.168**	**0.117**	**0.129**	**0.076**
C.D. ($p<0.001$)	**0.472**	**0.330**	**0.363**	**0.214**
Systems				
DLS (M_1)	31.77^{ab}	32.96^{a}	33.53^{b}	**32.85^{b}**
BCS (M_2)	32.10^{a}	33.11^{a}	33.86^{a}	**33.11^{a}**
SIS (M_3)	31.59^{b}	32.38^{b}	33.10^{c}	**32.43^{c}**
S.E.	**0.145**	**0.102**	**0.112**	**0.066**
C.D. ($p<0.001$)	**0.409**	**0.286**	**0.315**	**0.186**
Breeds × Systems				
Vanaraja				
DLS	32.82^{ab}	33.32^{abc}	33.87^{bc}	**33.38^{abc}**
BCS	32.38^{abc}	33.46^{ab}	34.09^{ab}	**33.39^{ab}**
SIS	32.72^{ab}	32.88^{c}	33.38^{cd}	**33.02^{cde}**
Gramapriya				
DLS	32.02^{bc}	33.38^{abc}	33.26^{cd}	**32.97^{de}**
BCS	33.01^{a}	33.63^{a}	33.86^{bc}	**33.54^{a}**
SIS	31.75^{c}	33.69^{a}	32.79^{de}	**32.84^{e}**
Srinidhi				
DLS	31.61^{c}	32.85^{c}	34.11^{ab}	**33.13^{bcde}**
BCS	33.03^{a}	33.20^{abc}	34.54^{a}	**33.48^{ab}**
SIS	32.18^{bc}	32.97^{bc}	34.23^{ab}	**33.21^{abcd}**
Desi				
DLS	30.62^{d}	32.27^{d}	32.47^{ef}	**31.89^{f}**
BCS	30.01^{de}	32.14^{d}	33.39^{cd}	**32.01^{f}**
SIS	29.73^{e}	29.99^{e}	32.02^{f}	**30.66^{g}**
S.E.	**0.241**	**0.168**	**0.185**	**0.109**
C.D. ($p<0.001$)	**0.677**	**0.473**	**0.520**	**0.307**

^{abcdefg}Means under each class in the same column with different superscripts differed significantly

4.3.1.4.2 Effect of management system on the egg shape index

The data of the egg shape index according to rearing systems are shown in Table 4.12 and graphically depicted in Fig. 4.24. The average egg shape index was significantly higher in deep litter system and battery cage system than semi intensive system as 58.70, 58.52 and 58.00, respectively. The present findings were in close conformity with those reported by Kumar *et al.* (2018) as 74.975±217, 73.967±0.08 and 72.792±0.107 in intensive, extensive and semi intensive system, respectively. Similar, findings were recorded by Padhi *et al.* (2014$_a$) as 74.57±1.68 74.88±0.57 75.73±0.64 73.89±0.71 74.66±0.57 on 32, 40, 52, 64 and 72 wks of age under intensive system. Dorji and Phurba (2014) also recorded parallel finding for Red Jungle fowl-like, Phulom Frizzle, Yuebjha Narp (Black-feathered), Khuilay (Naked neck), Hyline Brown and Bhutanese indigenous chicken as 74.45±3.37, 75.82±4.64, 72.78±3.46, 74.50±2.98 and 76.68±2.07, respectively under intensive system of management.

4.3.1.4.3 Effect of interaction between breeds and systems on egg shape index

The average length, width of eggs and shape index was calculated and tabulated in Table 4.12. The perusal of Table 4.12, indicated that interactions between breeds and systems on egg shape index significantly highest for Desi in battery cage system and deep litter system as 59.45 and 59.30 followed by Srinidhi in deep litter system and battery cage system (58.81 and 58.72), Vanaraja in semi intensive system and deep litter system (58.66 and 58.61), Gramapriya in battery cage system and deep litter system (58.19 and 58.09), Srinidhi in semi intensive system (58.08), Vanaraja in battery cage system (57.72), Desi in semi intensive system (57.67) and Gramapriya in semi intensive system (57.60). The egg shape index values estimated in the present experiment were lower than those reported by Hussain *et al.* (2013) as 81.20 ± 0.85, 80.21 ± 0.98 and 80.40 ± 1.19 for different sources of eggs.

Table 4.12 Average egg shape index (ESI) of improved indigenous poultry breeds under different management regimes

Treatments/Phases	**Early laying (19-33 wks.)**	**Mid laying (34- 44 wks.)**	**Late laying (45 - 62 wks.)**	**Avg. ESI (19 - 62 wks.)**
Breeds				
Vanaraja (B_1)	59.56_{a}	57.45_{c}	58.28_{ab}	**58.34_{b}**
Gramapriya (B_2)	58.78_{ab}	57.88_{bc}	57.44_{b}	**57.97_{b}**
Srinidhi (B_3)	59.11_{ab}	58.38_{ab}	58.27_{ab}	**58.80_{a}**
Desi (B_4)	58.31_{b}	58.99_{a}	58.98_{a}	**58.54_{a}**
S.E.	**0.351**	**0.281**	**0.388**	**0.194**
C.D. (p<0.001)	**0.986**	**0.791**	**1.089**	**0.545**
Systems				
DLS (M_1)	59.11_{a}	58.82_{a}	58.28_{ab}	**58.70_{a}**
BCS (M_2)	58.65_{a}	58.25_{a}	58.70_{a}	**58.52_{a}**
SIS (M_3)	59.06_{a}	57.46_{b}	57.758_{b}	**58.00_{b}**
S.E.	**0.304**	**0.244**	**0.336**	**0.168**
C.D. (p<0.001)	**0.854**	**0.685**	**0.943**	**0.471**
Breeds × Systems				

Vanaraja				
DLS	60.39^{a}	58.07^{bc}	57.78^{bcd}	**58.61^{abc}**
BCS	58.43^{bcde}	56.77^{cd}	58.16^{bcd}	**57.72^{cd}**
SIS	59.87^{ab}	57.52^{bc}	58.93^{ab}	**58.66^{ab}**
Gramapriya				
DLS	58.15^{cde}	57.85^{bc}	58.31^{abc}	**58.09^{bcd}.**
BCS	59.72^{abcd}	57.62^{bc}	57.64^{bcd}	**58.19^{bcd}**
SIS	58.50^{bcde}	58.16^{b}	56.38^{d}	**57.60^{d}**
Srinidhi				
DLS	58.27^{bcde}	58.75^{b}	59.29^{ab}	**58.81^{ab}**
BCS	59.25^{abcd}	58.10^{bc}	58.97^{ab}	**58.72^{ab}**
SIS	59.83^{abc}	58.29^{b}	56.58^{cd}	**58.08^{bcd}**
Desi				
DLS	59.65^{abcd}	60.57^{a}	57.76^{bcd}	**59.30^{a}**
BCS	57.25^{e}	60.52^{a}	60.05^{a}	**59.45^{a}**
SIS	58.04^{de}	55.89^{d}	59.15^{ab}	**57.67^{cd}**
S.E.	**0.503**	**0.404**	**0.556**	**0.278**
C.D. ($p<0.001$)	**1.413**	**1.134**	**1.561**	**0.780**

^{abcdefg}Means under each class in the same column with different superscripts differed significantly

4.3.1.5 Egg shell weight

4.3.1.5.1 Effect of breed on egg shell weight

The results of the egg shell weight (g) as breeds wise are shown in Table 4.13 and graphically presented in Fig.4.25. The egg shell weights were significantly higher ($p<0.01$) for Gramapriya (5.215 g) and Vanaraja (5.178g) than Srinidhi (5.019g), Desi (4.769 g). The results of present experiment were in agreement with Rayan *et al.* (2013) who reported that the egg shell weight was significantly affected by strain. The brown hens had significantly heavier (5.71 g) shell weight compared to the white ones (5.34 g). However, Chatterjee *et al.* (2007) reported the non-significant breed difference in shell weight for six indigenous chicken breeds from Andamans. The egg shell weighed in present experiment was higher than those reported for eggs laid by native hen of Indian (Rajkumar *et al.* 2009), Bangla Desis (Islam and Dutta 2010), Iraqi (Al-Rubaiee 2012) and Nigerian (Isidahomen *et al.* 2013). However, heavier than Libyan (El- Safty 2012). On the other hand, comparable values were reported in free rangelocal hen’s egg of Tanzania (Nonga *et al.* 2010).

4.3.1.5.2 Effect of management system on the egg shell weight (g)

The results of egg shell weight (g) according to rearing systems are given in Table 4.13 and graphically shown in Fig. 4.26. The average egg shell weight was significantly higher in battery cage system (5.106 g) as compared to deep litter system (5.055 g) and semi intensive system (4.975 g). The present findings were in close conformity with those reported by Ogunwole *et al.* (2015) as egg shell weight significantly higher in battery cage system as 5.89 g as compared to deep litter system (5.58 g). Similar finding was also reported by Choudhuri *et al.* (2016). They recorded higher egg shell weight for Nicobari, Nicorock and Nishibari as 6.38±0.41, 6.01±0.10 and 6.41±0.21 g in intensive system as compared to same genotypes as 4.74±0.25, 5.59±0.20, 5.25±0.50 g under backyard condition, respectively. However, present findings disagreed with Ojedapo (2013) who reported significantly higher shell weight in deep litter system (7.36±0.28 g) as compared to battery cage system (6.83 ± 0.21g).

Table 4.13 Average egg shell weight (g) of improved indigenous poultry breeds under different management regimes

Treatments/Phases	**Early laying (19-33 wks.)**	**Mid laying (34- 44 wks.)**	**Late laying (45 - 62 wks.)**	**Avg. Shell wt. (19 - 62 wks.)**
Breeds				
Vanaraja (B_1)	4.952^{a}	5.367^{a}	5.158^{a}	**5.178^{a}**
Gramapriya (B_2)	5.087^{a}	5.481^{a}	5.045^{a}	**5.215^{a}**
Srinidhi (B_3)	4.662^{b}	5.174^{b}	5.133^{a}	**5.019^{b}**
Desi (B_4)	4.213^{c}	4.899^{c}	5.057^{a}	**4.769^{c}**
S.E.	**0.054**	**0.051**	**0.046**	**0.026**
C.D. ($p<0.001$)	**0.152**	**0.143**	**0.131**	**0.075**
Systems				
DLS (M_1)	4.750^{a}	5.254^{a}	5.084^{a}	**5.055^{a}**
BCS (M_2)	4.758^{a}	5.343^{a}	5.130^{a}	**5.106^{a}**
SIS (M_3)	4.677^{a}	5.094^{b}	5.081^{a}	**4.975^{b}**
S.E.	**0.046**	**0.044**	**0.040**	**0.023**
C.D. ($p<0.001$)	**0.131**	**0.124**	**0.113**	**0.065**
Breeds × Systems				
Vanaraja				
DLS	4.920^{b}	5.268^{bc}	5.204^{a}	**5.150^{b}**
BCS	4.963^{ab}	5.422^{ab}	5.104^{ab}	**5.181^{ab}**
SIS	4.972^{ab}	5.411^{ab}	5.165^{ab}	**5.202^{ab}**
Gramapriya				
DLS	5.217^{a}	5.434^{ab}	4.774^{dc}	**5.134^{bc}**
BCS	5.191^{a}	5.495^{ab}	5.191^{a}	**5.301^{a}**
SIS	4.852^{b}	5.515^{ab}	5.169^{ab}	**5.208^{ab}**
Srinidhi				
DLS	4.406^{c}	5.281^{abc}	5.178^{ab}	**5.005^{cd}**
BCS	4.791^{b}	5.519^{a}	4.959^{bc}	**5.117^{bc}**
SIS	4.789^{b}	4.721^{e}	5.262^{a}	**4.936^{de}**
Desi				
DLS	4.457^{c}	5.035^{cd}	5.178^{ab}	**4.929^{de}**
BCS	4.088^{d}	4.934^{de}	5.266^{a}	**4.824^{e}**
SIS	4.095^{d}	4.728^{e}	4.728^{d}	**4.555^{f}**
S.E.	**0.077**	**0.073**	**0.066**	**0.038**
C.D. ($p<0.001$)	**0.218**	**0.205**	**0.187**	**0.108**

^{abcdefg}Means under each class in the same column with different superscripts differed significantly

4.3.1.5.3 Effect of interaction between breeds and systems on shell weight

The results of interaction between breeds and systems on average egg shell weight (g) are presented in Table 4.13. The perusal to data indicated that interactions between breeds and systems on egg shell weight was highest for Gramapriya in battery cage system (5.301 g) followed by Gramapriya in semi intensive system (5.208 g), Vanaraja in semi intensive system, battery cage system and deep litter system (5.202, 5.181 and 5.150 g), Srinidhi in battery cage system (5.117 g), Gramapriya on deep litter system (5.134 g), Srinidhi on deep litter system (5.005 g), Srinidhi in semi intensive system

(4.936 g), Desi on deep litter, battery cage and semi intensive system as 4.929, 4.824 and 4.555 g, respectively. The egg shell weights observed in the present experiment were comparable with those reported by Lewko and Gornowicz (2011) as 4.93, 5.50 and 5.76 g shell weight in deep litter, cage and free range system, respectively. Egg shell weights favoured in all three systems namely, deep litter, battery cage and semi intensive housing disagreed with the findings of Tumova *et al.*(2011) who reported non-significant differences in weights between those housing systems.

4.3.1.6Egg shell thickness

4.3.1.6.1 Effect of breed on the egg shell thickness

The data of the egg shell thickness (mm) of different chickens are shown in Table 4.14 and graphically presented in Fig.4.27. The egg shell thickness showed significantly higher ($p<0.01$) for Srinidhi (0.321 mm) than Gramapriya (0.313 mm), Vanaraja (0. 0.312 mm) and lowest ($p<0.01$) was observed in Desi (0.297 mm). The results of present experiment were in accordance with Rayan *et al.* (2013) who reported that the egg shell thickness (mm) was significantly affected by strains. They reported that the brown hens had significantly higher shell thickness (0.365 mm) as compared to the white ones (0.346 mm). Similar, finding was also reported by Rath *et al.* (2015) for Whiate Leghorn (0.32 mm) and Padhi *et al.* (2014_a) also noted significantly difference in shell thickness as 0.3425±0.005, 0.3421±0.005, 0.3684±0.003, 0.3463±0.005 and 0.3548±0.005 at 32, 40, 52, 64 and 72 wks of age. These results were in conformity with finding of Ledvnika *et al.* (2000) and Badawe (2006). They concluded that poultry strains affected egg shell thickness.

4.3.1.6.2 Effect of management system on the egg shell thickness

The data of the egg shell thickness (mm) according to rearing systems are shown in Table 4.14 and graphically depicted in Fig. 4.28. The average egg shell thickness (mm) was significantly higher in battery cage system (0.318 mm) as compared to semi intensive system (0.311 mm) and deep litter system (0.304 mm). The present findings were in close conformity with those reported by Ogunwole *et al.* (2015) as egg shell thickness significantly was higher in battery cage system (0.35 mm) as compared to deep litter system (0.33 mm). Similar findings were reported by Choudhuri *et al.* (2016). They found significantly higher shell thickness in intensive system (0.30±0.03 mm) than backyard system (0.28±0.04 mm) for Nishibari birds. Lower egg shell thickness was recorded by Hussain *et al.* (2013) as 0.24±0.001, 0.26±0.001 and 0.53±0.003 mm for market eggs, farm eggs and indigenous poultry eggs, respectively.

4.3.1.7.3 Effect of interaction between breeds and systems on shell thickness

The results of the interaction between breeds and systems on average egg shell thickness (mm) are presented in Table 4.14. The results indicated that interactions between breeds and systems on egg shell thickness highest for Gramapriya in battery cage system (0.329 mm) followed by Srinidhi in semi intensive system (0.328 g), Vanaraja in semi intensive system (0.324 mm),Srinidhi in battery cage system (0.319 mm), Srinidhi in deep litter system (0.317 mm), Desi in battery cage system (0.315 mm), Gramapriya in semi intensive system (0.312 mm), Vanaraja in battery cage system (0.310 mm), Vanaraja in deep litter system (0.302 mm), Gramapriya in battery cage system (0.300 mm), Desi in deep litter (0.299 mm) and Desi in semi intensive system (0.278 mm). The egg shell thickness obtained in the present experiment was comparable with those reported by Lewko and Gornowicz (2011) as 317.71, 333.71 and 360.14 mm shell thickness in deep litter, cage and free range system,respectively.

Table 4.14 Average egg shell thickness (mm) of improved indigenous poultry breeds under different management regimes

Treatments/Phases	Early laying (19-33 wks.)	Mid laying (34- 44 wks.)	Late laying (45 - 62 wks.)	Avg. Shell Thickness (19 - 62 wks.)
Breeds				
Vanaraja (B_1)	0.263^{c}	0.323^{b}	0.339^{a}	**0.312^{b}**
Gramapriya (B_2)	0.279^{b}	0.325^{b}	0.328^{bc}	**0.313^{b}**
Srinidhi (B_3)	0.295^{a}	0.341^{a}	0.3228^{c}	**0.321^{a}**
Desi (B_4)	0.242^{d}	0.305^{c}	0.331^{ab}	**0.297^{c}**
S.E.	**0.003**	**0.004**	**0.002**	**0.002**
C.D. ($p<0.001$)	**0.009**	**0.011**	**0.008**	**0.005**
Systems				
DLS (M_1)	0.260^{b}	0.317^{b}	0.326^{a}	**0.304^{c}**
BCS (M_2)	0.278^{a}	0.334^{a}	0.332^{a}	**0.318^{a}**
SIS (M_3)	0.271^{a}	0.320^{b}	0.332^{a}	**0.311^{b}**
S.E.	**0.003**	**0.003**	**0.002**	**0.001**
C.D. ($p<0.001$)	**0.008**	**0.009**	**0.007**	**0.004**
Breeds × Systems				
Vanaraja				
DLS	0.248^{f}	0.301^{ef}	0.345^{a}	**0.302^{de}**
BCS	0.251^{f}	0.332^{bc}	0.333^{abcd}	**0.310^{cd}**
SIS	0.289^{bc}	0.336^{abc}	0.340^{ab}	**0.324^{ab}**
Gramapriya				
DLS	0.255^{ef}	0.321^{bcd}	0.312^{e}	**0.300^{e}**
BCS	0.305^{ab}	0.335^{abc}	0.341^{ab}	**0.329^{a}**
SIS	0.277^{cd}	0.320^{cde}	0.330^{bcd}	**0.312^{cd}**
Srinidhi				
DLS	0.283^{cd}	0.340^{ab}	0.320^{de}	**0.317^{bc}**
BCS	0.288^{bc}	0.350^{a}	0.312^{e}	**0.319^{abc}**
SIS	0.3141^{a}	0.332^{abc}	0.335^{abc}	**0.328^{a}**
Desi				
DLS	0.254^{ef}	0.304^{def}	0.327^{bcd}	**0.299^{e}**
BCS	0.271^{de}	0.320^{cde}	0.3445^{a}	**0.315^{bc}**
SIS	0.202^{g}	0.292^{f}	0.322^{cde}	**0.278^{f}**
S.E.	**0.005**	**0.005**	**0.004**	**0.002**
C.D. ($p<0.001$)	**0.014**	**0.016**	**0.011**	**0.008**

^{abcdefg}Means under each class in the same column with different superscripts differed significantly

4.3.1.7Egg specific gravity

4.3.1.7.1 Effect of breed on egg specific gravity

The data of the egg specific gravity as breeds wise are shown in Table 4.15 and graphically depicted in Fig.4.29. The results revealed non- significant differences for egg specific gravity between all poultry breeds. The highest egg specific gravity was recorded for Gramapriya (1.023) followed by Vanaraja (1.022), Srinidhi (1.022) and Desi (1.020). The results of present experiment corroborated to Kumar *et al.* (2008) who reported that the specific gravity did not differed significantly between strains as

1.08±0.002 and 1.08±0.001 for shank feathered strain and clean shank strain, respectively. Specific gravity values were found to be in their normal range as 1.020 to 1.023. However, higher egg specific gravity was observed by Qureshi and Krishna (2015) as 1.12 ± 0.007 for Naked neck X Polish cap cross as compared to current experiment. Dorji and Phurba (2014) also recorded higher specific gravity for Seim (Red Jungle fowl-like), Phulom (Frizzle), Yuebjha Narp (Black-feathered), Khuilay (Naked neck), and Hyline Brown as 1.11±±0.09, 1.09±±0.07, 1.03±0.09, 1.17±0.09 and 1.12±0.03,respectively.

4.3.1.7.2 Effect of management system on the egg specific gravity

The results of the egg specific gravity according to rearing systems are shown in Table 4.15 and graphically given in Fig. 4.30. The average egg specific gravity was highest in deep litter system (1.023) followed battery cage system (1.022) and semi intensive system (1.022). The present findings were in close conformity with those reported by Saki *et al.* (2012) as non- significantly variation in egg specific gravity. They recorded egg specific gravity as 1.08, 1.08, 1.08 and 1.08 when birds raised at 2,000 cm^2, 1000 cm^2, 667 cm^2 and 500 cm^{2}density of cage, respectively.

Table 4.15 Average egg specific gravity of improved indigenous poultry breeds under different management regimes

Treatments/Phases	**Early laying (19-33 wks.)**	**Mid laying (34- 44 wks.)**	**Late laying (45 - 62 wks.)**	**Avg. SG (19 - 62 wks.)**
Breeds				
Vanaraja (B$_1$)	1.025^{a}	1.022^{a}	1.021^{a}	**1.022^{a}**
Gramapriya (B$_2$)	1.022^{a}	1.023^{a}	1.024^{a}	**1.023^{a}**
Srinidhi (B$_3$)	1.023^{a}	1.021^{a}	1.023^{a}	**1.022^{a}**
Desi (B$_4$)	1.026^{a}	1.015^{b}	1.021^{a}	**1.020^{a}**
S.E.	**0.001**	**0.002**	**0.002**	**0.001**
C.D. ($p<0.001$)	**0.005**	**0.006**	**0.006**	**0.003**
Systems				
DLS (M$_1$)	1.026^{a}	1.021^{a}	1.022^{a}	**1.023^{a}**
BCS (M$_2$)	1.023^{a}	1.022^{a}	1.021^{a}	**1.022^{a}**
SIS (M$_3$)	1.024^{a}	1.018^{a}	1.021^{a}	**1.022^{a}**
S.E.	**0.001**	**0.001**	**0.001**	**0.0009**
C.D. ($p<0.001$)	**0.004**	**0.005**	**0.005**	**0.002**
Breeds × Systems				
Vanaraja				
DLS	1.029^{a}	1.023^{a}	1.024^{ab}	**1.025^{ab}**
BCS	1.022^{a}	1.022^{a}	1.017^{b}	**1.020^{b}**
SIS	1.024^{a}	1.022^{a}	1.020^{ab}	**1.022^{ab}**
Gramapriya				
DLS	1.023^{a}	1.020^{a}	1.021^{ab}	**1.021^{b}**
BCS	1.022^{a}	1.022^{a}	1.023^{ab}	**1.022^{ab}**
SIS	1.022^{a}	1.027^{a}	1.027^{a}	**1.026^{ab}**
Srinidhi				

DLS	1.023^{a}	1.019^{a}	1.019^{ab}	**1.020^{b}**
BCS	1.021^{a}	1.019^{a}	1.022^{ab}	**1.020^{b}**
SIS	1.024^{a}	1.026^{a}	1.029^{a}	**1.027^{a}**
Desi				
DLS	1.027^{a}	1.022^{a}	1.025^{ab}	**1.024^{ab}**
BCS	1.026^{a}	1.025^{a}	1.020^{ab}	**1.023^{ab}**
SIS	1.024^{a}	1.019^{b}	1.019^{ab}	**1.013^{c}**
S.E.	**0.002**	**0.003**	**0.003**	**0.001**
C.D. ($p<0.001$)	**0.007**	**0.008**	**0.008**	**0.004**

^{abcdefg}Means under each class in the same column with different superscripts differed significantly

4.3.1.5.3 Effect of interaction between breeds and systems on specific gravity

The results of the interaction between breeds and systems on average egg specific gravity are presented in Table 4.15. The results indicated that interaction between breeds and systems on egg specific gravity was highest for Srinidhi in semi intensive system (1.027) followed by Gramapriya in semi intensive system (1.026), Vanaraja in deep litter system (1.025), Desi in deep litter system (1.024), Desi in battery cage system (1.023), Gramapriya in battery cage system (1.022), Gramapriya in deep litter system (1.021), Vanaraja in battery cage system (1.020), Srinidhi in deep litter and battery cage system (1.020), Desi in semi intensive system (1.013). The egg specific gravity values of the present experiment resemble with those reported by Lewko and Gornowicz (2011) as 1.008, 1.005 and 1.060 g egg specific gravity in deep litter, cage and free range system, respectively. Egg specific gravity were reported to be optimum in all three systems namely, deep litter, battery cage and semi intensive housing which disagreed with the findings of Tumova *et al.* (2011) who reported nonsignificant differences in egg specific gravity between these housing systems.

4.3.2 Internal egg quality parameters

4.3.2.1 Egg yolk weight

4.3.2.1.1 Effect of breed on the egg yolk weight

In terms of yellow egg component, the results of the egg yolk weight (g) of different chickens are shown in Table 4.16 and graphically depicted in Fig.4.31. The egg yolk weight (g) recorded significantly higher ($p<0.01$) for Vanaraja (19.694 g) than Gramapriya (19.418 g), Srinidhi (18.870 g) and Desi (17.615 g) breed. The existence of mean yolk weight differences was not found among the all other poultry breeds ($p<0.01$). This study was in line with few authors who noted significant differences in each yolk weight between exotic and native chickens (Offiong *et al.*, 2006 and Moula *et al.*, 2010). The results of present experiment was comparable with Rayan *et al.* (2013) who recorded that yolk weight (g) of the white eggs was significantly heavier (14.64 g) than those of brown ones (14.23 g). On contrary, Islam and Dutta (2010)

Table 4.16 Average egg yolk weight (g) of improved indigenous poultry breeds under different management regimes

Treatments/Phases	Early laying (19-33 wks.)	Mid laying (34- 44 wks.)	Late laying (45 - 62 wks.)	Avg. Yolk wt

(19 - 62 wks.)

Breeds				
Vanaraja (B_1)	16.869^{a}	21.758^{a}	20.218^{a}	**19.694^{a}**
Gramapriya (B_2)	16.243^{b}	21.099^{b}	19.650^{b}	**19.418^{a}**
Srinidhi (B_3)	17.264^{a}	19.452^{c}	19.492^{b}	**18.870^{b}**
Desi (B_4)	14.228^{c}	18.267^{d}	19.505^{b}	**17.615^{c}**
S.E.	**0.196**	**0.196**	**0.183**	**0.120**
C.D. ($p<0.001$)	**0.551**	**0.552**	**0.514**	**0.338**
Systems				
DLS (M_1)	15.957^{b}	20.312^{a}	19.871^{a}	**18.964^{a}**
BCS (M_2)	16.737^{a}	20.323^{a}	19.599^{a}	**19.082^{a}**
SIS (M_3)	15.759^{b}	19.797^{b}	19.678^{a}	**18.659^{b}**
S.E.	**0.170**	**0.170**	**0.158**	**0.104**
C.D. ($p<0.001$)	**0.478**	**0.478**	**0.445**	**0.293**
Breeds × Systems				
Vanaraja				
DLS	16.208^{cd}	21.818^{ab}	19.218^{bc}	**19.692^{ab}**
BCS	16.267^{bcd}	22.692^{a}	21.171^{a}	**20.171^{a}**
SIS	16.254^{cd}	20.765^{c}	16.238^{cd}	**19.218^{bc}**
Gramapriya				
DLS	16.238^{cd}	20.615^{cd}	17.212^{b}	**18.483^{d}**
BCS	17.212^{b}	21.209^{bc}	17.157^{bc}	**19.801^{ab}**
SIS	17.157^{bc}	21.474^{bc}	19.786^{de}	**19.971^{a}**
Srinidhi				
DLS	16.557^{bcd}	19.265^{e}	19.306^{e}	**18.912^{cd}**
BCS	19.104^{a}	19.786^{de}	19.552^{e}	**18.733^{cd}**
SIS	16.132^{d}	19.306^{e}	17.604^{f}	**18.965^{cd}**
Desi				
DLS	14.825^{e}	19.552^{e}	18.483^{d}	**18.769^{cd}**
BCS	14.365^{ef}	17.604^{f}	19.801^{ab}	**17.621^{f}**
SIS	13.494^{f}	17.644^{f}	19.971^{a}	**16.455^{f}**
S.E.	**0.281**	**0.281**	**0.262**	**0.172**
C.D. ($p<0.001$)	**0.790**	**0.791**	**0.737**	**0.485**

^{abcdefg}Means under each class in the same column with different superscripts differed significantly

reported that there was no significance of difference among the local and layer birds ($p<0.05$).The strains differences on yolk weight among local birds were not observed and were in agreement with Rajkumar *et al.* (2009), Moula *et al.* (2010) and Isidahomen *et al.* (2013).

4.3.2.1.2 Effect of management system on the egg yolk weight

The results concerning the effect of housing system on egg yolk weight (g) according to rearing systems are shown in Table 4.16 and graphically depicted in Fig. 4.32. The average egg yolk weight was significantly higher in battery cage system (19.082 g) as compared to deep litter system (18.964 g) and semi intensive system (18.659 g). The findings of current experiment agreed with Ogunwole *et al.* (2015) who recorded higher yolk weight in battery cage system (14.13 g) than deep litter system (13.91 g). A lower estimate of yolk weight (15.18 g) was observed in Kadaknath (Parmar *et al.*, 2006). Chatterjee *et al.* (2007) reported higher yolk weights in Naked Neck, Barred Desi and Frizzle Fowl and lower yolk weights in Brown and Black Nicobari breeds of Andaman and Nicobar Islands.

4.3.2.1.3 Effect of interaction between breed and management system on yolk weight

The results concerning the effect of the interaction between breeds and systems on average egg yolk weight (g) are presented in Table 4.16. The results indicated that interactions between breeds and systems on egg yolk weight was highest for Vanaraja in battery cage system (20.171 g) followed by Gramapriya in semi intensive system (19.971 g), Gramapriya in battery cage system (19.801 g), Vanaraja in deep litter system (19.692 g), Vanaraja in semi intensive system (19.218 g), Srinidhi in semi intensive system (18.965 g), Desi in deep litter system (18.769 g), Srinidhi in battery cage system (18.733 g), Desi in battery cage system (17.621 g) and Desi in semi intensive system (16.455 g). The finding of present experiment were comparable with those reported by Lewko and Gornowicz (2011) who recorded significantly higher yolk weight in cage system (18.20 g) as compared to free range system (16.95 g) and deep litter (16.79 g).

Similar results were also reported by Ledvinka *et al.* (2012) in conventional cage system (16.00 g) and deep litter system (15.90 g).

4.3.2.2 Egg yolk width

4.3.2.2.1 Effect of breed on the egg yolk width

The results of the egg yolk width of different poultry breeds are shown in Table 4.17 and graphically depicted in Fig.4.33. The egg yolk width significant higher ($p<0.01$) recorded for Gramapriya (38.111 mm) than Vanaraja (38.069 mm), Srinidhi (36.981 mm) and Desi (36.887 mm). The results of present experiment were comparable with Singh *et al.* (2010) as 36.9±0.08, 36.8±0.08 and 36.6±0.08 mm at 30, 36 and 44 wks, respectively. Udoh *et al.* (2012) recorded parallel finding as 4.27, 4.36 and 4.16 cm for normal feathered, naked neck and frizzled feather, respectively. However, higher yolk width (mm) as 40.9, 40.6, 41.4 and 41.2 was reported for heavy ecotype (HE), light ecotype (LE), HE×LE (main crossbred), LE×HE (reciprocal crossbred), respectively (Momoh *et al.*, 2010).

4.3.2.2.2 Effect of management system on the egg yolk width

The results concerning the effect of housing system on egg yolk width (mm) are shown in Table 4.17 and graphically presented in Fig. 4.34. The average egg yolk width (mm) was significantly higher in deep litter system (37.740 mm) and battery cage system (37.663 mm) than semi intensive system (37.133 mm). The findings of current experiment were in agreement with Ogunwole *et al.* (2015) who recorded higher yolk width in battery cage system (34.675 mm) than deep litter system (33.640 mm). A higher yolk width was observed in Indigenous chickens as 46.43±0.40, 46.64±0.11 and 44.44±0.76 (Hussain *et al.*, 2013). Choudhari *et al.* (2015) reported similar results as 38.71±0.14, 40.89±0.67 and 36.65±0.02 mm for Nicobari, Nicorock and Nishibari chickens, respectively under intensive system.

Table 4.17 Average egg yolk width (mm) of improved indigenous poultry breeds under different management regimes

Treatments/Phases	Early laying (19-33 wks.)	Mid laying (34- 44 wks.)	Late laying (45 - 62 wks.)	Avg. Yolk Width (19 - 62 wks.)
Breeds				
Vanaraja (B_1)	37.653^{a}	39.438^{a}	37.013^{a}	**38.069^{a}**
Gramapriya (B_2)	37.270^{a}	39.889^{a}	36.964^{a}	**38.111^{a}**
Srinidhi (B_3)	36.063^{b}	37.741^{b}	36.910^{a}	**36.981^{b}**
Desi (B_4)	36.603^{b}	37.691^{b}	36.295^{b}	**36.887^{b}**
S.E.	**0.226**	**0.226**	**0.184**	**0.117**
C.D. ($p<0.001$)	**0.636**	**0.636**	**0.518**	**0.330**
Systems				
DLS (M_1)	37.529^{a}	38.913^{a}	36.727^{a}	**37.740^{a}**
BCS (M_2)	37.143^{a}	38.842^{ab}	36.873^{a}	**37.663^{a}**
SIS (M_3)	36.020^{b}	38.314^{b}	36.787^{a}	**37.133^{b}**
S.E.	**0.196**	**0.196**	**0.160**	**0.102**
C.D. ($p<0.001$)	**0.551**	**0.551**	**0.449**	**0.286**
Breeds × Systems				
Vanaraja				
DLS	37.675^{a}	40.378^{a}	37.121^{ab}	**38.456^{a}**
BCS	37.555^{a}	40.192^{a}	36.864^{abcd}	**38.263^{a}**
SIS	37.731^{a}	37.742^{dc}	37.054^{abc}	**37.489^{bc}**
Gramapriya				
DLS	37.458^{ab}	40.219^{a}	36.211^{cde}	**38.009^{ab}**
BCS	37.400^{ab}	39.594^{ab}	37.551^{a}	**38.253^{a}**
SIS	36.953^{abc}	39.853^{ab}	37.130^{ab}	**38.072^{a}**
Srinidhi				
DLS	37.841^{a}	37.557^{d}	37.041^{abc}	**37.446^{bc}**
BCS	37.205^{abc}	38.773^{bc}	36.094^{de}	**37.371^{cd}**
SIS	33.142^{d}	36.895^{d}	37.596^{a}	**36.127^{f}**
Desi				
DLS	37.142^{abc}	37.498^{d}	36.535^{bcd}	**37.051^{cde}**
BCS	36.414^{bc}	36.809^{d}	36.981^{abcd}	**36.845^{de}**
SIS	36.253^{c}	38.766^{bc}	35.369^{e}	**36.764^{e}**
S.E.	**0.325**	**0.325**	**0.264**	**0.168**
C.D. ($p<0.001$)	**0.912**	**0.912**	**0.743**	**0.474**

^{abcdefg}Means under each class in the same column with different superscripts differed significantly

4.3.2.2.3 Effect of interaction between breeds and systems on yolk width

The effect of the interactions between breeds and systems on average egg yolk width (mm) are presented in Table 4.17. The results revealed that interactions between breeds and systems on egg yolk width was highest for Vanaraja in deep litter system (38.456 mm) followed by Vanaraja in battery cage system (38.263 mm), Gramapriya in battery cage system, semi intensive system and deep litter system (38.253, 38.072 and 38.009 mm), Vanaraja in semi intensive system (37.489 mm), Srinidhi in deep litter system and battery cage system (37.446 and 37.371 mm), Desi in deep litter system (37.051 mm), Desi in battery cage system and semi intensive system (36.845 and 36.764 mm) and Srinidhi in semi intensive system (36.127 mm). The results of present experiment were comparable with those reported by Choudhari *et al.* (2015) who recorded yolk width as 37.95±0.64 39.66±1.31 and 37.14±0.84 mm for Nicobari, Nicorock and Nishibari under backyard condition and 38.71±0.14, 40.89±0.67 and 36.65±0.02 mm under intensive system, respectively.

4.3.2.3 Egg yolk height

4.3.2.3.1 Effect of breed on the egg yolk height

The results of the egg yolk height (mm) of different chickens are shown in Table 4.18 and graphically illustrated in Fig.4.35. The egg yolk height was significant higher ($p<0.01$) for Srinidhi (16.458 mm), Vanaraja (16.371 mm), Gramapriya (16.220 mm) than Desi (15.817 mm). The results of present experiment were comparable with Zaman *et al.* (2005) as 18.70, 19.93, 19.22 and 18.15 mm for Fay, RIR×Fay, NN×Fay and NN×RIR, respectively. Similar result was also reported as 17.63±0.17 mm and 16.97±0.43 mm in Rhode Island Red by Hanusova *et al.* (2015). However, lower yolk height (mm) as 11.80±0.12, 13.80±0.73 and 11.70±0.12 mm was noticed for Nicobari, Nicorock and Nishibari chickens, respectively (Choudhary *et al.*, 2015).

Table 4.18 Average egg yolk height (mm) of improved indigenous poultry breeds under different management regimes

Treatments/Phases	**Early laying (19-33 wks.)**	**Mid laying (34- 44 wks.)**	**Late laying (45 - 62 wks.)**	**Avg. Yolk Height (19 - 62 wks.)**
Breeds				
Vanaraja (B_1)	15.465_{b}	15.914_{b}	17.358_{a}	**16.317_{a}**
Gramapriya (B_2)	15.384_{b}	15.949_{b}	17.119_{a}	**16.220_{a}**
Srinidhi (B_3)	15.764_{a}	16.408_{a}	17.028_{a}	**16.458_{a}**
Desi (B_4)	14.317_{c}	15.517_{c}	17.242_{a}	**15.817_{b}**
S.E.	**0.097**	**0.116**	**0.176**	**0.085**
C.D. ($p<0.001$)	**0.274**	**0.326**	**0.495**	**0.239**
Systems				
DLS (M_1)	15.895_{a}	16.126_{a}	17.149_{a}	**16.435_{a}**
BCS (M_2)	15.026_{b}	16.084_{a}	17.350_{a}	**16.256_{a}**
SIS (M_3)	14.777_{c}	15.632_{b}	17.061_{a}	**15.918_{b}**
S.E.	**0.084**	**0.100**	**0.152**	**0.07379**
C.D. ($p<0.001$)	**0.238**	**0.282**	**0.429**	**0.206**
Breeds × Systems				
Vanaraja				
DLS	15.578_{b}	15.462_{d}	17.526_{abc}	**16.244bc**
BCS	15.269_{bcd}	16.065_{bc}	17.749_{ab}	**16.460_{b}**
SIS	15.547_{b}	16.217_{bc}	16.799_{cd}	**16.246_{bc}**
Gramapriya				
DLS	15.068_{cde}	16.187_{bc}	16.798_{cd}	**16.104_{bc}**
BCS	15.510_{bc}	15.769_{Cd}	17.303_{abcd}	**16.256_{b}**
SIS	15.575_{b}	15.890_{bcd}	17.255_{abcd}	**16.300_{b}**

Srinidhi				
DLS	17.960^{a}	16.813^{a}	16.970^{bcd}	**17.183^{a}**
BCS	14.650^{e}	16.166^{bc}	16.496^{d}	**15.872^{c}**
SIS	14.684^{e}	16.246^{bc}	17.618^{abc}	**16.319^{b}**
Desi				
DLS	14.975^{de}	16.041^{bc}	17.302^{abcd}	**16.209^{bc}**
BCS	14.674^{e}	16.336^{ab}	17.852^{a}	**16.434^{b}**
SIS	13.303^{f}	14.174^{e}	16.572^{d}	**14.809^{d}**
S.E.	**0.140**	**0.166**	**0.253**	**0.121**
C.D. ($p<0.001$)	**0.393**	**0.467**	**0.710**	**0.342**

^{abcdefg}Means under each class in the same column with different superscripts differed significantly

4.3.2.3.2 Effect of management system on the egg yolk height

The results concerning the effect of housing system on egg yolk height (mm) are shown in Table 4.18 and graphically depicted in Fig. 4.36. The average egg yolk width was significantly higher in deep litter system (16.435 mm) and battery cage system (16.256 mm) than semi intensive system (15.918 mm). The findings of current experiment agreed with Ogunwole *et al.* (2015) who recorded yolk height in battery cage system as 15.075 mm and deep litter system as 13.840 mm. A higher yolk height was observed in Shank feathered strain and Clean shank strain as 17.06±0.17 mm and 17.50±0.22 mm (Kumar *et al.*, 2014). Singh *et al.* (2010) reported similar results as 16.9±0.04 and 17.3±0.04 mm at 36 and 44 wks of age, respectively.

4.3.2.3.3 Effect of interaction between breed and management system on yolk Height

The describing results the effect of the interaction between breeds and systems on average egg yolk height (mm) are presented in Table 4.18. The findings revealed that interactions between breeds and systems on egg yolk height was highest for Srinidhi in deep litter system (17.183 mm) followed by Vanaraja in battery cage system (16.460 mm), Desi in battery cage system (16.433 mm), Srinidhi in semi intensive system (16.319), Gramapriya in semi intensive system and battery cage system (16.300 and 16.256 mm), Desi in deep litter system (16.209 mm), Gramapriya in deep litter system (16.104 mm), Srinidhi in battery cage system (15.872 mm) and Desi in semi intensive system (14.809 mm). The results of present experiment were comparable with those reported by Singh *et al.* (2010) who recorded yolk height as 15.8±0.03, 16.9±0.04 and 17.3±0.04 mm at 30, 36 and 44 wks of age.

4.3.2.5 Albumin height

4.3.2.5.1 Effect of breed on the albumin height

The results of the albumin height (mm) of different breeds are shown in Table 4.19 and graphically presented in Fig.4.37. In present experiment, the average albumin height was significantly ($p<0.01$) higher for Vanaraja (7.743 mm) followed by Srinidhi (7.315 mm), Gramapriya (7.190 mm) and Desi breed (5.144 mm). The results of present experiment were comparable with Choudhuri *et al.* (2015) reported significant variation for albumin height as 5.60±0.03, 5.26±0.09 and 5.64±0.09 mm for Nicobari, Nicorock and Nishibari, respectively. However, Dorji and Phurba (2014) was reported non-significant effect of poultry breeds on albumin height as 6.57±1.10, 6.93±1.09, 6.60±1.26, 5.98±1.06 and 11.21±1.21 mm for Seim (Red Junglefowl-like), Phulom (Frizzle), Yuebjha Narp (Black-feathered), Khuilay (Naked neck); HL, Hyline Brown, respectively. The highly significant difference in the albumen height between the different breeds could be attributed to variations in their genotype (Lado *et al.*, 2015).

4.3.2.5.2 Effect of management system on the albumin height

The results on albumin height (mm) according to rearing systems are shown in Table 4.19 and graphically depicted in Fig. 4.38. The average albumin height was highest in deep litter system (7.014 mm) followed by battery cage system (6.846 mm) and semi intensive system (6.684 mm). The findings of present experiment were in agreement with Ogunwole *et al.* (2015) who recorded higher albumin height of egg in deep litter system (3.69 mm) than battery cage system (3.50 mm). Choudhuri *et al.* (2015) also reported as 5.74±0.34, 5.34±0.11 and 5.48±0.08 for Nicobari, Nicorock and Nishibari, respectively under backyard condition. There were non-significant differences for albumin height between deep litter, battery cage and semi intensive rearing systems. This differences might be due to size of eggs and nutrition (Khan *et al.,* 2004)

4.3.2.5.3 Effect of interaction between breed and management system on albumin height

The describing results the effect of interaction between breeds and systems on average albumin height (mm) are presented in Table 4.19. The findings revealed highest albumin height (mm) recorded for Vanaraja in deep litter system (8.387 mm), than Srinidhi in deep litter system (7.617 mm) Vanaraja in semi intensive system (7.446 mm), Srinidhi in semi intensive system (7.408

Table 4.19 Average albumin height (mm) of improved indigenous poultry breeds under different management regimes

Treatments/Phases	**Early laying (19-33 wks.)**	**Mid laying (34- 44 wks.)**	**Late laying (45 - 62 wks.)**	**Overall (19 - 62 wks.)**
Breeds				
Vanaraja (B_1)	7.643_{a}	8.061_{a}	7.743_{a}	7.743_{a}
Gramapriya (B_2)	7.423_{ab}	6.766_{b}	7.523_{ab}	7.190_{b}
Srinidhi (B_3)	7.272_{b}	6.960_{ab}	7.372_{b}	7.315_{b}
Deshi (B_4)	5.064_{c}	5.130_{c}	5.164_{c}	5.144_{c}
S.E.	**0.074**	**0.394**	**0.088**	**0.142**
C.D. ($p<0.001$)	**0.208**	**1.107**	**0.248**	**0.401**
Systems				
DLS (M_1)	7.000_{a}	7.067_{a}	7.100_{a}	7.014_{a}
BCS (M_2)	6.832_{ab}	6.597_{a}	6.932_{ab}	6.846_{a}
SIS (M_3)	6.720_{b}	6.523_{a}	6.820_{b}	6.684_{a}
S.E.	**0.078**	**0.341**	**0.076**	**0.123**
C.D. ($p<0.001$)	**0.221**	**0.959**	**0.214**	**0.348**
Breeds × Systems				
Vanaraja				
DLS	7.791_{a}	9.629_{a}	7.891_{a}	8.387_{a}
BCS	7.427_{ab}	7.370_{b}	7.527_{ab}	7.395_{bc}
SIS	7.711_{a}	7.184_{b}	7.811_{a}	7.446_{bc}
Gramapriya				

DLS	7.034^{bc}	6.593^{bcd}	7.134^{bc}	7.065^{bc}
BCS	7.709^{a}	6.948^{bc}	7.809^{a}	7.332^{bc}
SIS	7.526^{a}	6.756^{bcd}	7.626^{a}	7.173^{bc}
Srinidhi				
DLS	7.395^{ab}	7.402^{b}	7.495^{ab}	7.617^{b}
BCS	6.752^{c}	6.594^{bcd}	6.852^{c}	6.918^{c}
SIS	7.669^{a}	6.885^{bcd}	7.769^{a}	7.408^{bc}
Deshi				
DLS	5.188^{d}	5.211^{cd}	5.288^{d}	5.254^{d}
BCS	5.051^{d}	5.181^{cd}	5.091^{d}	5.090^{d}
SIS	5.014^{d}	4.998^{d}	5.114^{d}	5.087^{d}
S.E.	**0.113**	**0.5645**	**0.126**	**0.2035**
C.D. ($p<0.001$)	**0.3185**	**1.5865**	**0.355**	**0.575**

^{abcdefg}Means under each class in the same column with different superscripts differed significantly mm), Vanaraja in battery cage system (7.395 mm), Gramapriya in battery cage system (7.332 mm), Gramapriya in semi intensive system (7.173 mm), Gramapriya in deep litter system (7.065 mm),Srinidhi in battery cage system (6.918 mm), Desi in deep litter system (5.254 mm), Desi in battery cage system (5.090 mm) and Desi in semi intensive system (5.087 mm). The results of experiment were in close agreement with Ogunwole *et al.* (2015) who reported significantly higher albumin height in deep litter system as 3.69 mm compared to battery cage system (3.50 mm). Lower values of albumin height was reported by Yakubu *et al.* (2007) they found 4.65 and 4.29 mm albumin height for naked neck and normal feathers chicken and Lado *et al.* (2015) as 3.969±0.022 and 3.308±0.039 for Rode Island Red and indigenous breed, respectively. The egg albumen height was greatly influenced by genetic factors with minor effects of nutrition on specific cases (Benabdeljelil and Jensen, 1990). Therefore, the highly significant difference in the albumen height between the different breeds could be attributed to variations in their genotype (Lado *et al.,* 2015).

4.3.2.6 Albumin weight

4.3.2.6.1 Effect of breed on the albumin weight

The results of the albumin weight (g) of egg of different breeds are shown in Table 4.20 and graphically depicted in Fig.4.39. In present experiment, the average albumin weight was significant ($p<0.01$) higher for Vanaraja (33.346 g), Gramapriya (32.194 g) and Srinidhi (31.756 g) than Desi (23.402 g). The results of present experiment were close comparable with Choudhuri *et al.* (2015) who reported albumin weight as 31.41±0.23, 31.98±1.12 and 27.65±0.53 g for Nicobari, Nicorock and Nishibari, respectively. The highly significant difference in the albumen weight between the different breeds could be attributed to variations in their genotype (Lado *et al.,* 2015). Higher albumin weight was reported by Rayan *et al.* (2013) as 43.78 and 40.30 g for Brown and W-36 layers, respectively. However, lower albumin weight as 26.22±4.08, 29.55±2.47, 27.48±4.43 and 28.69±3.91 g was observed for Seim (Red Jungle fowl), Phulom (Frizzle), Yuebjha Narp (Black-feathered) and Khuilay (Naked neck) chicken strains of Bhutanese, respectively (Dorji and Phurba, 2014).

4.3.2.6.2 Effect of management system on the albumin weight

The results of on albumin weight (g) according to rearing systems are shown in Table 4.20 and graphically presented in Fig. 4.40. The average highest albumin weight of egg was noticed in deep litter system (32.186 g) followed by battery cage system (31.303 g) and semi intensive system (27.035 g). The results of present experiment were in agreement with Ojedapo (2013). They recorded in deep litter housing higher values of albumen weight (36.98±3.45 g) than cage housing type (35.17±4.88 g).The housing system affected albumen quality which was higher in deep litter housing were in agreement with previous studies of Williams, (1992) who reported that deep litter layer showed more variable albumen quality with layer age than the caged layers. However, Paulouski *et al.* (1981) found that albumen quality of deep litter eggs was higher than cage eggs. Meanwhile, Wang *et al.* (2009b) reported non-significant difference in albumen quality between the two housing systems. The results documented for albumen quality were not also in agreement with the finding of Benton and Brake (2000) that obtained lower albumen quality in eggs from litter system and contributed their finding on the fact that eggs from a litter system were more exposed to ammonia from litter, which would reduce the albumen quality.

4.3.2.6.3 Effect of interaction between breed and management system on albumin weight

The describing results the effect of the interaction between breeds and systems on average albumin weight (g) are presented in Table 4.20. The results revealed that highest albumin weight for Vanaraja in deep litter system (33.536 g) than Vanaraja in battery cage system (33.463 g), Gramapriya in battery cage system (33.375 g), Srinidhi in deep litter system (33.130 g) Vanaraja in semi intensive system (33.038 g), Gramapriya in semi intensive system (32.970 g), Srinidhi in semi intensive system (32.560 g), Desi in deep litter system (31.842 g), Gramapriya in deep litter system (30.235 g), Srinidhi in battery cage system (29.576 g), Desi in battery cage system (28.321 g) and Desi in semi intensive system (26.640 g). The results of experiment were in close agreement with Kamil *et al.* (2012) who that reported rearing system significantly affected albumen

Table 4.20 Average albumin weight (g) of improved indigenous poultry breeds under different management regimes

Treatments/Phases	Early laying (19-33 wks.)	Mid laying (34- 44 wks.)	Late laying (45 - 62 wks.)	Avg. Albumin Wt. (19 - 62 wks.)
Breeds				
Vanaraja (B_1)	30.840^{a}	32.174^{a}	36.400^{a}	**33.346^{a}**
Gramapriya (B_2)	30.856^{a}	31.499^{ab}	33.890^{a}	**32.194^{ab}**
Srinidhi (B_3)	30.030^{a}	30.888^{bc}	33.921^{a}	**31.756^{ab}**
Desi (B_4)	25.083^{b}	30.000^{c}	15.540^{a}	**23.402^{b}**
S.E.	**0.331**	**0.347**	**0.336**	**0.338**
C.D. ($p<0.001$)	**0.929**	**0.976**	**0.945**	**0.950**
Systems				
DLS (M_1)	29.571^{a}	31.576^{a}	34.760^{a}	**32.186^{a}**
BCS (M_2)	30.311^{a}	31.253^{ab}	20.361^{a}	**27.035^{a}**
SIS (M_3)	27.724^{b}	30.592^{b}	34.700^{a}	**31.303^{a}**
S.E.	**0.286**	**0.301**	**0.301**	**0.296**
C.D. ($p<0.001$)	**0.805**	**0.845**	**0.845**	**0.832**
Breeds × Systems				
Vanaraja				
DLS	31.056^{ab}	32.307^{abc}	36.626^{a}	**33.536^{a}**
BCS	31.303^{ab}	32.291^{abc}	36.255^{a}	**33.463^{a}**
SIS	30.161^{bc}	31.924^{abc}	36.311^{a}	**33.038^{a}**
Gramapriya				
DLS	32.217^{a}	28.953^{d}	30.032^{a}	**30.235^{a}**
BCS	31.648^{ab}	32.094^{abc}	35.950^{a}	**33.375^{a}**
SIS	28.703^{c}	33.450^{a}	35.691^{a}	**32.970^{a}**
Srinidhi				

DLS	29.087^{c}	33.351^{ab}	35.940^{a}	**33.130^{a}**
BCS	31.767^{ab}	28.350^{d}	29.160^{a}	**29.576^{a}**
SIS	29.235^{c}	30.963^{c}	36.650^{a}	**32.560^{a}**
Desi				
DLS	25.926^{d}	31.692^{bc}	36.429^{a}	**31.842^{a}**
BCS	26.526^{d}	32.277^{abc}	26.160^{b}	**11.722^{b}**
SIS	22.797^{e}	26.031^{e}	30.132^{a}	**26.640^{b}**
S.E.	**0.474**	**0.498**	**0.487**	**0.486**
C.D. ($p<0.001$)	**1.332**	**1.398**	**1.368**	**1.366**

^{abcdefg}Means under each class in the same column with different superscripts differed significantly weight and their ratio. Albumen weight showed different tendencies in each rearing system signifying a rearing system×genotype interaction ($p<0.05$). These result that albumen weight was affected by rearing system was in accordance with the findings of the previous studies in which brown layers were used (Van Den Brand *et al.*, 2004; Cerolini *et al.*, 2005 and Rizzi *et al.*, 2006). However, in contrast Cherian *et al.* (2002) found that white eggs in organic system had higher albumen weight than those produced in a conventional cage system.

4.4 Physiological parameters

4.4.1 Rectal temperature

4.4.1.1 Effect of breed on rectal temperature

The results of the rectal temperature (ºF) of different breeds are shown in Table 4.21 and graphically depicted in Fig. 4.41. In present experiment, the average rectal temperature was significantly ($p<0.01$) higher for Vanaraja (104.657ºF) than Gramapriya (104.574ºF), Desi (104.414ºF) and Srinidhi (104.345ºF). The results of present experiment were in close comparable with Kedaree (2015) who reported rectal temperature as 105.41±0.23, 106.98±1.12 and 105.65±0.53 ºF for White Leghorn hens to supplemented different herbals.

4.4.1.2 Effect of management system on the rectal temperature

The results of the rectal temperature (ºF) under different management are showed in Table 4.21 and graphically depicted in Fig. 4.42. In present investigation non-significant differences for rectal temperature were observed between birds under various management systems. The average rectal temperature was highest in semi intensive system (104.497ºF) followed by deep litter system (104.455 ºF) and battery cage system (104.420 ºF). The difference was non-significant. The results of present experiment were in agreement with Kedaree (2015) who reported 105.41±0.23, 106.98±1.12 and 105.65±0.53 ºF for White Leghorn hens to supplemented different herbals under battery cage system.

Table 4.21 Average rectal temperature (°F) of improved indigenous poultry breeds under different management regimes

Treatments/Phases	**Chick stage (1 day - 8 wks.)**	**Growing stage (9 - 18 wks.)**	**Early laying (19 - 33 wks.)**	**Mid laying (34 - 44 wks.)**	**Late laying (45 - 62 wks.)**	**Avg. R.T. (19 - 62 wks.)**
Breeds						
Vanaraja (B_1)	105.123^{a}	104.322^{bc}	104.552^{a}	104.589^{b}	104.701^{a}	**104.657^{a}**

Gramapriya (B$_2$)	104.698^{b}	104.432^{ab}	104.353^{b}	104.753^{a}	104.638^{ab}	**104.574^{b}**
Srinidhi (B$_3$)	104.158^{c}	104.496^{a}	104.156^{c}	104.312^{c}	104.603^{b}	**104.345^{d}**
Desi (B$_4$)	104.655^{b}	104.287^{c}	104.431^{b}	104.204^{c}	104.495^{c}	**104.414^{c}**
S.E.	**0.038**	**0.042**	**0.040**	**0.040**	**0.031**	**0.038**
C.D. ($p<0.001$)	**0.108**	**0.120**	**0.114**	**0.112**	**0.089**	**0.108**
Systems						
DLS (M$_1$)	--	104.393^{ab}	104.386^{a}	104.545^{a}	104.498^{c}	**104.455^{a}**
BCS (M$_2$)	--	104.325^{b}	104.345^{a}	104.390^{b}	104.623^{b}	**104.420^{a}**
SIS (M$_3$)	--	104.434^{a}	104.389^{a}	104.459^{ab}	104.707^{a}	**104.497^{a}**
S.E.	--	**0.037**	**0.035**	**0.034**	**0.027**	**0.033**
C.D. ($p<0.001$)	--	**0.104**	**0.099**	**0.097**	**0.077**	**0.094**
Breeds × Systems						
Vanaraja						
DLS	--	104.052^{d}	104.825^{a}	104.697^{ab}	104.698^{abcd}	**104.568^{bc}**
BCS	--	104.270^{c}	104.358^{cde}	104.548^{bcd}	104.683^{bcd}	**104.464^{ef}**
SIS	--	104.645^{a}	104.476^{bc}	104.523^{bcd}	104.725^{abc}	**104.592^{bc}**
Gramapriya						
DLS	--	104.622^{a}	104.485^{bc}	104.873^{a}	104.552^{de}	**104.633^{a}**
BCS	--	104.293^{c}	104.403^{dc}	104.707^{ab}	104.813^{ab}	**104.554^{bcd}**
SIS	--	104.381^{bc}	104.172^{ef}	104.679^{abc}	104.550^{de}	**104.445^{e}**
Srinidhi						
DLS	--	104.569^{ab}	104.087^{f}	104.485^{dc}	104.445^{ef}	**104.396^{fg}**
BCS	--	104.543^{ab}	104.119^{f}	104.173^{ef}	104.650^{cd}	**104.371^{fg}**
SIS	--	104.377^{bc}	104.263^{def}	104.280^{ef}	104.715^{abc}	**104.408^{fg}**
Desi						
DLS	--	104.330^{c}	104.148^{f}	104.132^{f}	104.300^{f}	**104.227^{h}**
BCS	--	104.197^{cd}	104.501b^{c}	104.132^{f}	104.347^{f}	**104.294^{h}**
SIS	--	104.334^{c}	104.645^{ab}	104.355^{de}	104.839^{a}	**104.543^{bcde}**
S.E.		**0.039**	**0.037**	**0.037**	**0.029**	**0.035**
C.D. ($p<0.001$)		**0.112**	**0.106**	**0.104**	**0.083**	**0.101**

^{abcdefg}Means under each class in the same column with different superscripts differed significantly

4.4.1.3 Effect of interaction between breed and management system on the rectal temperature

The describing results of the interaction between breeds and systems on rectal temperature (ºF) are presented in Table 4.21. The results revealed that highest rectal temperature for Gramapriya in deep litter system (104.633ºF) than Vanaraja in semi intensive system (104.592 ºF), Vanaraja in deep litter system (104.568 ºF), Gramapriya in battery cage system (104.554 ºF), Desi in semi intensive system (104.543 ºF), Vanaraja in battery cage system (104.464 ºF), Gramapriya in semi intensive system (104.445 ºF), Srinidhi in semi intensive system (104.408 ºF), Srinidhi in deep litter system (104.396 ºF), Srinidhi in battery cage system (104.371 ºF), Desi in battery cage system (104.294 ºF) and Desi in deep litter system(104.227 ºF).These finding were comparable with Kedaree (2015).

4.4.2 Respiration rate

4.4.2.1 Effect of breed on the respiration rate

The results of the respiration rate (/minute) of different breeds are shown in Table 4.22 and graphically depicted in Fig. 4.43. In present study, the average respiration rate was significantly ($p<0.01$) higher for Vanaraja (29.452/minute) than Gramapriya (28.770), Desi (28.350/minute) and Srinidhi (28.132/minute). The higher respiration rate/minute as compared to present findings were recorded by Kedhari (2015). They reported respiration rate range as 34.04 to 34.85 per minute for White Leghorn hens.

4.4.2.2 Effect of management system on the respiration rate

The data of the respiration rate (/minute) of different breeds under different management systems are presented in Table 4.22 and graphically depicted in Fig. 4.44. In present study, the average respiration rate was recorded highest in semi intensive system (28.777/minute) than deep litter system (28.7693/minute) and battery cage system (28.558/minute). The results of statistics analysis showed that, there was non-significant difference. In semi intensive system respiration rate (/minute) higher might be due to more exercise space.

Table 4.22 Average respiration rate (no/minute) of improved indigenous poultry breeds under different management regimes

Treatments/Phases	Chick stage (1 day -8 wks.)	Growing (9 - 18 wks.)	Early laying (19 - 33 wks.)	Mid laying (34 - 44 wks.)	Late laying (45 - 62 wks.)	Avg. Res. (19-62 wks.)
Breeds						
Vanaraja (B_1)	30.250_{a}	31.307_{a}	28.860_{a}	29.164_{a}	28.481_{a}	29.452_{a}
Gramapriya (B_2)	31.152_{a}	29.376_{b}	28.770_{ab}	28.801_{ab}	28.133_{ab}	28.770_{b}
Srinidhi (B_3)	31.120_{a}	27.891_{d}	28.585_{ab}	28.226_{b}	27.824_{b}	28.132_{c}
Desi (B_4)	30.185_{a}	28.627_{c}	28.369_{b}	28.347_{b}	28.058_{ab}	28.350_{c}
S.E.	**0.174**	**0.210**	**0.172**	**0.208**	**0.188**	**0.112**
C.D. ($p<0.001$)	**0.487**	**0.588**	**0.482**	**0.583**	**0.526**	**0.314**
Systems						
DLS (M_1)	--	29.436_{a}	28.686_{a}	28.683_{a}	27.969_{a}	28.693_{a}
BCS (M_2)	--	29.410_{a}	28.211_{b}	28.459_{a}	28.152_{a}	28.558_{a}
SIS (M_3)	--	29.054_{a}	29.041_{a}	28.762_{a}	28.251_{a}	28.777_{a}
S.E.	--	**0.182**	**0.149**	**0.180**	**0.163**	**0.097**
C.D. ($p<0.001$)	--	**0.509**	**0.418**	**0.505**	**0.456**	**0.272**
Breeds × Systems						
Vanaraja						
DLS	--	31.314_{a}	29.228_{abc}	28.140_{cd}	28.062_{abc}	29.186_{b}
BCS	--	30.903_{ab}	27.981_{d}	29.078_{bc}	28.736_{a}	29.174_{b}
SIS	--	31.703_{a}	29.371_{ab}	30.273_{a}	27.769_{bc}	29.998_{a}
Gramapriya						
DLS	--	30.230_{b}	29.610_{a}	29.430_{ab}	28.644_{ab}	29.260_{b}
BCS	--	30.273_{b}	28.286_{d}	28.406_{cd}	28.241_{abc}	28.801_{bc}
SIS	--	27.624_{d}	28.414_{cd}	28.568_{bcd}	28.389_{abc}	28.249_{de}
Srinidhi						
DLS	--	27.733_{d}	27.904_{d}	28.424_{bcd}	27.989_{abc}	28.012_{de}
BCS	--	27.527_{d}	28.090_{d}	28.188_{cd}	27.576_{c}	27.846_{e}
SIS	--	28.412_{cd}	29.762_{a}	28.066_{d}	27.908_{abc}	28.537_{cd}
Desi						
DLS	--	28.466_{cd}	28.003_{d}	28.738_{bcd}	28.056_{abc}	28.315_{cde}
BCS	--	28.938_{c}	28.485_{cd}	28.163_{cd}	28.056_{abc}	28.412_{cd}

SIS -- 28.478^{cd} 28.619^{bcd} 28.140^{cd} 28.062^{abc} 28.324^{cde}
S.E. 0.193 0.160 0.194 0.175 0.104
C.D. (p<0.001) 0.548 0.450 0.589 0.529 0.318
^{abcdefg}Means under each class in the same column with different superscripts differed significantly

4.4.2.3 Effect of interaction between breed and management system on the respiration rate

The describing results of the interaction between breeds and systems on respiration rate are presented in Table 4.22. The results revealed highest respiration rate for Vanaraja in semi intensive system (29.998/minute), Gramapriya in deep litter system (29.260/minute) than Vanaraja in deep litter system (29.186/minute), Vanaraja in battery cage system (29.174/minute), Gramapriya in battery cage system (28.801/minute), Srinidhi in semi intensive system (28.537/minute), Desi in battery cage system (28.412/minute), Desi in semi intensive system (28.324/minute), Desi in deep litter system (28.315/minute), Gramapriya in semi intensive system (28.249/minute), Srinidhi in Srinidhi in deep litter system (28.012/minute) and Srinidhi in battery cage system (27.846/minute), and These finding were comparable with Kedaree (2015).

4.5 Mortality and survivability rate

The data of the mortality and survivability rate (%) of birds are presented in Table 4.23. The results showed that mortality rate and survivability rate during experimental period was in normal rage. Livability was found to be greater in battery cage system (100 %) as compared with deep litter and semi intensive system. Disease, predation and injuries due to cannibalism might be the cogent reasons behind the lower level of survivability rate in free range laying hens (Golden *et al.,* 2011; Holt *et al.*, 2011 and Elson, 2015). Likewise, a study was conducted to compare free range system with furnished cage system, demonstrated an elevated level of survivability rate in cage system than in free range (Black and Christensen, 2009 and Sherwin *et al.,* 2010) portraying cage system a better choice in term of survivability of birds as compared with the free range (Weeks *et al.,* 2012).

Table 4.23 Average mortality and Survivability rate of improved indigenous poultry breeds under different management systems
Breeds
Systems
Phases (%)
Chicks stage
Growing phase
(30)
Early laying
(30)
Mid laying
(30)
Late laying
(30)
Total/mean
(No/%)
Mortality numbers and Mortality rate (%)
Vanaraja
(210)
DLS 5 (2.38%) 0 0 1 (3.33%) 1 (3.33%) **2 (6.66%)**
BCS 0 0 0 0 0 **0**

SIS 0 0 1 (3.33%) 1 (3.33%) 0 **2 (6.66%)**
Gramapriya
(210)
DLS 4 (1.90%) 0 0 0 0 **0**
BCS 0 0 0 1 (3.33%) 0 **1 (3.33%)**
SIS 0 0 0 1 (3.33%) 0 **1 (3.33%)**
Srinidhi
(224)
DLS 6 (2.67%) 0 1 (3.33%) 0 1 (3.33%) **2 (6.66%)**
BCS 0 0 1 (3.33%) 1 (3.33%) 0 **2 (6.66%)**
SIS 0 0 1 (3.33%) 0 1 (3.33%) **2 (6.66%)**
Desi
(204)
DLS 8 (3.92%) 1 (3.33%) 0 0 1 (3.33%) **2(6.66%)**
BCS 0 0 1 (3.33%) 1 (3.33%) 0 **2(6.66%)**
SIS 0 0 2 (6.66 %) 0 1 (3.33%) **3 (10.00%)**
Survivability rate (%)
Vanaraja
DLS 97.62 100.00 100.00 96.67 96.56 **98.307**
BCS 100.00 100.00 100.00 100.00 100.00 **100.00**
SIS 100.00 100.00 96.67 96.56 100.00 **99.140**
Gramapriya
DLS 98.10 100.00 100.00 100.00 100.00 **100.00**
BCS 100.00 100.00 100.00 96.67 100.00 **99.167**
SIS 100.00 100.00 100.00 96.67 100.00 **99.334**
Srinidhi
DLS 97.33 100.00 96.67 100.00 96.67 **98.335**
BCS 100.00 100.00 96.67 96.67 100.00 **98.668**
SIS 100.00 96.67 100.00 100.00 96.67 **99.167**
Desi
DLS 96.08 96.67 100.00 100.00 96.67 **98.335**
BCS 100.00 100.00 96.67 96.67 100.00 **98.668**
SIS 100.00 100.00 93.34 100.00 96.67 **97.502**
Note: DLS: Deep litter system, BCS: Battery cage system, SIS: Semi-intensive system
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4.6. Economic assessment of different poultry breeds

The data pertaining to cost of production of different poultry breeds under various rearing systems are furnished in 4.24. The cost items included the cost of chick, feed, rearing materials, vitamins, vaccination, labour, light, electricity and miscellaneous items. Expenses involved for birds were included in total cost and net profits were calculated on egg production and live weight of bird basis. It is evident from the Table 4.24 that average total feed consumption of different poultry breeds was 35.81, 34.79 and 24.93 kg for Vanaraja, 34.65, 34.01 and 24.49 kg for Gramapriya, 34.34, 33.47 and 24.41 kg for Srinidhi and 31.35, 29.19 and 22.08 kg for Desi in deep litter, battery cage and semi intensive system, respectively. It was clear from the obtained data that the total cost of production were Rs. 1315.84, 1353.29 and 953.37 for Vanaraja, 1272.81, 1323.62 and 915.49 for Gramapriya, 1264.14, 1337.47 and 914.92 for Srinidhi and 1163.47, 1160.83 and 837.46 for Desi under deep litter system, battery cage system and semi intensive system, respectively. The total return/bird was highest in battery cage system as compared to deep litter and semi intensive system as Rs. 1715.31 for Vanaraja, Rs. 1711.34 for Gramapriya, Rs. 1671.59 for Srinidhi and 1225.72 for Desi, respectively. In deep litter system total return/bird was recorded as Rs. 1619.05 for Vanaraja, Rs. 1593.27 for Gramapriya, Rs. 1576.03 for Srinidhi and Rs.1091.47 for Desi. The lowest total return/bird was recorded in semi intensivesystem because in this system 50 per cent quantity of feed required was offeredfor bird and total return was Rs. 1493.14 for Vanaraja, Rs. 1441.78 for Gramapriya, Rs. 1462.80 for Srinidhi and Rs. 886.23 for Desi. Net profit per bird was higher in semi intensive system than deep litter and battery cage system *i.e.*, Rs. 526.29, 467.41, 446.97 and 48.77 for Gramapriya, Srinidhi, Vanaraja and Desi, respectively. In deep litter system, net profit/bird was higher for Gramapriya (Rs. 320.46) followed by Srinidhi (Rs. 311.89), Vanaraja (Rs. 302.21) and Desi (Rs. 31.02). Same pattern for net/profit/bird recoded under battery cage system as Gramapriya (Rs. 387.72) followed by Srinidhi (Rs. 334.12), Vanaraja (Rs. 362.02) and Desi (Rs. 64.89).

Table 4.24. Economic assessment of poultry breeds reared under management regimes (per bird)

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Attributes Vanaraja Gramapriya Srinidhi Desi
DLS BCS SIS DLS BCS SIS DLS BCS SIS DLS BCS SIS
A. ***Variable cost***
1. Cost of day old chicks (₹) 16.00 16.00 16.00 14.00 14.00 14.00 16.00 16.00 16.00 20.00 20.00 20.00
2. Labour wages @ ₹180 / day 0.50 0.50 0.50 0.50 0.50 0.50 0.50 0.50 0.50 0.50 0.50 0.50
3. Total feed consumption per bird (Kg) 35.81 34.79 24.93 34.65 34.01 24.49 34.34 33.47 24.41 31.35 29.19 22.08
4. Cost of feed/bird @ ₹31.40/Kg 1124.43 1092.40 782.80 1088.01 1067.91 768.98 1078.27 1050.95 766.47 984.39 916.56 693.31
5. Medicine and vaccination charge (₹) 20.00 20.00 20.00 20.00 20.00 20.00 20.00 20.00 20.00 20.00 20.00 20.00
6. Other miscellaneous charge (₹) 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00
7. Total variable cost 1165.93 1133.90 842.30 1127.51 1107.41 808.48 1119.77 1120.45 807.97 1029.89 962.06 738.81
8. Interest on total variable cost @ 12 % 139.91 136.06 101.07 135.30 132.88 97.01 134.37 134.45 96.95 123.58 115.44 88.65
Total variable cost (₹) 1305.84 1269.96 943.37 1262.81 1240.29 905.49 1254.14 1254.90 904.92 1153.47 1077.50 827.46
Depreciation @ 10 per cent
a. Area of poultry unit used = 1 birds @ 1
Sq. ft./bird (₹ 100/Sq. ft.)
10.00 10.00 10.00 10.00 10.00 10.00 10.00 10.00 10.00 10.00 10.00 10.00
Depreciation cost of cage (₹) - 73.33 - - 73.33 - - 73.33 - - 73.33 -
14. Total fixed cost (₹) 10.00 83.33 10.00 10.00 83.33 10.00 10.00 83.33 10.00 10.00 83.33 10.00
Total cost (12+14) 1315.84 1353.29 953.37 1272.81 1323.62 915.49 1264.14 1337.47 914.92 1163.47 1160.83 837.46
15. Total egg production/bird (No.) 159.97 174.03 150.28 177.50 195.96 163.58 175.69 188.10 156.71 124.65 141.41 92.22
16. Return from eggs sale @ ₹6/egg **959.82 1044.18 901.68 1065.00 1175.76 981.48 1054.14 1128.60 940.26 747.90 848.46 553.32**
17. Average weight of saleble birds (g) 3.07 3.14 2.35 2.43 2.47 2.15 2.40 2.51 2.07 1.53 1.71 1.53
18. Return from saleble birds @ ₹. 200/Kg 614.00 628.00 560.00 486.00 494.00 430.00 480.00 502.00 494.00 306.00 342.00 306.00
19. Return from their by-products
a. Gunny bag @ ₹5/bag 3.56 3.47 2.49 3.46 3.40 2.44 3.44 3.34 2.44 3.13 2.91 2.20
b. Manure @ ₹3/Kg 37.60 36.52 26.17 36.38 35.71 25.71 36.05 35.14 25.63 32.91 30.64 23.18
20. Total return/bird (₹) [16+17+18+19] 1618.05 1715.31 1493.14 1593.27 1711.34 1441.78 1576.03 1671.59 1462.80 1091.47 1225.72 886.23
21. Net return per bird (₹) 302.21 362.02 446.97 320.46 387.72 526.29 311.89 334.12 467.41 31.02 64.89 48.77

CHAPTER V

SUMMARY AND CONCLUSION

The present investigation was conducted as per the objectives pertaining to "Production Performance of Improved Poultry Breeds under Different Management Regimes" at Poultry Unit, Instructional Livestock Farm, College of Agriculture, Dr. BSKKV., Dapoli, Dist. Ratnagiri, Maharashtra state Vidyapeeth from June, 2016 to November, 2017. In this investigation, a total of eight hundred day old chicks *viz.*Vanaraja,Gramapriya, Srinidhi were procured from ICAR-PDP, Rajendranagar, Hyderabad and two hundred "Desi" chicks were collected from Private hatchery at Phaltan, Dist. Satara. After completion brooding, 90 birds per breed were selected on the basis of similar body weight and body pattern. The experiment was conducted using factorial randomized block design (FRBD) on 360 birds of four above mentioned genotypes. There were ten (10) birds of each genotype reared individually with separate replication. The details of the experiment were as under.

Total no. of birds : 360

Main treatments : 04

Sub- treatments : 03

Replications : 03

No. of birds/treatment : 90
No. of birds/replication : 10

5.1 Treatment details

5.1.1 Major treatment details: Four poultry breeds

5.1.1.1 Vanaraja (B_1)
5.1.1.2 Gramapriya (B_2)
5.1.1.3 Srinidhi (B_3)
5.1.14 Desi (B_4)

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5.1.2 Sub-treatment details: Three management system

5.1.2.1 Deep litter system (**M_1**)
5.1.2.2 Battery cage system (**M_2**)
5.1.2.3 Semi-intensive system (**M_3**)

The experiment was aimed to evaluate the production performance of Vanaraja, Gramapriya, Srinidhi and Desi birds under Konkan Agro-climatic condition. All day old chicks were procured in good condition. The chicks were selected from the same hatch and reared under uniform management conditions brooded from day old to 8^{th} week of their age (chick stage) on litter, then all birds were divided into three subtreatment groups, with three replications and each group had ninety birds (90) per treatment with ten birds (10) per replicate. The sub-treatment was three different management systems. The first sub-treatment group was raised in the deep litter system, second sub-treatment group was the battery cage system and third sub-treatment group was the semi-intensive system (backyard system). Birds in all three management systems were kept upto 62 weeks. The poultry house, cages, feeders and waterers were cleaned, washed, disinfected and were kept ready before the birds brought for experimental purpose. The day old chicks were housed on litter up to completion of their growing stage (*i.e.* up to 8^{th}wks) and then they were transferred into deep litter system, battery cage system and backyard system reared under ordinary feeding trial upto 52 weeks of their age. Debeaking of all the birds was done to avoid cannibalism and egg breaking. The veterinary aids were provided to all the birds as and when required. Deworming at regular interval was carried out and necessary vaccination was also carried out from chick stage up to laying stage.

5.2 Summary

5.2.1 Daily feed consumption during growing stage

The average daily feed consumption (g) was recorded maximum in Srinidhi (54.01 g/bird) followed by Vanaraja (50.48 g/bird), Gramapriya (34.06 g/bird) and Desi (27.32/bird) during brooding stage. As per different poultry breeds highest daily feed consumption was recorded for Vanaraja (96.32 g/bird) followed by Srinidhi (95.57 g/bird), Gramapriya (86.68 g/bird) and Desi (69.68 g/bird). Daily feed consumption was higher (103.38 g/bird) in deep litter system as compared to battery cage system (99.41 g/bird) and semi intensive system (58.41 g/bird). The overall means demonstrated significant difference ($p<0.05$) in daily feed consumption with respect to different rearing systems, chicken genotypes and their interaction. The findings of experiment showed significantly higher feed intake recorded in Vanaraja when raised on deep litter system (114.20 g/bird) than Srinidhi kept in battery cage system (112.97 g/bird), Vanaraja in battery cage system (112.95 g/bird), Srinidhi on deep litter (111.92 g/bird), Gramapriya on deep litter (102.14g/bird), Gramapriya in battery cage (96.09g/bird), Desi on deep litter (85.26g/bird), Desi in battery cage (75.62 g/bird), Vanaraja,Gramapriya and Srinidhi in semi intensive system (61.82 g/bird) and Desi in semi intensive system (48.18g/bird).

5.2.1 Daily feed consumption in laying period

The data revealed that the daily feed consumption per bird of different poultry breeds was maximum for Vanaraja (103.87±1.29g/bird) followed by Srinidhi (100.79±1.29g/bird), Gramapriya (99.43±1.29g/bird) and Desi (87.31±1.29g/bird), respectively. The feed consumption of Desi birds was low (87.31±1.29g). According to various management systems significantly ($p<0.05$) higher feed consumption was recorded when birds reared on deep litter system (111.30 g/bird) followed by battery cage system (107.20 g/bird) and semi-intensive system (75.05 g/bird), respectively. The interaction between the breeds and rearing systems significantly influenced the feed consumption per bird. The Vanaraja birds consumed significantly higher feed when reared on the deep litter system (118.00 g/bird) and battery cage system (115.05 g/bird) followed by Srinidhi on deep litter (113.65 g/bird), Gramapriya on deep litter (112.49 g/bird), Srinidhi in battery cage system (111.55 g/bird), Gramapriya in battery cage system (109.56 g/bird), Desi on deep litter and battery cage system (101.06 and 92.63g/bird), Vanaraja, Gramapriya and Desi on semi-intensive system as 78.54, 76.24and68.23g/bird), respectively. The birds in semi-intensive system had the lowest feed intake as compared to deep litter and battery cage system.

5.2.2 Total feed consumption

5.2.2.1 Total feed consumption during growing stage

The average total feed consumption (kg) was significantly higher for Srinidhi (3.02kg/bird) than Vanaraja (2.82 kg/bird), Gramapriya (1.90 kg/bird) and Desi (1.56 kg/bird), respectively from 1st week to 8th weeks. Among all chicken genotypes had significant ($p<0.05$) differences in total feed consumption during chick stage. The total feed consumption of chicken breeds recorded significantly higher for Vanaraja (7.41 kg/bird) than Srinidhi (7.35 kg/bird), Gramapriya (6.68 kg/bird) and Desi (5.36 kg/bird). In case of rearing systems, maximum feed intake was found in deep litter system (5.78 kg/bird) followed by battery cage system (5.56 kg/bird) and semi intensive system (3.27 kg/bird).

5.2.2.2 Total feed consumption during laying period

The average total feed consumption of poultry breeds was recorded significantly ($p<0.05$) higher for Vanaraja followed by Srinidhi, Gramapriya and Desi as 31.82, 30.86, 30.74 and 27.60 kg/bird, respectively. As per rearing systems, average total feed consumption of present experiment was 34.12, 32.85 and 23.80 kg/bird recorded in deep litter, battery cage and semi intensive systems, respectively. The finding of present study revealed that birds on deep litter system consumed more feed than those reared on battery cage system and semi intensive system. In the interaction, the maximum ($p<0.05$) feed intake of 35.83 kg/bird was obtained for Vanaraja on deep litter system followed by Vanaraja in battery cage system (34.77), Gramapriya on deep litter system (34.60 kg/bird), Srinidhi on deep litter system (34.37 kg/bird), Gramapriya in battery cage system (33.97 kg/bird), Srinidhi in battery cage system (33.49 kg/bird) Desi on deep litter system (31.67 kg/bird), Desi in battery cage system (29.16 kg/bird), Vanaraja in semi intensive system (24.85 kg/bird), Srinidhi in semi intensive system (24.34 kg/bird) Gramapriya in semi intensive system (23.92 kg/bird) and Desi in semi intensive (21.98 kg/bird).

5.2.3 Live body weight

5.2.3.1 Average live body weight during growing stage

The average live body weight upto 8th wks was achieved significantly ($p<0.05$) higher by Vanaraja (1035.62 g) than Srinidhi (905.59 g), Gramapriya (799.77 g) and Desi (593.49 g). During growing phase, significantly maximum live body weight was recorded in Vanaraja following by Gramapriya, Srinidhi and Desi as 1741.42,1348.81, 1232.19 and 980.10d g/bird, respectively.

5.2.3.2 Average live body weight during laying period

The average live body weights differences of Vanaraja, Gramapriya, Srinidhi and Desi from early laying phase to late laying phase (19 to 62 wks) were significant ($p<0.05$). On the basis breed wise overall mean of live body weights (19 to 62 wks) were significantly higher live body weight by Vanaraja birds (2790.03g/bird) as compared to Srinidhi (2295.00 g/bird), Gramapriya (2211.74 g/bird) and Desi (1486.54 g/bird). The average live body weight (g/bird) of chicken breeds under different systems was significantly higher were recorded in battery cage system (2272.26g/bird) and deep litter system (2253.79 g/bird) than semi-intensive system (2064.69 g/bird). Overall means demonstrated significant difference ($p<0.05$) in live body weight with respect to different rearing systems. The interaction of rearing systems with breeds depicted maximum live body weight in birds of Vanaraja breed under batter cage system (2938.90 g/bird) whereas, Desi manifested the lowest body weight under semi intensive system (1386.93 b/bird).

5.2.4 Age at first laying

The results of present experiment revealed that the age at first egg laying was significantly superior found in Srinidhi when reared on deep litter system (128 days), followed by Desi in battery cage system (129 days), Gramapriya in battery cage system (131 days), Gramapriya on deep litter system (141 days), Vanaraja in battery cage system (142 days) Desi on deep litter (143 days), Srinidhi in semi intensive system (147 days), Desi in semi intensive system (148 days), Gramapriya in semi intensive system (149 days), Vanaraja on deep litter system (157 days)and Vanaraja in semi intensive system (162 days).

5.2.5 Egg production performance

5.2.4.1 Hen day egg production

The results of HDEP of different poultry breeds revealed that the average hen day egg production was significantly higher in Gramapriya (61.19 %) than Srinidhi (58.60%), Vanaraja (56.27 %) and Desi (42.48 %). Higher peak daily egg production (HDEP %) was observed at mid laying phase by Srinidhi (69.98 %) followed by Gramapriya (69.74%), Vanaraja (66.69%) and Desi (58.37 %). The higher egg production recorded in Srinidhi during initial period was perhaps due to significantly early age at sexual maturity observed in Srinidhi as compared to Gramapriya, Vanaraja and Desi breed. Overall relatively higher egg production up to 62 weeks was observed in Gramapriya as compared to Srinidhi, Vanaraja and Desi. The hen day egg production under different management systems was significantly higher in battery cage system followed by deep litter system and semi-intensive system as 58.96, 55.28 and 49.67 per cent, respectively. This implies that hen genotypes significantly differed in their response to different management procedures.

5.2.4.2 Hen egg production per week

Among different breeds, hens of Gramapriya (4.28 no/bird) breed showed significantly ($p<0.05$) higher weekly egg production than other three breeds *viz.* Srinidhi (4.08 no/bird), Vanaraja (4.02 no/bird) and Desi (2.96 no/bird). The results as per statistical analysis showed significantly improved egg production in birds reared in battery cage system (4.14±0.05 no/bird) than those reared under deep litter system (3.87±0.05 no/bird) and semi intensive systems (3.50±0.05). The finding of interaction between breeds with rearing systems demonstrated significantly higher weekly egg production of Gramapriya (4.54 no/bird) in battery cage system followed by Gramapriya on deep litter system (4.32 no/bird), Srinidhi in battery cage system (4.31 no/bird) Vanaraja also in battery cage system (4.30 no/bird), Srinidhi on deep litter system (4.12 no/bird), Gramapriya in semi intensive system (3.96 no/bird), Srinidhi in semi intensive system (3.85 no/bird), Vanaraja in semi intensive system (3.84 no/bird), Desi in battery cage, deep litter, semi intensive (3.39, 3.13 and 2.35 no/bird), respectively.

5.2.4.3 Hen egg production per year

The results of annual egg production of poultry breeds showed that Gramapriya birds yielded highest eggs (184.33 no/bird) as compared to Srinidhi (174.72 no/bird), Vanaraja (173.13 no/bird) and Desi (122.94 no/bird). However, Srinidhi and Vanaraja birds were at par to each other. In rearing pattern, significantly higher number of eggs were yielded in battery cage system (176.76 no/bird) followed by deep litter system (164.98 no/bird) and semi intensive system (149.55 no/bird). The overall results of interaction between rearing systems with breeds demonstrated higher annual egg production in Gramapriya birds under battery cage system (196.77 no/bird) followed by Gramapriya in deep litter system (186.19 no/bird), Vanaraja in battery cage system (186.14 no/bird), Srinidhi in battery cage system (183.92 no/bird), Srinidhi in deep litter system (175.32 no/bird), Gramapriya in semi intensive system (171.61 no/bird), Vanaraja in semi intensive system (164.71 no/bird), Srinidhi in semi intensive system (164.66 no/bird), Desi in battery cage system (141.25 no/bird), Desi in deep litter system (129.91 no/bird) and Desi in semi intensive system (96.72 no/bird).

5.2.4.4 Feed conversion efficiency/dozen eggs

It was observed that the feed consumption per dozen of eggs was significantly lower in Gramapriya (2.04) followed by Srinidhi (2.10), Vanaraja (2.47) and Desi (5.10), respectively with significant ($p<0.05$) difference among all four breed groups. In different management significantly better feed efficiency/dozen eggs was found in battery cage system (2.31) as compared to deep litter system (2.74) and semiintensive system (3.75). The results of interaction, showed that feed utilization in Desi birds raised in semi intensive system was significantly inferior (9.67) followed by Desi raised on deep litter system (3.31), Vanaraja on deep litter system (2.92), Desi in battery cage system (2.61), Vanaraja in battery cage system (2.49), Gramapriya in battery cage system (2.45), Srinidhi on deep litter system (2.33), Srinidhi in battery cage system (2.22), Vanaraja in semi intensive system (2.02), Gramapriya in battery cage system (1.98), Srinidhi (1.77) and Gramapriya in semi intensive system (1.70). The interaction effect between breeds and systems was significant.

5.2.4.5 Feed conversion efficiency/Kg eggs

The average feed efficiency per kg eggs of different poultry ecotypes was significantly superior in Gramapriya (3.01) followed by Srinidhi (3.15), Vanaraja (3.28) and Desi (4.79) with significant ($p<0.05$) differences. In case of management systems feed consumption per kg eggs was significantly superior in semi intensive system followed by battery cage system and deep litter system as 3.35, 3.39 and 3.93 with significant ($p<0.05$) difference among all four breed groups. The overall results of interaction between breed and management system for feed efficiency values per dozen of eggs were noted superior for Gramapriya (2.54) birds raised in semi intensive system followed by Srinidhi raised in semi intensive system (2.79), Vanaraja in semi intensive system (2.92), Gramapriya in battery cage system (3.02), Srinidhi in battery cage system (3.16), Vanaraja in battery cage system (3.29), Gramapriya on deep litter system (3.47), Srinidhi on deep litter system (3.49), Vanaraja on deep litter system (3.72), Desi in battery cage system (4.11), Desi on deep litter system (5.02) and Desi in semi intensive system (5.24). The interaction effect between breeds and systems was significant ($p<0.05$).

5.2.5Egg quality parameters

5.2.5.1 External egg quality parameter

5.2.5.1.1 Egg weight

The data of average egg weight of different poultry breeds showed significant difference between the breeds ($p<0.01$). The average egg weights recorded as 58.16 gfor Gramapriya, 58.01 g for Vanaraja, 56.94 g for Srinidhi and 49.34 g for Desi. In different management systems, higher egg weight was recorded in battery cage system followed by deep litter system and semi intensive system as 56.56, 55.97 and 54.26 g, respectively. There was a significant ($p<0.01$) differences in egg weight observed under three housing systems. The results of interactions between breeds and systems on egg weight revealed that there was significant difference in egg weight for ecotypes whenreared in different housing systems.

5.2.5.1.2 Egg length

According to different breeds, there was non-significant difference for egg length. The average higher egg length was recorded for Gramapriya followed by Vanaraja, Srinidhi and Desi as 59.56, 57.19, 56.50 and 54.05 mm, respectively. The results of the egg length under various management systems revealed that higher egg length was recorded in battery cage system (56.55 mm) followed by deep litter system (56.14 mm) and semi intensive system (47.29 mm). The results of interaction between breeds and systems on egg length revealed significantly higher egg length for Gramapriya in battery cage system (61.54 mm) than Vanaraja in battery cage system (57.70 mm), Gramapriya on deep litter system (57.60 mm), Vanaraja on deep litter system (56.99 mm), Vanaraja in semi intensive system (56.86 mm) Srinidhi in semi intensive system (56.66 mm), Srinidhi on deep litter system (56.58 mm), Gramapriya in semi intensive system (56.53 mm), Srinidhi in battery cage system (56.25 mm), Desi in battery cage system (54.62 mm), Desi on deep litter system (54.45 mm) and Desi in semi intensive system (53.08 mm).

5.2.5.1.3 Egg width

The results obtained in the respect of effect of breeds on the egg width were showed highest egg width as 33.27 mm for Srinidhi followed by Vanaraja (33.26 mm), Gramapriya (33.12 mm) and Desi (31.52 mm) but there was non-significant difference in egg widths between Srinidhi, Vanaraja Gramapriya except Desi. In different management systems egg width was found significantly higher in battery cage system than deep litter system and semi intensive system as 33.11, 32.85 and 32.43 mm,respectively. The results of interactions between breeds and systems on egg width showed that higher egg width recorded for Gramapriya (33.54 mm) for battery cagesystem followed by Srinidhi in battery cage system (33.48 mm), Vanaraja in battery cage system (33.39 mm), Vanaraja on deep litter system (33.38 mm), Srinidhi in semi intensive system (33.21 mm), Srinidhi on deep litter system (33.13 mm), Vanaraja in semi intensive system (33.02 mm), Gramapriya on deep litter system (32.97 mm), Gramapriya in semi intensive system (32.84 mm), Desi in battery cage system (32.01 mm), Desi on deep litter system (31.89 mm) and Desi in semi intensive system (30.66 mm) management system.

5.2.5.1.4 Egg shape index

The egg shape index showed significant difference between four poultry breeds. The highest shape index was 58.80 of Vanaraja and lowest was observed in Gramapriya (57.97). Shape Index was 58.54 for Srinidhi and 58.34 for Desi. The data of the egg shape index according to rearing systems showed highest in deep litter system followed by battery cage system and semi intensive system as 58.70, 58.52 and 58.00, respectively. The results indicated that interactions between breeds and systems on egg shape index was significantly higher for Desi in battery cage system and deep litter system as 59.45 and 59.30 followed by Srinidhi in deep litter system and battery cage system (58.81 and 58.72), Vanaraja in semi intensive system and deep litter system (58.66 and 58.61), Gramapriya in battery cage system and deep litter system (58.19 and 58.09), Srinidhi in semi intensive system (58.08), Vanaraja in battery cage system (57.72), Desi in semi intensive system (57.67) and Gramapriya in semi intensive system (57.60).

5.2.5.1.5 Egg shell weight

The results of shell weight of different poultry breeds showed significantly higher ($p<0.01$) for Gramapriya (5.215 g) than Vanaraja (5.178g), Srinidhi (5.019g) and lowest in Desi (4.769 g). In case of management systems, the average egg shell weight was significantly higher in battery cage system (5.106 g) as compared to deep litter system (5.055 g) and semi intensive system (4.975 g). The results indicated that interactions between breeds and systems on egg shell weight was highest for Gramapriya in battery cage system (5.301 g) followed by Gramapriya in semi intensive system (5.208 g), Vanaraja in semi intensive system, battery cage system and deep litter system (5.202, 5.181 and 5.150 g), Srinidhi in battery cage system (5.117 g), Gramapriya on deep litter system (5.134 g), Srinidhi on deep litter system (5.005 g), Srinidhi in semi intensive system (4.936 g), Desi on deep litter, battery cage and semi intensive system as 4.929, 4.824 and 4.555 g, respectively.

5.2.5.1.6Egg specific gravity

The results showed significant ($p<0.01$) differences for egg specific gravity between all poultry breeds. The highest egg specific gravity was recorded for Gramapriya (1.023) followed by Vanaraja (1.022), Srinidhi (1.022) and Desi (1.020). In case of management systems, the average egg specific gravity higher in deep litter system (1.023) than battery cage system (1.022) and semi intensive system (1.022). The results of interactions between breeds and systems indicated that interactions between breeds and systems on egg specific gravity was highest for Srinidhi in semi intensive system (1.027) followed by Gramapriya in semi intensive system (1.026), Vanaraja in deep litter system (1.025), Desi in deep litter system (1.024), Desi in battery cage

system (1.023), Gramapriya in battery cage system (1.022), Gramapriya in deep litter system (1.021), Vanaraja in battery cage system (1.020), Srinidhi in deep litter and battery cage system (1.020), Desi in semi intensive system (1.013).

5.2.5.1.7 Egg shell thickness

The egg shell thickness of different poultry breeds was significantly higher ($p<0.01$) for Srinidhi (0.321 mm) followed by Gramapriya (0.313 mm), Vanaraja (0. 0.312 mm) and lowest ($p<0.01$) was observed in Desi (0.297 mm). In various systems, the average egg shell thickness was significantly higher in battery cage system (0.318 mm) as compared to semi intensive system (0.311 mm) and deep litter system (0.304 mm). The findings of the effect of interactions between breeds and systems on average egg shell thickness indicated that egg shell thickness was highest for Gramapriya in battery cage system (0.329 mm) followed by Srinidhi in semi intensive system (0.328 g), Vanaraja in semi intensive system (0.324 mm), Srinidhi in battery cage system

(0.319 mm), Srinidhi in deep litter system (0.317 mm), Desi in battery cage system (0.315 mm), Gramapriya in semi intensive system (0.312 mm), Vanaraja in battery cage system (0.310 mm), Vanaraja in deep litter system (0.302 mm), Gramapriya in battery cage system (0.300 mm), Desi in deep litter (0.299 mm) and Desi in semi intensive system (0.278 mm).

5.2.5.2 Internal egg quality parameters

5.2.5.2.1 Egg yolk weight

The yellow egg component of different poultry breeds was significantly higher ($p<0.01$) for Vanaraja (19.694 g) than Gramapriya (19.418 g), Srinidhi (18.870 g) and Desi (17.615 g). In various housing systems, the average egg yolk weight was significantly higher in battery cage system (19.082 g) as compared to deep litter system (18.964 g) and semi intensive system (18.659 g). The interactions between breeds and systems indicated that egg yolk weight was highest for Vanaraja in battery cage system (20.171 g) followed by Gramapriya in semi intensive system (19.971 g), Gramapriya in battery cage system (19.801 g), Vanaraja in deep litter system (19.692 g), Vanaraja in semi intensive system (19.218 g), Srinidhi in semi intensive system (18.965 g), Desi in deep litter system (18.769 g), Srinidhi in battery cage system (18.733 g), Desi in battery cage system (17.621 g) and Desi in semi intensive system (16.455 g).

5.2.5.2.2 Egg yolk width

The egg yolk width of different poultry breeds showed significantly higher ($p<0.01$) for Gramapriya (38.111 mm) than Vanaraja (38.069 mm), Srinidhi (36.981

mm) and Desi (36.887 mm). The results concerning the effect of housing system on egg yolk width revealed significantly higher in deep litter system (37.740 mm) than battery cage system (37.663 mm) and semi intensive system (37.133 mm). In case of interactions**,** the egg yolk width was highest for Vanaraja in deep litter system (38.456 mm) followed by Vanaraja in battery cage system (38.263 mm), Gramapriya in battery cage system, semi intensive system and deep litter system (38.253, 38.072 and 38.009 mm), Vanaraja in semi intensive system (37.489 mm), Srinidhi in deep litter system and battery cage system (37.446 and 37.371 mm), Desi in deep litter system (37.051 mm), Desi in battery cage system and semi intensive system (36.845 and 36.764 mm) and Srinidhi in semi intensive system (36.127 mm).

5.2.5.2.3 Egg yolk height

The egg yolk height of poultry breeds was significantly higher ($p<0.01$) for Srinidhi (16.458 mm), Vanaraja (16.371 mm) and Gramapriya (16.220 mm) than Desi (15.817 mm). The average egg yolk width was significantly higher in deep litter system (16.435 mm) and battery cage system (16.256 mm) than semi intensive system (15.918 mm). The interaction findings revealed that egg yolk height highest for Srinidhi in deep litter system (17.183 mm) followed by Vanaraja in battery cage system (16.460 mm), Desi in battery cage system (16.433 mm), Srinidhi in semi intensive system (16.319), Gramapriya in semi intensive system and battery cage system (16.300 and 16.256 mm), Desi in deep litter system (16.209 mm), Gramapriya in deep litter system (16.104 mm), Srinidhi in battery cage system (15.872 mm) and Desi in semi intensive system (14.809 mm).

5.2.5.2.4 Albumin height

In present experiment, the average albumin height was significantly ($p<0.01$) highest for Vanaraja (7.743 mm) followed by Srinidhi (7.315 mm), Gramapriya (7.190 mm) and Desi (5.144 mm). The results of the housing system on average albumin height (mm) was highest in deep litter system (7.014 mm) followed by battery cage system (6.846 mm) and semi intensive system (6.684 mm). The findings of the interactions between breeds and systems revealed that significantly higher albumin length (mm) recorded for Vanaraja in deep litter system (8.387 mm) than Srinidhi in deep litter system (7.617 mm) Vanaraja in semi intensive system (7.446 mm), Srinidhi in semi intensive system (7.408 mm), Vanaraja in battery cage system (7.395 mm), Gramapriya in battery cage system (7.332 mm), Gramapriya in semi intensive system (7.173 mm), Gramapriya in deep litter system (7.065 mm), Srinidhi in battery cage

system (6.918 mm), Desi in deep litter system (5.254 mm), Desi in battery cage system (5.090 mm) and Desi in semi intensive system (5.087 mm).

5.2.5.2.4 Albumin weight

In present experiment, the average albumin weight (g) was significantly ($p<0.01$) higher for Vanaraja (33.346 g), Gramapriya (32.194 g) and Srinidhi (31.756 g) than Desi (23.402 g). In case of rearing systems highest albumin weight was observed in deep litter system (32.186 g) followed by battery cage system (31.303 g) and semi intensive system (27.035 g). The results interactions between breeds and systems on average albumin weight (g) revealed that higher albumin weight (g) was recorded for Vanaraja in deep litter system (33.536 g) than Vanaraja in battery cage system (33.463 g), Gramapriya in battery cage system (33.375 g), Srinidhi in deep litter system (33.130 g) Vanaraja in semi intensive system (33.038 g), Gramapriya in semi intensive system (32.970 g), Srinidhi in semi intensive system (32.560 g), Desi in deep litter system (31.842 g), Gramapriya in deep litter system (30.235 g), Srinidhi in battery cage system (29.576 g), Desi in battery cage system (28.321 g) and Desi in semi intensive system (26.640 g).

5.2.6 Mortality and survivability rate

The data of the mortality and survivability rate (%) showed that mortality rate and survivability rate during experimental period was in normal rage. Livability was found to be greater in battery cage system (100 %) as compared with deep litter and semi intensive system.

5.2.6 Economic assessment of different poultry breeds

The cost items included the cost of chick, feed, rearing materials, vitamins, vaccination, labour, light, electricity and miscellaneous items. Expenses involved for birds were included in total cost and net profits were calculated on egg production and live weight of bird basis. The average total feed consumption of different poultry breeds was 35.81, 34.79 and 24.93 kg for Vanaraja, 34.65, 34.01 and 24.49 kg for Gramapriya, 34.34, 33.47 and 24.41 kg for Srinidhi and 31.35, 29.19 and 22.08 kg for Desi in deep litter, battery cage and semi intensive system, respectively. It can be stated that the total costs of production was Rs. 1315.84, 1353.29 and 953.37 for Vanaraja, 1272.81, 1323.62 and 915.49 for Gramapriya, 1264.14, 1337.47 and 914.92 for Srinidhi and 1163.47, 1160.83 and 837.46 for Desi under deep litter system, battery cage system and semi intensive system, respectively.

The total return/bird was higher in battery cage system as compared to deep litter and semi intensive system as Rs. 1715.31 for Vanaraja, Rs. 1711.34 for Gramapriya, Rs. 1671.59 for Srinidhi and 1225.72 for Desi, respectively. In deep litter system total return/bird recorded as Rs. 1619.05 for Vanaraja, Rs. 1593.27 for Gramapriya, Rs. 1576.03 for Srinidhi and Rs. 1091.47 for Desi. The lowest total return/bird was recorded in semi intensive system because in this system offered 50 per cent quantity of feed requirement for bird as Rs. 1493.14 for Vanaraja, Rs. 1441.78 for Gramapriya, Rs. 1462.80 for Srinidhi and Rs. 886.23 for Desi.

Net profit per bird was recorded higher in semi intensive system than deep litter and battery cage system *i.e.,* Rs. 526.29, 467.41, 446.97 and 48.77 for Gramapriya, Srinidhi, Vanaraja and Desi breed, respectively. In deep litter system, net profit/bird was recorded higher for Gramapriya (Rs. 320.46) than Srinidhi (Rs. 311.89), Vanaraja (Rs. 302.21) and Desi (Rs. 31.02). Same pattern for net/profit/bird recoded under battery cage system as Gramapriya (Rs. 387.72) than Srinidhi (Rs. 334.12), Vanaraja (Rs. 362.02) and Desi (Rs. 64.89).

5.3 Conclusions

From the results of the present experiment, the following conclusions are drawn.

1 Results showed that Vanaraja birds gained higher body weight as compared to Srinidhi, Gramapriya and Desi birds under battery cage, deep litter and semiintensive system.

2 Weekly egg production and annual egg production, feed efficiency/dozen eggs and feed efficiency/kg eggs was significantly higher in Gramapriya birds as compared to Srinidhi, Vanaraja and Desi birds under three management systems.

3 The Haemato-biochemical parameters *viz.*, Haemoglobin, serum protein, glucose, and cholesterol level influenced by systems and it was found in normal range.

4 The external and internal egg quality trait *viz.,* egg weight, egg shape index, yolk weight, albumin weight and shell thickness were influenced by genotypes and management systems.

5 Birds in battery cage system performed better than those kept on deep litter in terms of hen-housed egg production, egg weight and mortality.

6 The economic evaluation revealed that the net profit per bird was maximum in Gramapriya as compared to Srinidhi, Vanaraja and Desi under different management systems *viz.*, semi-intensive, deep litter and battery cage system. Overall production cost of the birds kept under semi-intensive was lower than deep litter and battery cage management system.

7 From the overall results of present investigation, it can be concluded that the Gramapriya bird could perform better for important economic traits than Srinidhi, Vanaraja and Desi birds under same management. Therefore, rearing of Gramapriya birds are more beneficial to rear under semi intensive system (Rs. 526.29/bird), battery cage system (Rs. 387.72/bird) and deep litter system (Rs. 320.46/bird).

5.4 Suggestions

1 From, the results it can clearly, said that a Gramapriya bird is superior to other three breeds.

2 Desi birds also gave excellent results in term of egg production, egg quality and age at sexual maturity. If local poultry birds are reared with scientific management, better production can be obtained.

5.5 Recommendation

From the results of experiment, it can be recommended that Gramapriya breed is excellent genotype of improved poultry breed for commercial rearing purpose under *Konkan* Agro-climatic condition in semi intensive system, battery cage system and deep litter system.

CHAPTER IV

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Experimental Design

Note: **1. DLS:** Deep litter system, **2. BCS:** Battery cage system and, **3. SES:** Semi-intensive system.

Total Layers (360)

DLS BCS SIS

Vanaraja **(T_1)** ***Gramapriya*** **(T_2)**

Srinidhi **(T_3)** ***Desi*** **(T_4)**

DLS BCS SIS DLS BCS SIS DLS BCS SIS

R_1, R_2, R_3 R_1, R_2, R_3 R_1, R_2, R_3 R_1, R_2, R_3 R_1, R_2, R_3 R_1, R_2, R_3 R_1, R_2, R_3 R_1, R_2, R_3

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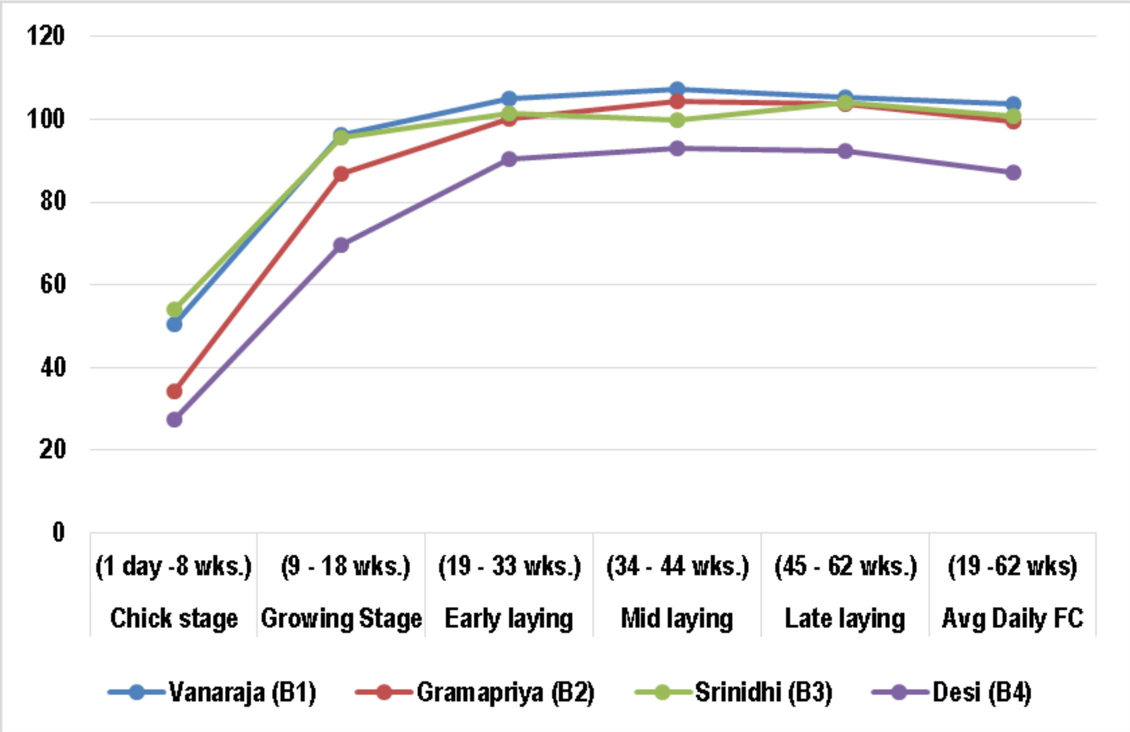
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(1 day -8 wks.) Chick stage
(9 - 18 wks.) Growing Stage
(19 - 33 wks.) Early laying
(34 - 44 wks.) Mid laying
(45 - 62 wks.) Late laying
(19 -62 wks) Avg Daily FC
Vanaraja (B1)
Gramapriya (B2)
Srinidhi (B3)
Desi (B4)

SEPARATOR

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