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Productivity, Management Practices And Disease Incidences Of The Indigenous, Exotic And Crossbred Chickens Under Smallholders' Conditions In Rajshahi, Bangladesh

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Productivity, Management Practices And Disease Incidences Of The Indigenous, Exotic And Crossbred Chickens Under Smallholders' Conditions In Rajshahi, Bangladesh

A Dissertation Submitted for the Degree of
Doctor of Philosophy

By
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December, 2014

Dedicated

To

My Honourable

Parents and Supervisor

DECLARATION

I hereby declare that the thesis entitled **"Productivity, Management Practices And Disease Incidences Of The Indigenous, Exotic And Crossbred Chickens Under Smallholders' Conditions In Rajshahi, Bangladesh"** for the degree of Doctor of Philosophy in Zoology specialized by Genetics & Molecular Biology, has not so far been submitted for the award of any other Degree or diploma in any university. All sources of information are shown in the text and listed in References. The assistance and help received during the course of investigation have duly been acknowledged.

21st December 2014, Rajshahi

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CERTIFICATE

I am pleased to certify that the dissertation titled '**Productivity, Management Practices And Disease Incidences Of The Indigenous, Exotic And Crossbred Chickens Under Smallholders' Conditions In Rajshahi, Bangladesh**' submitted by Mr. Ripon Kumar Dutta, to the Department of Zoology, Faculty of Life and Earth Sciences, University of Rajshahi, Bangladesh, for the Degree of Doctor of Philosophy, is an original work by the candidate.

I hereby certify that the candidate has fulfilled the requirements and the research work embodied in the thesis was carried out by the candidate. To the best of my knowledge, all the materials are genuine and the thesis contains no materials previously published or written by any other person except when due reference is made in the text.

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Dated: 21st December 2014, Rajshahi

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The author

ABSTRACT

This research work evaluated the productivity, management practices and disease incidences of various chicken breeds under smallholders' conditions at 10 Upazillas of Rajshahi District, Bangladesh. The productivity study, conducted on six available chicken breeds *viz*., Cobb 500 (broiler), cockerel, Fayoumi, indigenous (*Deshi*), RIR and *Sonali* from one government farm (GOV), ten private farms (PRI) and ten backyard chicken farms (BCF) from the urban, semi-urban and rural areas of Rajshahi, revealed that the crossbred *Sonali* was the highest in production number in both the GOV and PRI farms during 2011-12 and 2012-13 fiscal years whereas broilers attained the highest in 2013-14. The BCF earned the maximum profit (profitability index, PI=0.646) than PRI (PI=0.114) whereas GOV showed a negative PI (-0.021) indicating economic losses. The PI values gradually decreased from 2011-12 to FY 2013-14 throughout the entire production period which indicated economic instability in the poultry farming in the study area.

Using a five-scale scoring system, eight major management practices (MP) namely, room temperature (RT), water source (WS), vaccination (VC), bio-safety measures (BM), boundary walls (BW), human residence (HR), chicken transportation (CT) and feeding management (FM), were considered to rank the farms under study. On average, GOV farm scored 4.00 indicating good management practices for BW, HR and FM, PRI farms achieved 3.42 for FM but the BCF exhibited a lower level to satisfactory scores (2.23-2.62) for all the parameters.

Disease incidences (DI) such as bacterial diseases (BD), viral diseases (VD), fungal diseases (FD), flock-wise disease commonness (FDC) and seasonal disease prevalence (SDP) were taken into account to rank the poultry farms using a five-scale scoring system. Results showed that the GOV farm scored the highest 4.33 (severe to elevated) for SDP, the PRI farms scored 2.74 (mild to gross) for BD, and the BCF scored 1.06 (absent to mild) for FD. The DI parameters showed highly significant differences for BD and SDP ($P<0.001$) followed by VD, FD and FDC ($P<0.01$) among the farms during the study period.

For meat yield studies, a total of 768 day-old Fayoumi and *Sonali* chickens of both sexes were divided into 16 diet groups, each containing 16 chickens with 3 replications, reared under four dietary treatments groups *viz*., T1 (premix, control), T2 (premix + vitA) , T3 (premix + EAAs) and T4 (premix + vitA + EAAs) to evaluate the growth performance, meat features and carcass features. The growth performance parameters included feed intake (FI), live weight gain (LWG), feed conversion ratio (FCR) and survivability (SB); the meat features were dressing yield (DY), total meat (TM), breast meat (BM), dark meat (DKM), drumstick meat (DM), wing meat (WM) and thigh meat (THM) and the carcass features were skin weight (SW), abdominal fat weight (AFW), neck weight (NW), head weight (HW) and giblet weight (GW). Analyses demonstrated that Fayoumi was the highest values for FI and LWG while *Sonali* was the highest for FCR. Male chickens showed the highest FI and LWG but the lowest for FCR than the female ones. The T4 group chickens showed the highest SB followed by T3, T2 and T1 groups. Meat features showed significant differences for LW, TM and BM ($P<0.001$), DKM ($P<0.01$) and WM ($P<0.05$) while, carcass features exhibited significant difference for LW and GW ($P<0.001$), SW and AFW ($P<0.01$) among the treatment groups.

For egg yield studies, a total of 384 day-old Fayoumi, indigenous, RIR and *Sonali* chickens were randomized in 16 diet groups, each containing 8 chickens with 3 replications, under four dietary treatment groups mentioned earlier for growth performance, egg production performance and egg quality performance. The growth performance parameters were day-old chick weight (DW), live weight at 20 weeks (LW), live weight gain (LWG), feed intake up to 20 weeks (FI), feed conversion ratio (FCR), final live weight at 48 weeks (FLW) and survivability (SB); egg production performance included egg weight (EW), age at sexual maturity (ASM), age at peak production (APP), egg production (EP), egg mass production (EMP), feed intake (FI) from 21 to 48 weeks and feed conversion ratio (FCR); and the egg quality parameters were egg weight (EW), egg shape index (ESI), albumen index (AI), yolk index (YI), albumen percentage (AP), yolk percentage (YP), shell percentage (SP), shell membrane percentage (SMP), shell thickness (STH), yolk colour score (YCS) and Haugh unit (HU). Analyses of the data on egg yield studies revealed that *Sonali* was the highest and indigenous the lowest followed by Fayoumi and RIR for EP. The indigenous chickens attained ASM and APP at the lowest production days while RIR at the highest production days. Moreover, the highest EP was found in T4 group and the lowest in T1 group followed by T3 and T2 groups. The T4 group chickens attained ASM and APP at the lowest production days while T1 group at the highest followed by T3 and T2 groups. Highly significant differences existed for EW, ESI, AP, YP, SMP, YI, STH and HU (P<0.001) among the breeds; while highly significant differences were found for ESI, SMP, AI, STH and HU (P<0.001) among the treatment groups.

To sum up, the present results demonstrate that the smallholder poultry farmers maintained sustainable production of their chickens which, in turn, improved the economic conditions of the growers as well as the nutritional status of the consumers in the region. Owing to their smaller size, popular meat characteristics, low cost and suitability for rearing under prevailing environment in the urban, semi-urban and rural areas, the crossbred *Sonali* chickens appeared to be commercially viable poultry birds in the study area. Since there was no detrimental effects of the feed supplement on the experimental chickens, it is therefore recommended that administration of suitable doses of VitA and EAAs to available poultry feed would result in enhanced growth, survivability, carcass characteristics, egg production and egg quality parameters. Supplement of EAAs only to the feed, however, would contribute to the increased productivity parameters of the chicken breeds under study.

LIST OF ABBREVIATIONS

Abbreviations	Full meanings
AA	Amino Acids
AFW	Abdominal Fat Weight
AI	Albumen Index
AP	Albumen Percentage
APP	Age at Peak Production
Arg	Arginine
ASM	Age at Sexual Maturity
b	Bird
BCF	Backyard Chicken Farms
BD	Bacterial Diseases
BDT	Bangladeshi taka
BM	Bio-Safety Measures
BM	Breast Meat
BW	Boundary Walls
CBR	Cost-benefit Ratio
cm	Centimetre
Contd.	Continued
CRO	Crossbred
CT	Chicken Transportation
d	day
DI	Disease Incidences
DKM	Dark Meat
DM	Drumstick Meat
DOC	Day-old chick
DW	Day-Old Chick Weight
DY	Dressing Yield
EAAs	Essential Amino Acids
EMP	Egg Mass Production
EP	Egg Production

LIST OF ABBREVIATIONS (Contd.)

Abbreviations	**Full meanings**
ESI	Egg Shape Index
et al.	*Et alia*
etc.	*Et cetera*
EW	Egg Weight
EXO	Exotic
FCR	Feed Conversion Ratio
FD	Fungal Diseases
FDC	Flock-Wise Disease Commonness
FI	Feed Intake
FLW	Final Live Weight
FM	Feeding Management
FY	Fiscal Year
g	Gram
GOV	Government farm
Govt.	Government
GR	Gross Ratio
GW	Giblet Weight
HPAI	Highly Pathogenic Avian Influenza
HR	Human Residence
HU	Haugh Unit
HW	Head Weight
i.e.	That is (*id est*)
IBD	Infectious Bursal disease
IND	Indigenous
Iso	Isoleucine
kg	Kilogram
L	Length
LSD	Least significant difference
LWG	Live Weight Gain

LIST OF ABBREVIATIONS (Contd.)

Abbreviations	**Full meanings**
Lys	Lysine
Met	Methionine
mg	Milligram
MP	Management Practices
ND	Newcastle Disease
No.	Number
NP	Net Profit
NRC	National Research Council
ns	Not significant
NW	Neck Weight
Obs.	Observation
PI	Profitability Index
PRI	Private Farms
RIR	Rhode Island Red
RRI	Rate of Return on Invest
RT	Room Temperature
SB	Survivability
SD	Standard deviation
SDP	Seasonal Disease Prevalence
SE	*Salmonella enteritidis*
SMP	Shell Membrane Percentage
SP	Shell Percentage
SPSS	Statistical Package for Social Science
STH	Shell Thickness
SW	Skin Weight
TCP	Total Cost of Production
THM	Thigh Meat
Thr	Threonine
Tk	Taka

LIST OF ABBREVIATIONS (Contd.)

Abbreviations	**Full meanings**
TM	Total Meat
TR	Total Revenue
Trp	Tryptophan
Val	Valine
VC	Vaccination
VD	Viral Diseases
VitA	Vitamin A
viz.	Videlicet (namely)
W	Width
WM	Wing Meat
WS	Water Source
wt.	Weight
YCS	Yolk Colour Score
YI	Yolk Index
YP	Yolk Percentage

LIST OF SYMBOLS

Symbols	**Full meanings**
♂	Male
♀	Female
×	Cross
˚C	Degree Celsius
π	Pie (22/7)
=	Is equal to
%	Percentage
±	Plus minus
<	Smaller than
>	Greater than
*	Significant at 5% level
**	Significant at 1% level
***	Significant at 0.1% level

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CHAPTER ONE

GENERAL INTRODUCTION

1.1 Background information

Bangladesh is an agro-based developing country in the Southeast Asian region. Poultry is one of the most important sectors for the protein source in Bangladesh. The indigenous (non-descriptive, *Deshi*) breeds are being reared in our country since long time ago. These breeds are like wild types and that are not cultured in a confined area (Haque, 1991). The exotic breeds like Rhode Island Red (RIR), Fayoumi and Cobb 500 (broiler) have been adapted with our climate due to rearing of these varieties for a long time and now they can easily reproduce their eggs. In Bangladeshi farms the *Sonali* variety of chicken breed is produced by crossing RIR cocks with Fayoumi hens. According to the latest estimate by the Bangladesh Poultry Industries Association (BPIA) and the National Council for Protecting Poultry Farms (NCPPF), the number of poultry farms up to June 2009 was 1,14,763, which gradually declined to 97,580 in December 2010; came down to around 72,580 in March 2011; and people associated with the poultry enterprise are approximately 50,000,00 (Gupta and Juel, 2011). However, chickens are considered as one of the most important and widely distributed avian species among poultry birds. It is a very good source of animal protein for human consumption. In comparison to other livestock, it requires less investment to start the farming. Persons from low-income group may also start the business on a small scale (Dutta *et al*., 2013). Therefore, productivity, management practices and disease incidence and feed supplement studies of the chicken breeds will reveal some important information that could be utilized to understand the breeds as well as to combat the common diseases in this highly economic commodity in Bangladesh.

1.2 Origin and domestication of poultry

Zoologically the fowl belongs to the genus *Gallus* of the family Phasianidae. The domestic fowl is called simply *Gallus domesticus*. The ancestors of the domestic chicken originated in Southeast Asia. It has been subjected to extensive breeding for size, colour patterns and conformation and egg laying ability during long domesticated history. Like other birds, it has a coating of feathers, no teeth, shoe-like appearance and legs with spars. The very presence of comb distinguishes it from other birds (Campbell and Lasley, 1975).

The term poultry applies to a rather wide variety of birds of several species and it refers to them whether they are alive or slaughtered and prepared for markets. The poultry also refers to domesticated birds, which are reared for their flesh, eggs and feather, and it includes a number of avian species such as chicken, duck, turkey, geese, swan, guinea fowl, peafowl, pigeons, pheasant and quail. But it is very often used synonymously to chicken. Fowls have a relatively high breathing and pulse rate, and body temperature ranges from 105°F to 109°F, which is higher than that of other domestic animals. In the twentieth century, poultry keeping has become an important small-scale industry due to modern need for palatable and nutritive food, which it provides in the form of eggs as well as meat (Banarjee, 1992). The domestic fowl *Gallus domesticus* belongs to the Phylum Chordata, Sub phylum Vertebrata, Class Aves, Subclass Neornithes, Order Galliformes, Family Phasianidae (Das, 1994). The storage and transport facilities also have helped to a great extent in its becoming popular at large and the scientists in particular necessitating new research on breeding, hatching and rearing of fowls.

Poultry is believed to be originated from ancient winged creature called *Archaeopteryx* at about 150 million years ago. It includes those species of birds, which render man an economic service and reproduce freely under his care. Poultry has a very long history of origin and domestication. The development of breeds and varieties come later and the attempt of improvement of poultry as a source of egg and meat is only recent. The whole group of birds is called Aves, a Latin word meaning a bird. They comprise many Orders and Families. Poultry is classified as Order Galliformes or as Anseriformes. The Order Galliformes includes the domestic fowl *Gallus domesticus*, the Turkey *Meleagris gallopavo*, the Quail *Coturnix coturnix*, the Guinea Fowl *Numida meleagris*, and the Pheasant *Phasianus colchicum*. The Order Anseriformes, on the other hand, includes the domestic duck *Anser platyrhynchus,* the Muscovy duck *Cairina moschata*, and the geese *Anser anser* and *Anser cygnoides*. The chicken (domestic fowl), the turkey, the quail, the guinea fowl and the pheasant belong to the Family Phasianidae. The domestication of the ancestors of modern breeds of poultry was brought about largely as a result of their economic importance in providing eggs and meat for human consumption (Carmen and George, 1997).

1.3 World-wide distribution of poultry

Poultry producers have a global perspective concerning poultry in order to know which countries are potential competitors and what is ahead. The leading chicken producing countries like. China holds a commanding lead in chicken numbers, 1321 million followed by 718 million in USSR, 379.2 million in USA, 280 million in Brazil, 245 million in Japan, 205 million in France, 166.9 million in Poland, 162.9 million in Mexico and 142 million in India. The major poultry breeds in the world are The American breeds Rhode Island Red (RIR), Plymouth Rock, Jersey black giant, New Hampshire and Wyandotte. The Asiatic breeds are Brahma, Cochin and Langshan black. The English breeds are Australorp, Cornish (dark), Dorking (silver gray), Orpington (buff and white), Sussex and Red cap. The Mediterranean breeds are White Leghorn, Minorca (S.C. black), Ancona and Andalusian (blue) (Banerjee, 1992).

Poultry farming in India has registered a phenomenal growth during the past few decades. From a gross annual value of production of less than Rs. 40 cores in 1960, when commercial poultry farming first started, it crossed Rs. 1000 cores in 1985 and Rs. 1400 cores in 1989 (Prasad, 2000). In the present days the per capita availability of egg in the country is just 20 as compared to 400 eggs in Denmark, 340 eggs in the USA and 250 eggs in the UK. About 150 million broilers are produced in every year. Yet the availability of broiler meat per head per year is only 265g as against 20 to 30kg of broiler meat per capita consumption in developed countries. Farmers with floor and flat deck systems are also asking for these birds, as they just seem to be stronger and perform better in the later production stage (Mack *et al.*, 2005).

Despite the rapid development of commercial poultry systems world-wide, it has been estimated that still more than 80 percent of the global poultry population occurs in traditional family-based production systems and that the latter contribute up to 90 percent of the total poultry products in many countries. The large scale commercial and small-scale rural family poultry sectors need not be mutually exclusive, nor be in direct competition. Indeed, the commercial sectors with its wealth of human, technical and financial resources could play a major catalytic role in promoting rural poultry production as a practical and viable option for poverty alleviation.

1.4 Poultry production schemes in Bangladesh

The poultry production system has invented a number of technologies for increasing productivity and contributed substantially to generate income and reduce poverty, gender empowerment and nutritional enhancement for building a poverty free and healthy society. A suitable farm is the prime need for the raising of poultry birds in the intensive methods. The farming arrangement varies according to prevailing weather condition of the locality and system of poultry rearing. However, there are four systems of poultry farming generally found to follow among the poultry keepers (Prasad, 2000). These include: (1) Free-range system, (2) Semi-intensive system, (3) Folding unit system and (4) Intensive system. The latter is of two types, *viz*., cage or battery system and deep litter system.

***Free-range system*:** The poor farmers keep small number of poultry birds in this system. It is one of the oldest methods. This method is generally adopted where there is no shortage of land. Rearing of Indigenous (*Deshi*) fowls in this system is profitable enterprises. The poultry birds find appreciable amount of feeds in the surroundings during daytime and take shelter in a house during night. This method is not suitable for commercial poultry farming.

***Semi-intensive system*:** This system is adopted where the amount of free space availability is limited. The house and run is situated in small land surrounded by wire mesh. The poultry birds spend the daytime in the run and take shelter in apex hut during night. The birds should be provided 3-4 square feet per bird in the house and 150-200 square feet in the run. The space may be divided giving a run on either side of the house.

***Folding unit system*:** This system of poultry farming is an innovation of recent years. The poultry birds should be provided one square feet space in the house and 3 square feet in the run. The folding house measuring 5 square feet wide and 20 feet long is suitable for 25 birds. The whole area (side and top) is surrounded with wire netting.

***Intensive system*:** This system is usually adopted where land is limited and expensive. The birds are entirely confined to the house. Intensive systems of poultry rearing are of two types in this fashion cage or battery system and deep litter system as well.

A. *Cage or battery system*: The cage system is the latest contribution of the inventor for the poultry lover of the town. The cage system is gradually gaining popularity and is useful for those having small quantity of floor space at their disposal. In this system, the birds are confined in a cage just large enough to permit very limited movement and allow the bird to stand and sit comfortably. The usual floor space of cage is 14 by 16 inches and the height is 17 inches. The floor is made with strong galvanized wire and a tray is fixed underneath the floor for collection of dropping. The feeder and waterer remain outside of the cage. It is mostly used for commercial egg production. Cage system can be used for birds of all age groups and in all climate conditions.

B. *Deep litter system*: Deep litter system is widely used for scientific and successful poultry farming in all over the world. In this system, poultry birds are kept in large pen up to 250 birds each in a house, whose floor is covered with dry litter up to a depth of 20 to 30 cm. Rice husk, saw dust, dried leaf, chopped straw and ground nutshells depending upon their availability, can be used as litter materials. It resembles to dry compost.

Bangladesh is a good example of how poultry can have an impact on the empowerment of the poorest women and on poverty reduction. The present day poultry were the wild jungle birds and lived in the forest. The forest provided their protection from sunlight, they laid their eggs very few and maintained their range to each they belong on basis of survival of the fittest. The domesticated birds required proper housing for their protection as well as the production of more eggs and meat. The poultry house should be designed to protect birds from extreme weather, parasites, predators and thrives and also to avoid the spread of infections and contagious diseases (Nielsen, 1998). However, according to Mountney and Parkhurst (2000), the followings should be considered at the initiation of poultry farming such as, the poultry farm should be located at a convenient place where there is good market for eggs and meat and at the same time the common poultry feeds should be readily available at cheaper rates. The farm should be well connected with roads and other modes of transportation having no poultry farm nearby. It should be located at a place where electricity and water is available at reasonable cost and ease. The high land with loamy soil should be selected for poultry farm as they provide good drainage. There should have enough space for future expansion and should be located in the open space for good ventilation.

The smallholder concept developed in Bangladesh through an adaptation process conditions in Malawi (Jensen, 2001; Gondwe *et al*., 2001) and Southern Africa. The adaptation process is rather complicated, as all stakeholders have to be involved and need to be convinced that the poorest segment of the village population is capable of contributing and managing an income-generating activity based on loans. According to a survey (Karim, 2001), the per capita egg and meat production in our country were 28 pieces and 5.27 kg, respectively, whereas the actual needs were 120 and 9.5 kg, respectively. It was estimated that the rural farmers in the homestead of Bangladesh raise 77.29% chicken and 84.41% duck (Khan, 2003), while the status of poultry production in the country was estimated to be at 140 million chickens and 13 million ducks (FAO, 2003). Livestock plays an important role in the national economy of Bangladesh with a direct contribution of around 3% percent to the agricultural GDP and providing 15% of total employment in the economy particularly for the rural poor that are the functionally landless. According to Bangladesh Economic Review (2006), the growth rate in GDP in 2004-05 for livestock was the highest of any sub-sector at 7.23%, compared to 0.15% for crops and 3.65% for fisheries sub-sector. About 75% people rely on livestock to some extent for their livelihood, which clearly indicates that the poverty reduction potential of the livestock sub-sector is high (NLDP, 2007). These changes have been prompted by a rapid growth in demand for livestock products due to increase in income, rising population and urban growth.

Literature survey revealed that there are only about 52,000 registered farms in Bangladesh although there exists some 3 lac farms in the country (Islam, 2008), which support overall 1.6% of the GDP (Parvez, 2008). According to an estimate (Billah, 2008), we need from 4.5 to 5 metric tones of processed broiler chicken as meat per day, poultry can provide 90% protein in which the percentage of processed chicken is only 15%, and about 1.75-2.00 lacs chicken are consumed by human per day only in Dhaka City. Faruque *et al.* (2009) described that the chicken, duck and pigeon are the most popular poultry genetic resources in Bangladesh. Dutta (2010) studied the productivity and management practices of the poultry breeds in Rajshahi City Corporation areas. The mortality and disease status of layer chickens of commercial layer farms has been observed by Uddin *et al*. (2011). Etiological analysis showed that the highest mortality caused by bacterial diseases (7.08%), followed by viral diseases (5.81%), fungal diseases (2.18%) and mycoplasmosis (1.89%).

Dutta *et al*. (2012a) investigated the production performance and economic efficiencies of broiler of Cobb 500, cockerel of ISA Brown, Fayoumi, Rhode Island Red and *Sonali* available in Rajshahi. Bhuyian *et al*. (2013) analyzed the farmers' communication exposure and knowledge in poultry farming. Findings revealed that the exposure to communication media for poultry farming had a positive and significant relationship with only education. Huque and Sarker (2014) reported that diversification and production of quality feeds and fodders, synchronization of feed production and availability to animals, conservation and improvement of new pasturage systems, mitigation of climate change impacts and domestic protection to feed safety and quality feed import are some of the options forward to increased supply of feeds and fodders help increased production and productivity of farm animals in the country.

1.5 Poultry management practices

At present it has become imperative to know the techniques of scientific poultry keeping as modern poultry keeping has become as much as an art. It is essential to combine scientific principles with arts of poultry keeping reaping the best harvest. The management of poultry birds requires the following considerations:

Housing**:** The chicken should be kept in a clean dry and well-ventilated room. Poultry house should have proper ventilations as this provides the birds with fresh air and the poultry house should have wire screening (Das, 1994). For egg type pullets (small strain) of 0 to 18 weeks and 18 to 21 weeks the standard floor space is 0.13 sq. ft. and 0.18 sq. ft. respectively. The egg type pullets of medium and large strains of 0 to 18 and 18 to 22 weeks the ideal floor space is 0.18 sq. ft. and 0.20 sq. ft. respectively. The floor space of egg type breeder pullets is 0.22 sq. ft. and the egg type breeder cookeries are 0.25 sq. ft. Obviously the meat type pullets and meat type cookeries should have the floor space of 0.30 sq. ft. and 0.40 sq. ft., respectively.

Purchase of chicks**:** The improvement and high yielding chicken should be purchased from a reputed farm or farm maintaining high yielding birds supervised by expert geneticist who are producing there hybrid yielder through proper breeding.

Brooding**:** After receipt of the chicks they should be put in well-heated brooder, which should be run 24 hours before the arrival of the chicks with proper temperature of 90º to 95ºF with adequate dry litter on the floor duly covered with thick papers to avoid litter eating by these young chicks during first three or four days of their lives. The brooder provided with chicks guard to avoid straying of chicks for off places away from heat zones during these earlier stage. During the first 6 weeks of chicks' life the temperature of the brooder is to be reduced by 5ºF every week starting from 90ºF from the first day as per season (Das, 1994).

Chicks' management in brooder**:** Chicks' management in the brooder follows the adjustment of temperature as per requirement of the chicks. Chicks should not get access to heated parts of the lamp at any cost. In case of dampness, however, a deep litter can solve the problem. Discourage litter eating by the chicks scatter mash over egg case flats when the chicks are first taken out of their boxes keep chicks hoppers filled. Keep provision for the entrance of fresh air. Clean fresh water should be provided to the chicks. Chicks after 3 weeks old may be provided chopped green grasses. Clean daily the brooders including feed hoppers and follow a regular vaccination programme with daily inspection of birds and their faces to sort abnormality (Banerjee, 1998).

Vaccination programmes**:** The successful poultry rearing depends solely on routine vaccination programmes during rearing periods. At the day-old stage Mareck's vaccine is to be administered for the chicks. On the 4^{th} day the chicks are required to be given vaccine through nasal drop to protect them against disease or Mareck's vaccine is administered on the first day. At six week, these chicks are again given a short of R 2B vaccine to protect them for life against fowl pox. At the end of 17 weeks these are to be given a booster dose of the R 2B vaccine (Lakhotia, 2003).

De-beaking**:** The most important management task of poultry bird next to vaccination is de-beaking. Chicken should be de-beak to prevent feed wastage, feather picking and cannibalism. The 6^{th} to 8^{th} day of old is the ideal age for de-beaking. A combined hot blade or electrical de-beaker should be used to execute this job. About one half of both the upper and lower beak is removed, keeping the lower beak slightly longer than the upper (Kobbaduzzaman, 2000).

***Feed and feeders*:** The growing birds should be provided ration crushed maize, may be fed in paper or chick boxes lids or on plastic filler flats for two days chick size feeders through type is ideal. Small quantities of feed should be fed at a time but often during first 2 to 3 days. The chick should be fed starter mash containing 20-22 percent protein and 2400 to 2500 calories/µg met abolished energy for the first 6 weeks of age.

***Waste management*:** Poultry manure is an extremely rich source of nitrogenous and organic materials. Hence it is highly regarded as a fertilizer. Poultry droppings are higher than cow-dung in nitrogen, phosphorus and potassium content. The manure either may be pure droppings of the birds or used old built-up litters, which are cleaned either every year or once in every two years. A laying hen produces about 220g of fresh dropping (75% moisture) everyday. Poultry industry is also producing by-product such as bones and feathers while, the neighbouring countries earns about 4.54% of the total foreign exchange (DLS, 1998). Above all, the sub-sector is supplying on an average 42.54% of the animal protein in the form of meat and eggs (BBS, 1998).

Al-Amin *et al*. (2009) evaluated the droppings disposal in layer farm and measures adapted to protect environmental pollution. Findings exposed that droppings disposal is a real problem for aesthetic, public safety and environmental point of view. Cleaning technique and tools desired to be modernized for efficient and cost effective cleaning. Sharma (2010) studied the poultry production, management and bio-security measures and found that poultry health management is important due to emergence of highly pathogenic diseases like Highly Pathogenic Avian Influenza (HPAI) in different parts of the world. Bio-security measures become vital for better performance and quality of poultry production in competitive world.

Dutta *et al*. (2012a) investigated the management practices, incidences of common diseases, uses of indigenous knowledge (IK) and conditions and problems of the poultry farmers in some selected areas of Rajshahi, Bangladesh. Findings revealed eighteen parameters on management practices, 13 diseases, 20 indigenous knowledge items, 11 problems encountered and top 10 opinions of the poultry farmers were identified. Satisfactory to good management practices were recorded for indigenous in Godagari and that for exotic and crossbred in Rajpara. All the remaining farms practiced moderate to unacceptable management practices. Musa *et al*. (2012)

found that manage poultry wastes under intensive production system led to the discovery of suitable poultry droppings and litter materials. Litter type and management are dependent upon cost, availability and quality of materials used. Economic losses as a result of poor litter and poor liter management are significantly high. The facts discovered that careful selection, adequate management and proper storage and utilization of poultry litter are of paramount importance to reduce environmental pollution, disease spread and economic losses. Bhuyian *et al*. (2013) analyze the farmers' communication exposure and knowledge in poultry farming. Findings revealed that the exposure to communication media for poultry farming had a positive and significant relationship with only education. Wang *et al*. (2014) reviews the social, economic and political elements of poultry production. They discover that under increased public concerns on bio-security, integration of the small scale poultry producers into safe and high value production chains is a key political issue in developing countries.

1.6 Incidences of poultry diseases and their management

In Bangladesh, farmers face a wide range of poultry diseases, which reduce the optimal production of the flock. Ali (1994) reported that, about 30% mortality of chickens in Bangladesh every year due to outbreak of several diseases. The prevalence of diseases in a particular area depends on various factors like geo-climatic condition, management practices, immunization status, social awareness etc. To establish commercial poultry farm, the incidence of diseases should be considered for prevention and control of diseases. The high incidence of diseases is one of the major constraints to smallholder poultry production systems (Gueye, 2002). However, an earlier introduction of LPAI virus (H9N2) in backyard chickens tested during 2000-2003 was sero-positive for AI virus (Alam *et al*., 2003). Subsequently, Bhuiyan (2007) mentioned an environment-friendly poultry waste management system. In the March 2007, HPAI was first recognized in Bangladesh, although neighbouring countries like Pakistan, India and Myanmar experienced HPAI outbreaks in domestic poultry in early 2006 (Islam and Giasuddin, 2007; FAO, 2007). During the outbreak, bird-flu was reported from 306 incident points covering 136 Upazillas, 14 Metropolitan Thanas of 47 Districts, where around 1.67 million birds were culled and disposed off (Alam *et al*., 2008). Alamgir *et al.* (2008) suggested not be scaring of bird flu, but emphasizing to increase awareness in common people which would be the best solution for preventing the disease.

Khan (2008) mentioned that the poultry farming was at extreme danger in Bangladesh while ICDDR, B (International Centre for Diarrhoeal Disease Research, Bangladesh) reported that in Bangladesh backyard poultry system maintains most of the demand and they are maintaining the original genotype of the fowls for research. The Directorate General of Health Services (DGHS) reported that monitoring poultry workers with H5 influenza exposure in Bangladesh was essential (DLS, 2008) while Miazi (2008) mentioned some procedures of the Fayoumi and *Sonali* chicks under vaccination programme and Ibrahim (2008) suggested some bio-security measures for small flock owners of the country against AI. The presence or absence of AI virus is detected in the country at 17 primary labs in Joypurhat, Gaibandha, Feni, Sylhet, Barishal and Manikganj (Haque, 2008). Epidemiologically the viruses spread initially to native chickens and then to the commercial farms through the market chain because of the breaches in bio-safety practices (Alam *et al*., 2009). Hasib (2010a, 2010b) cautioned about the coming back of bird flu because recurrent attacks of this disease were found in several poultry farms of Bangladesh.

Amongst the most ordinary *Salmonella* infections in poultry, *Salmonella typhimurium*, *Salmonella enteritidis* and *Salmonella heidelberg* infections may be produced by 10-20 different serotypes (Carrique-Mas and Davies, 2008). Some species or strains are more pathogenic than others. The prevalence of other species differs widely spatially and temporally (O'Bryan *et al*., 2008). Transmission normally occurs horizontally from infected birds, contaminated environments, feed or infected rodents (Babu and Raybourne, 2008). *Salmonella* spp. infections in poultry are comparatively common and have public health importance due to the consumption of contaminated poultry products (Vandeplas *et al*., 2010).

Avian coccidiosis is a parasitic disease of intestinal tract caused by single cell protozoan parasite belonging to genus *Eimeria* (Dalloul and Lillehoj, 2005). Coccidiosis has been considered as a very harmful disease affecting growth and performance of birds in the intense poultry (Lin *et al*., 2006; Mujahid *et al*., 2007; Bachaya *et al*., 2012) and contributory factor in the pathogenesis of several diseases (Kris-Etherton *et al*., 2004; Shahzad *et al*., 2012). It causes massive destruction of the epithelial cells, which leads to bloody diarrhoea, reduced weight gain and temporary reduction in egg production (Razzaq *et al*., 2011). Control of coccidiosis mostly depends upon the chemoprophylaxis by using anticoccidial drugs, however, managerial skills are also important to get maximum anticoccidial effect of these drugs (Tewari and Maharana, 2011). Seven species have been recognized to infect poultry according to site of infection, immunogenicity and pathogenicity (Williams, 1998; Akhtar *et al*., 2012).

Newcastle disease is one of the most common and serious disease in Bangladesh affecting commercial as well back yard poultry. It is caused by paramyxo virus Type-1 called ND virus. It belong to the family paramyxoviridae based on pathogenicity the virus can be differentiated in to lentogenic, mesogenic and velogenic strain. The disease is endemic, all ages are generally susceptible and natural resistance increases with aging (Anjum, 1997). Infectious bursal disease (Gumboro disease) is highly contagious of young chicken caused by infectious bursal disease virus characterized by immune suppression and mortality generally at 3 to 6 weeks of age. The disease was first discovered in Gumboro, Dilaware in 1962. It is economically important to the poultry industry worldwide due to increased susceptibility to other disease and negative interference with effective vaccination (Anjum, 1990; Balamurgan and Kataria, 2006).

The usual source of infection for healthy commercial and village chickens are infected chickens which are suffering from the disease and shedding the virus and those that are incubating the virus and shedding them at the same time (Nwanta *et al*., 2008). In contrast to developed countries that are mainly rearing industrialized poultry, family poultry represents one of the most important sub-sectors of livestock of Bangladesh. Studies have shown that about 80-90% of rural households keep poultry (Das *et al*., 2008), and family poultry is raised by about 90% of total population of Bangladesh (Dolberg, 2008). These poultry contribute the protein need of the country and also represents a sustainable source of income of villagers. The rural poultry handlers are interested to know about possible steps to block transmission of similar outbreaks of infectious diseases. Almost few studies have been conducted at Bangladesh to address their queries. It is true that studies have been conducted in mainly developed countries about possible blocking of transmission cycle of infections agents (Sims *et al*., 2005; Ellis *et al*., 2006; Khan *et al*.,2009; Martin *et al*., 2010; Cecchinato *et al*., 2011). The scarcity of information on the presence and prevalence of the above diseases in backyard chickens may reflect a lack of resources for disease surveillance and control in backyard production systems.

1.7 Performance of indigenous, exotic and crossbred chicken breeds

In the Indian Sub-continent the following four wild chicken species available such as the Red Jungle Fowl (*Gallus gallus*), Gray Jungle Fowls (*Gallus sonnerati*), Cylon Fowl (*Gallus lafayuttii*) and Green Jungle Fowl (*Gallus rarius*) (Beede, 1931). The *Gallus bankiva* is believed to be the major contributor to the development of modern commercial breeds (Lush, 1945). Among the native fowls there are some distinct categories namely Hilly, Naked neck, Aseel, Yasine, Native dwarf and Non-descriptive *Deshi* (*Gallus domesticus*). Collection, evaluation and conservation of different genotypes are required due to future changes in the environment, management and food habits (Crawford, 1984). Indigenous chickens are reported to be derived from the *Gallus gallus* (Faruque *et al*., 1987). A random mated and unselected indigenous population is a huge treasure of variable genotypes (Yeasmin and Howlider, 1998). Many researchers have made their efforts to develop high yielding breeds using the indigenous chicken.

Indigenous chickens have an inherent scavenging habit as they are more resistant to diseases, less prone to predator attacks and can survive under harsh nutritional and environmental conditions. However, their productivity under scavenging conditions is very low as some 35-45 eggs per year. Yeasmin and Howlider (1998) studied the production potentials of indigenous non-descriptive *Deshi* and native dwarf chickens under intensive rearing conditions. The dwarf chickens were found to have smaller body size, but higher egg production and better-feed conversion efficiency. The dwarf gene of indigenous chicken was found to be autosomal recessive in nature. They concluded that indigenous dwarf chickens are superior to their non-descriptive *Deshi* counterparts in egg production and should be used for developing egg type birds suitable for rural conditions. A selective breeding programmer has been initiated in BLRI (Bangladesh Livestock Research Institute), with some native chicken genotypes under intensive production system. Among the five genotypes the Naked neck, Non-descriptive *Deshi* and Hilly were found to have the highest production potentialities under intensive management system of rearing (Haque *et al.,* 1999).

Exotic breeds like Australop, RIR and White Leghorn are suitable for commercial poultry farm (Latif, 1981). These breeds are not well adjusted to farmers' condition of rearing. The exotic breeds such as Rhode Island Red and Fayoumi has shown good performance under farm condition. The nutritional and disease problem are the major constraints in Bangladesh for the development and maintenance of poultry. In Bangladesh, commercial poultry farms are few and most of our demand is fulfilled from the rural source where the farmers rear the chicken under the scavenging system. Selection of suitable breed and adequate knowledge of poultry management practices results in profitable poultry production (Mahapatra, 1990; Amin, 1990) which are lacking in traditional poultry rearing systems.

The Fayoumi chicken breed has been imported with the expectation of better productivity, adaptation and disease resistance. They are originated in Egypt, reported to be a hardy breed and particularly well suited to hot climates (Heinrichs, 2007). They are also very good foragers, and if left to their own devices on a free range basis they can fend for themselves in a nearly feral manner. Fayoumi hens are good layers of small white eggs. They are not given to broodiness as pullets, but can be when they reach two or three years of age. The breed is fast to mature, with hens laying by four and half months (Ekarius, 2007).

The crossbred *Sonali* derived from RIR male and Fayoumi female has the best performance with the highest egg production, lowest mortality and highest profit per hen among eight crossbreeds tested under rural conditions of Bangladesh. The Sonali reared in scavenging systems require feed supplementation in order to improve their egg production. The scavenging hens are allowed to scavenge for feed resources in the surroundings of the homestead during parts of the day. The *Deshi* hens normally do not receive extra feed, but several studies have shown that in order for the Sonali to fully improve egg-laying capacity they need to be supplemented with extra feed (Rahman *et al*., 1998a, 1998b). Ali (2002) found that at least 60g of feed supplementation is needed for the scavenging crossbred birds for viable production and that the amount of supplementation is dependent on location, availability of feed resources around the farmer's house and economic condition of the farmer. Rashid (2003) found that the birds fed supplemented feeds significantly improved production performance, shell thickness and yolk color index compared to the birds under fully scavenging system of rearing. However, the economic analysis showed that the cost of feed spent for supplementation might not be economic for laying hens. Therefore, protein supplementation is more essential than energy in the scavenging poultry production systems.

1.8 Impacts of smallholders' poultry production in Bangladesh

In developing countries nearly all families at the village level, even the poor and landless, are owners of poultry. Furthermore, poultry are mainly owned and managed by women and are often essential elements of female-headed households. Family poultry production represents an appropriate system to contribute to feeding the fast growing human populations and to provide income to poor small farmers, especially women (Gujit, 1994; Alders, 1996; Kitalyi and Mayer, 1998). It makes good use of locally available resources, requiring low inputs. The role of family poverty alleviation, food security and the promotion of gender equality in developing countries is well documented (Gueye, 2000a; 2000b).

Village chickens are active in pest control, provide manure and are required for special festivals and essential for many traditional ceremonies (Alders *et al*., 2003). Production is feasible at village level, where only low cost technology is needed to improve production considerably. Low investments only are required to achieve such change, land ownership is not a constraint, and village production is environmentally friendly (Upton, 2004). Though generally considered secondary to other agricultural activities by smallholder farmers, poultry production makes an important contribution to supplying local populations with additional income and high quality protein. Poultry products can be sold or bartered to meet essential family needs such as medicine, cloths and school fees.

Smallholder backyard chicken production is a subsistence activity, providing egg and meat for family consumption and to some extent, cash income (Farooq *et al.,* 2004). Fattah (2000) and Dolberg (2003) described the evolution in the work of the government of Bangladesh, which led to the development of the Bangladesh Poultry Development Model, which has been very effective in reaching and involving poor women in economic development. Dolberg (2003) contrasts the Bangladesh experience to that of India where, in some States, the commercial sectors has a strong presence. Despite their increased productivity, exotic and hybrid chickens often face great problems because of their susceptibility to diseases and less adaptability to environment in comparison with their native counterparts (Islam, 2003; Kingori *et al*., 2010). Accordingly, attempts have been made to increase disease resistance through vitamin A and amino acids supplement in chickens (Bhuiyan, 2004).

Further studies on cost-benefit analysis (Alabi and Aruna, 2005; Nworgu, 2007), common poultry diseases (Butcher *et al*., 2009), morphometrics of egg and body parameters (Islam and Dutta, 2010a; 2010b) and management practices of indigenous, exotic and hybrid chickens have been carried out. Islam *et al*. (2010) examines the existing scenario of the small-scale broiler farming in Bangladesh. The potentials of small-scale independent broiler farms and farmers' economic behavior in relation to farm size. Farm size is found to be closely related to farmers' behavior and attitude. Farmers' behavior and attitude appeared to be very crucial factor for the development of broiler production. Begum *et al*. (2010) examines the technical, allocative and economic efficiency of poultry meat production based on farm level survey. The findings are valuable to policy makers and extension workers in order to guide policies towards increasing efficiency.

Hossen *et al.* (2012) outlined some major concerns focusing on the entire problems of *Sonali* farming in Bangladesh. They consider some points as comprehensive issues towards the government that should adopt a system of approach for high productivity. Sultana *et al*. (2012) conducted a survey for profiling the existing broiler farming and considered some facts useful to farmers and researchers to identify the overall problems and their remedies on management and marketing related to broiler production. Ali and Hossain (2012) analyzed problems and prospects of poultry industry in Bangladesh. They identified the various aspect relating the growth and sustainability of poultry industry in Bangladesh. They proposed for providing subsidy to the local industry and protect safeguard to the local entrepreneur of the poultry industry.

Chowdhury (2013) review the current status of family poultry production in Bangladesh and found that family poultry with commercial hybrids is more challenging because of their small flock size which needs continuous technical support and a well planned biosecured environment. Khaleda and Murayama (2013) reported some constraints in value chain development mainly those related to its physical and infrastructural environment to verify the potential of microenterprises through an analysis of their geographic concentration in sites with different suitability levels and suggested recommendations as to how to overcome the constraints, with a view to ensuring higher profit levels for vulnerable poor.

Alam *et al*. (2014) observed the present status of backyard poultry production system. The backyard poultry farmers are low producers and chickens were found to be the most common poultry species reared by the farmers. Islam *et al*. (2014) analyzed the challenges and prospects of poultry industry in Bangladesh. Findings observed that to import poultry related products huge amount of valuable foreign exchange will be spent. Further it proposed for providing subsidy to the local industry and protect safeguard to the local entrepreneurs of the poultry industry. These led to design the present investigation in view of adding valuable information towards a better understanding of smallholder chicken farming system in Rajshahi Metropolis.

1.9 Poultry meat and egg production schemes and their significance

Poultry is one of the best tools for poverty reduction throughout the world. Smallholder backyard chicken production is a subsistence activity in providing egg and meat for family consumption and to some extent, cash income (Farooq *et al.*, 2004). A chicken starts laying when they are about six months of age. The broilers take only 1.9 kg of feed protein to produce 1.0 kg of broiler protein. Since they start laying at their age of six months, the farmer also starts getting return so early. A broiler pays them within 2-2.5 months. Farmers occasionally experience crop failures due to unaffordable weather conditions when poultry rising as mixed farming will tend stabilize farm income. Poultry farming offers opportunities for full time or part time employment particularly for women, children or elderly people on the farm operation. Factories for producing liquid egg, egg powder, dried yolk etc. may help for further employment opportunities (Kobbaduzzaman, 2000).

The nutritive value of poultry eggs and meat is very high. The egg most nearly approaches a perfect balance of all the nutrients among all the foods available to man. This is evident by the fact that the egg is the total source of nutrition for the developing embryo. Chick requires all the essential nutrients that we need for growth, maintenance, lactation and reproduction. The edible portion of the egg is made up of the yolk and the albumen. Nutritionally, people eat poultry for its high quality protein and its low fat content. Chicken meat is higher in protein and lower in fat than beef and other red meats (Lakhotia, 2003).

Poultry convert feed into food products quickly and efficiently. Their high rate of productivity results in relatively high nutrient needs. Poultry require the presence of at least 38 nutrients in their diets in appropriate concentrations and balance. The nutrient requirement figures published in Nutrient Requirements of Poultry (NRC, 1994) are the most recent available and should be viewed as minimal nutrient needs for poultry. Criteria used to determine the requirement for a given nutrient include growth, feed efficiency, egg production, prevention of deficiency symptoms, and quality of poultry product.

Optimum concentrations of vitamins in poultry diets allow today's poultry to perform to their genetic potential. Vitamin requirements established decades ago do not take into account the modern genetically superior birds with increased growth, egg production and improved feed efficiency. Vitamin intake per unit of output is continually declining. The yearly decline for layers is around 1% per egg produced, while for broilers has been 0.6-0.8% per kg body gain. Also vitamin allowances today need to take into account modern management procedures that increase bird densities and stress conditions for the producing birds. Vitamins are important for maintaining optimum immune response. Higher levels of vitamins for example, vitamins A, E and C have been shown to increase overall health by improving disease resistance as a result of improved immunity (McDowell, 2004). Amino acids which are said to be essential cannot be synthesized by the bird. These essential amino acids must therefore be fed in order to supply the building blocks needed in the synthesis of body proteins thereby supporting growth. When supply of a single amino acid does not meet the bird's requirement, it is considered to be limiting. At any given physiological stage of growth or age, a specific amino acid profile is needed to support optimal growth, with no limiting amino acids or surpluses. This profile has been termed an ideal ratio, or ideal protein (Dozier *et al.*, 2008). However, the smallholder poultry farmers might ensure sustainable production of their chickens, which in turn might improve the economic conditions of the growers and nutritional status of the consumers (Islam and Dutta, 2014).

1.10 Aims of the present study

From the current situation of small-scale production units, it has become essential to get some clear-cut conception on financial statement of poultry production scenario in the country. So, the present study was designed to evaluate the production performance and economic efficiencies of different genetic group of chickens available in Rajshahi. These findings would be valuable to the policy makers and extension workers in order to guide policies towards increasing efficiency of the poultry enterprise in Bangladesh. In view of diverse facts and circumstances discussed above, the present study was undertaken in Rajshahi, Bangladesh, with the following objectives:

1. To study the productivity of the poultry farms under smallholders' conditions;
2. To estimate the profitability index (PI) in the Govt., private and backyard poultry farms;
3. To study the management practices adopted by the poultry farm owners;
4. To study the disease incidences in the chicken breeds at the study area; and
5. To study the meat and egg yield efficiency of the selected chicken breeds by feed supplement experiments with vitamin A (VitA) and essential amino acids (EAAs).

The study will in turn might address many such questions as productivity status of poultry breeds in the country, their management practices, disease incidences including why farm chickens are susceptible to the highly HPAI (highly pathogenic avian influenza) or other diseases compared to the domesticated and wild birds, and profitability analyses of different breeds and farms under study. This obviously would enrich our understanding for better and healthy poultry enterprise in the country.

CHAPTER TWO

REVIEW OF LITERATURE

In Bangladesh, relatively little work has been done on the productivity, management practices and disease incidences of the available varieties of chicken breeds *viz*., broiler, cockerel, Fayoumi, indigenous, RIR and *Sonali* (RIR♂ × Fayoumi♀) throughout the country. For the betterment as well as upgrading of the chicken breeds, some feed supplement experiments with vitamins and amino acids have been reported sporadically. Therefore, a thorough review of literature on the above topics has been furnished in the following paragraphs.

2.1 Productivity study under smallholders' conditions

Productivity of rearing chicken breeds depend on a variety of factors for instance quality of chick, growth rate, feed efficiency, survivability, marketing age and market prices. Evidently, there are variations mostly due to management practices in addition to inherent genetic makeup. Literature related to productivity of the chicken breeds is reviewed below.

Alabi and Aruna (2005) assessed the technical efficiency of family poultry production. The technical efficiency estimate shows that the technical efficiency of family poultry ranges between 0.09 and 0.63, with mean of 0.22.They concludes that the output and technical efficiency of the family poultry production can be increased by the use of more feed, capital, medicine/vaccine and adoption of more innovations.

Roy *et al*. (2006) investigated production performance and economics of producing cockerels (Shaver 579 male chicks) up to different market weights. The average cost of rearing per bird was Tk. 66.42, 62.65 and 59.72 for market weight of 500g, 750g, and 1000g, respectively.

Nworgu (2007) conducted an experiment to assess the weight gain and the economic importance of broiler chickens. Broiler chickens can be served 30 to 120 ml of fluted pumpkin leaf extract (FPLE) per litre of water at 4 days interval during the hot period of the year to stimulate feed intake, increase weight gain and profit margin. The birds served 120 ml of FPLE per litre of water for 8 weeks had the best performance in terms of weight gain, profit, cost-benefit ratio and cost of feed per kg live weight gain.

Maqbool and Bukhsh (2007) documented the major contribution of poultry consumption in improving per capita nutrients level and suggested the policy of further improvement by lowering the prices at the consumer level and by improving the profitability of producers.

Sarkar *et al*. (2008) conducted an experiment on 'Comparative study on the productivity and profitability of commercial Broiler, Cockerel of a layer strain and cross-bred (RIR♂ x Fayoumi♀) chicks' and reported that commercial broiler, cockerel and cross-bred chicks could be reared up to 28, 56 and 63 days, respectively to reach target weights close to 1250, 850 and 850g, respectively to obtain maximum profit.

Zaman *et al*. (2008) studied the performance and cost benefit ratio of four genotypes of chickens at three different levels of supplementary feeds under semi-scavenging system. Gradual increase in production of RIR x Fayoumi was found with increased amount of supplementary feed. Fayoumi obtained highest benefit at 15g, RIR x Fayoumi obtained at 30 g and 45 g. All of the genotypes were found better in relation to benefit cost ratio at 15g. But the highest was in RIR x Fayoumi at 15g.

Gumulka *et al*. (2009) analyzed relationship of productivity and profitability of broiler chicken production to incidence of avian influenza in wild birds. The effect of market fluctuations in the prices of birds for slaughter on the profitability of broiler production has been observed but it has not been directly related to the flu epidemic. Because of the difficult market situation, the producers aimed to reduce the actual production costs of the factors that were able to influence.

Sonaiya (2009) studied that smallholder family poultry is affected by many technical factors including low bio-security, restriction to live bird markets, inadequate sources of inputs and services especially sources of technical information with lack of genetically improved breeds.

Bell (2009) examines that the efficiency and profitability of family enterprises using indigenous poultry are limited by disease, production constraints, and external factors. It can be largely alleviated through the use of vaccination programmes adapted to the local prevalence of diseases.

Singh *et al*. (2009) conducted an economic analysis of free range poultry to find out the economic potentials of free range indigenous fowl reared by rural women. Findings revealed that the average annual farm income from sale of eggs and birds were Rs. 7452, 15120 and Rs. 35625 for small, medium and large units, respectively.

Sumy *et al*. (2010) investigate backyard chicken production systems. The results indicate that backyard chicken rearing is profitable for the farmers. Vaccinations and balanced diets have a decisive effect on chicken rearing, providing quality products for human consumption and reducing nutritional deficiencies and poverty.

Mitrovic *et al.* (2010) determine the optimal density and duration of fattening in a way to achieve the best production results and the profitability of fattening the broiler chickens hybrids Cobb 500 in temperate continental climate, while preserving the welfare of poultry. The findings revealed that profitability could be more advantageous if the increased population density goes up to 16 birds per m^2; or the duration of fattening could be extended up to 40 days.

Ike and Ugwumba (2011) determine the effects of socioeconomic characteristics of broiler producers on output and to estimate the returns of broiler enterprise. Recommendation of the study was state and local governments should improve their credit delivery to farmers as this will go a long way in improving output.

Bano *et al*. (2011) investigate the profitability index of open house broiler farms. The analysis covers the descriptive analysis of socioeconomic characteristics of the sample poultry farmers along with cost and profitability analysis.

Sultana *et al*. (2012b) conducted an experiment an experiment to assess the effects of processed cassava tuber meals (CTM) with 0, 15, 30, and 45g kg^{-1} on growth responses, meat yield, and profitability of boilers. With the introduction of CTM, feed cost decreased linearly. The meat yield characteristics of broiler regardless of dietary treatments were preserved the similar characteristics. However, the high content of fiber and low content of protein inhibited the growth performance, thus decreased the profitability of boiler rearing.

Dutta *et al*. (2012a) investigated the production performance and economic efficiencies of broiler of Cobb500, cockerel of ISA Brown, Fayoumi, Rhode Island Red and *Sonali* available in Rajshahi. Findings revealed that although broiler of Cobb 500 was found to be the most popular for meat and RIR for egg, the cockerel of ISA Brown earned the maximum profit.

Aboki *et al* (2013) assessed the socio-economic characteristics and technical efficiency of family poultry production. The findings conclude that the output and technical efficiency of the family poultry production can be increased by the use of more feed, capital, medicine/vaccine and adoption of more innovations.

Siyaya (2013) conduct an economic analysis to study the factors that affecting profitability of the indigenous chickens production. Findings suggested that research on market size and spread should be undertaken to determine the demand patterns of indigenous chickens.

Kawsar *et al*. (2013) studied the socio-economic profile of small-scale broiler farmers. The most important factor affecting profit in this study appeared to be feed conversion ratio which resulted from quality of feed and chicks and the management techniques of the farm.

Adetola and Simeon (2013) evaluated and compared the cost of production and gross revenue of three strains of broiler chicken in order to determine their profitability. Findings revealed that the level of profitability and productivity of broiler depends among other factors on the strain.

Uddin *et al*. (2013) estimated the income from native poultry production and analyze the efficiency of resources used. It discloses that increasing returns to scale was found which indicates that there was bright prospect to earn more through the use of more inputs in the production process.

Isbandi *et al*. (2013) determine differences in productivity and profitability of layer Poultry farm that used small scale feed mill production quality and conclude that layer farmers who used produced small scale feed mill generally had business scale less than 5,000 chickens.

Melesse (2014) studied the significance of indigenous chickens for farmers combined with many consumers' preference for their eggs and meat suggests that these genetic resources are promising options for food security in the rural communities.

Uddin *et al*. (2014) conducted an economic analysis and resource use efficiency for *Sonali* chicken. The study also identified some of the major problems associated with *Sonali* chicken farming and suggested some possible steps for overcoming these problems.

2.2 Management studies on the chicken breeds

The management practices of chicken breeds depend on diverse factors such as feed, nutrition, watering, housing and environment in addition to inherent toward genetic makeup of the chicken breeds. Literature reviewed here is based on the management practices of the chicken breeds.

Jacob *et al*. (2008) characterized the production practices of small antibiotic-free flock producers and identify the possible points for introduction of food-borne pathogenic bacteria. They developed appropriate extension programs to improve the level of bio-security on such farms. The identified key areas for extension programs include feed and pasture choice, waste disposal, feed withdrawal before slaughter, and marketing.

Bleich *et al*. (2009) evaluated an approach by FAO to developing sustainable bio-security measures for use by small-scale poultry producers. The findings revealed that developing and achieving adoption of bio-security measures will require a multidisciplinary and participatory approach working with producers, intermediaries, traders and for backyard poultry, communities.

Al-Amin *et al*. (2009) evaluated the droppings disposal in layer farm and measures adapted to protect environmental pollution. Findings exposed that droppings disposal is a real problem for aesthetic, public safety and environmental point of view. Cleaning technique and tools desired to be modernized for efficient and cost effective cleaning.

Sharma (2010) studied the poultry production, management and bio-security measures and found that poultry health management is important due to emergence of highly pathogenic diseases like highly pathogenic avian influenza (HPAI) in different parts of the world. Bio-security measures become vital for better performance and quality of poultry production in competitive world.

Nerkar *et al*. (2010) investigated the adoption of sanitary measures in layer farms. They advised that layer farms can be adopted through intensive poultry extension activities to be more specific scientific and disciplined in maintaining sanitary conditions.

Akidarju *et al*. (2010) evaluated some poultry management practices and disease recognition by poultry farmers. They found that constraints in poultry industry due to management practices, such as bad housing, inadequate vaccination and high mortality possibly due to multiple antibiotics resistance are resulting from multiple antibiotics usage.

Bolan *et al*. (2010) examined the composition of poultry litter in relation to nutrient content and environmental contaminants, its value as a nutrient source, soil amendment, animal feed and fuel source, and cost-effective innovative technologies for improving its value. The review proposes best management practices to mitigate environmental consequences associated with air and water quality parameters that are impacted by land application in order to maintain the continued productivity, profitability, and sustainability of the poultry industry.

Shanaz *et al.* (2010) assessed the different management practices adopted by commercial broiler farmers. The findings revealed that majority of broiler farmers maintained a flock size of more than 2100 birds reared on deep litter system adopting all-in-all-out system fed broiler mash earning a profit of Rs 7-10 per birds.

Olumayowa and Abiodun (2011) examined the profit efficiency and poultry waste management and suggested that livestock farmers should be trained through workshops, conferences and extension services on the conversion and utilization of livestock waste into organic fertilizers which can easily be made available to the numerous small scale crop farmers to augment the scarce and very expensive inorganic fertilizer. They also recommended that effective monitoring services should be operated by government to sensitize poultry farmers to reduce environmental pollution and incidence of disease outbreak.

Ameji *et al*. (2012) determined the level of awareness, knowledge and readiness to report outbreak of HPAI and bio-security practices in Kogi state, Nigeria. The study revealed high level of awareness and readiness to report HPAI but poor knowledge and bio-security practices towards it. The failures in bio-security measures as seen in this study will greatly enhance introduction and spread of HPAI as well as other contagious poultry diseases in the state.

Dutta *et al*. (2012a) investigated the management practices, incidences of common diseases, uses of indigenous knowledge (IK) and conditions and problems of the poultry farmers in some selected areas of Rajshahi, Bangladesh. Findings revealed eighteen parameters on management practices, 13 diseases, 20 indigenous knowledge items, 11 problems encountered and top 10 opinions of the poultry farmers were identified. Satisfactory to good management practices were recorded for indigenous in Godagari and that for exotic and crossbred in Rajpara. All the remaining farms practiced moderate to unacceptable management practices.

Sultana *et al*. (2012a) conducted an experiment for profiling the existing broiler farming at Santhia upazilla under Pabna district of Bangladesh. The result of present study could be considered useful to farmers and researchers to identify the overall problems and their remedies on management and marketing related to broiler production.

Mandefro *et al*. (2012) assessed the bio-security situation and practices in live poultry markets. Findings revealed that there was high risk of diseases transmission and dissemination related to bio-security of live poultry markets. They suggested that systematic and integrated intervention should be undertaken by the government and concerned bodies to mitigate the problem.

Abubakar *et al*. (2012) reported that the adoption of an appropriate strategy for litter management aiming at optimizing both bird performance and cost of production largely depends on the availability and good quality bedding material at affordable cost. The economic significance of good litter management practices are hereby highlighted in this study.

Musa *et al*. (2012) found that manage poultry wastes under intensive production system led to the discovery of suitable poultry droppings and litter materials. Litter type and management are dependent upon cost, availability and quality of materials used. Economic losses as a result of poor litter and poor liter management are significantly high. The facts discovered that careful selection, adequate management and proper storage and utilization of poultry litter are of paramount importance to reduce environmental pollution, disease spread and economic losses.

Aboki *et al*. (2013) assessed the socio-economic characteristics and technical efficiency of family poultry production. The result of the study reveals that the respondents are relatively young with mean age of 44 years. Findings from the study showed that female constitutes 60% of the family poultry producers and the main reason for rearing family poultry is for sales. Findings indicated that on the average, the respondents are 63% efficient in the use of combination of their inputs.

Bhuyian *et al*. (2013) analyzed the farmers' communication exposure and knowledge in poultry farming. Findings revealed that the exposure to communication media for poultry farming had a positive and significant relationship with only education.

Justus *et al*. (2013) studied the current management practices and challenges faced by smallholder indigenous chicken farmers to gain insights into the underlying causes of production constraints. The study found that to improve production and attain increased productivity, policy should focus on repackaging extension messages that considers farmers economic situations and strengthens collective action initiatives.

Susilowati *et al.* (2013) identified the bio-security activities already adopted by farmers, and the farm and farmer characteristics that influence this adoption. They develop the discussion of how to measure adoption and then use these measures as dependent variables in identifying the factors that influence adoption.

Nigatu and Bezabih (2014) conducted a survey to generate base line information on chicken production under farmers' management condition. The findings discovered that holistic extension services such as applying breed and management improvement methods, besides to supplying chicken health service strategies are highly recommended for promote improvement of chicken production under farmer's management condition.

Wang *et al*. (2014) reviewed the social, economic and political elements of poultry production. They discover that under increased public concerns on bio-security, integration of the small scale poultry producers into safe and high value production chains is a key political issue in developing countries.

Ritz (2014) investigated Biosecurity measures are a critical component of disease prevention. Disease prevention is much less stressful and costly than disease control and recovery. Findings identified a score of better or outstanding, excellent, good, just fair and less score indicated a definite need for improvement.

Huque and Sarker (2014) reported that diversification and production of quality feeds and fodders, synchronization of feed production and availability to animals, strengthening feed milling capacity, conservation and improvement of new pasturage systems, mitigation of climate change impacts and domestic protection to feed safety and quality feed import are some of the options forward to increased supply of feeds and fodders help increased production and productivity of farm animals in the country.

2.3 Disease incidence studies on the chicken breeds

The contagious and infectious diseases are one of the major constraints to poultry development. Transmission of the disease is strongly linked to moving live birds, contaminated carcasses or litters (Prasad, 1991). Literature reviewed here is based on the disease incidences of rearing broiler, cockerel, Fayoumi, RIR, *Sonali* and indigenous chicken breeds.

Giasuddin *et al*. (2005) conducted an epidemiological investigation of infectious bursal disease (IBD). They observed mortality in vaccinated and non-vaccinated commercial breeds. Similar morbidity and mortality were found in heavy and light birds. The findings concluded that continuous antibiotic supplementation and stress factors reduced antibody production.

Mollenhorst *et al*. (2005) studied the risk factors associated for *Salmonella enteritidis* (SE) infections in laying hens. Results showed that bigger flocks increased the chance of infection with SE in all housing systems. However, a deep litter system did not increase the chance of infection with SE compared with a cage system. The main risk factors associated with SE infection were flock size, housing system, and farm with hens of different ages.

Humphrey (2006) examined that contaminated chicken meat remains an internationally important vehicle for human infection with *Salmonella* and *Campylobacter* spp. In addition, the last 20 years has seen an international pandemic of human salmonellosis caused by the contamination of eggs with *S. enteritidis*. It has been a long held scientific view that *Campylobacter* spp. and the common zoonotic salmonella are commensal in chickens.

Rahman *et al*. (2007) conducted a study to determine the incidence of bacterial diseases in various age groups of different flocks of birds from different poultry farms. The diseases were diagnosed based on history, signs and symptoms prior to death, lesions observed after post mortem examination of dead birds and by bacteriological examinations.

Omer *et al*. (2008) reported the Gumboro disease associated with colibacillosis among broiler and layer Chickens. They stated the contributing factors and mortality rate of the disease. Besides, *Escherichia coli* bacteria were isolated from a layer chick and outlined some recommendations for control measures.

Pieskus *et al*. (2008) intended a study to investigate a contamination of in broilers and laying hens with different housing system *i.e*., conventional and furnished cages. In most cases the prevalence of *Salmonella* in broilers was spring; in laying hens-winter, spring and autumn. The prevalent *Salmonella* serovars found in broilers and laying hens were *S. enteritidis* and *S. typhimurium*.

Priyantha (2009) reported salmonellosis as one of the prevalent diseases in commercial layers. Live vaccines are capable of controlling the human infections caused by non host specific Salmonella as a result of cross immunization in poultry. Both live attenuated and killed vaccine have many benefits and proven results for controlling of none host-specific Salmonella in poultry and also in reducing the occurrence of human food born infections.

Omer *et al*. (2010) reported the outbreak of colibacillosis among broiler and layer chicks reared under intensive and semi intensive management. The study provides documented information on the epidemiological and economical effects of the disease to assists in disease control policies and planning research priorities.

Leotta *et al*. (2010) determined the prevalence against *Salmonella* spp. and investigate the risk factors with the positivity of the pathogens in backyard chickens. The final logistic regression model indicated that free-range birds were more likely to have positivity against *Salmonella* spp., compared with caged birds.

Uddin *et al*. (2010) determined the prevalence of diseases in various age groups and different season. Among the diseases infectious bursal disease (IBD) was found in 24.96% followed by mycoplasmosis in 9.87%, Newcastle disease (ND) in 8.92%, aspergillosis in 7.98%, salmonellosis in 7.68%, coccidiosis in 7.32%, colibacillosis in 5.70%, omphalitis in 2.64%, infectious coryza in 0.32%, fowl cholera in 0.24% and infectious bronchitis in 0.24%.

Uddin *et al*. (2011) observed the mortality and disease status in Hy-Line and ISA-Brown strains of layer chickens in commercial layer farms. Etiological analysis showed that the highest mortality was caused by bacterial diseases (7.08%), followed by viral diseases (5.81%), fungal diseases (2.18%) and mycoplasmosis (1.89%).

Feizi and Nazeri (2011) assessed the effect of Newcastle disease on broiler breeder performance. ND is a serious and commonly fatal disease of chickens caused by a paramyxo virus. The study selected four ND afflicted broiler breeder flocks. Of cases studies can be refer the mortality rate, production loss, clinical signs, necropsy signs and disease period.

Okwor and Eze (2011) studied the outbreaks and prevalence of Newcastle disease (ND) in village chickens. The cold and harsh stress associated with this period is thought to worsen ND infected leading to spread and outbreaks. The study recommended the extension services involving education of the rural farmers, strategic vaccination prior to the period of outbreaks and biosecurity measures to help in the control of ND in village chickens.

Xavier *et al*. (2011) conducted a research work to study the seroprevalence of *Salmonella*, *Mycoplasma gallisepticum* (MG) and *Mycoplasma synoviae* (MS) infection in backyard chickens. *Salmonella*, MG, and MS infection are present at high levels in backyard chicken farms, and this presents a high risk to commercial poultry production.

Anuradha *et al*. (2011) conducted an experiment to assess the current status of coccidiosis in commercial broiler and broiler breeder farms. The severity of infection was found to be highest at age group of 4–6 weeks, but number of cases was more between 6 to 8 weeks. Based on necropsy, caecal coccidiosis was found to be the most predominant form.

Saha *et al*. (2012) isolated and identified *Salmonella* organisms from ovaries of dead layer birds and from inner content of laid eggs. Findings reported that salmonellosis has emerged as one of the most serious problems having adverse effects on poultry.

Chaka *et al*. (2012) estimated the seroprevalence of Newcastle disease, *Pasteurella multocida* (PM) infection, *Mycoplasma* infection, and infectious bursal disease and to assess the level of concurrent sero-positivity during the dry and wet seasons. Findings revealed that birds were concurrently sero-positive to more diseases during the wet season than during the dry season.

Chukwudi *et al*. (2012) studied the environs of Newcastle disease virus (NDV), shedding among apparently healthy commercial chickens reared under intensive management. The findings conclude that there is virus shedding among healthy commercial chickens and its environs should be considered an important epidemiological factor in the spread of the disease. Healthy carriers can serve as short term reservoirs and transmit the disease to other birds.

Jatau *et al*. (2012) reported the prevalence of coccidia infection and preponderance *Eimeria* species of free range indigenous and intensively managed exotic chickens. The study identified seven *Eimeria* species and mixed infections were common among the sampled chickens with overall prevalence.

Roy (2012) reviewed the diagnosis and control of Newcastle disease in developing countries. Successful disease control and diagnosis is often difficult because of a lack of bio-security at farm level, cost-effective field-based diagnostics and seromonitoring tests. The findings concentrate on different diagnostic tests and their usefulness under field conditions for rapid identification of the disease so that control measures can be implemented at an early stage.

Rashid *et al*. (2013) conducted a systematic field study on the outbreaks of infectious bursal disease (IBD) in commercial broiler farms of Bangladesh and China. The outbreak of IBD was also found in vaccinated birds ($P<0.05$) of the two countries. The findings of the study indicated the difference of occurrence of IBD in Bangladesh and China, thereby would help to develop appropriate control strategies for both the countries.

Patterson and Guerin (2013) studied the effects of climate change on avian migratory patterns and the dispersal of commercial poultry diseases. Many birds are able to modify migratory strategies when selection favours an adjustment. Climate change is provoking a range of responses from avian migrants and affecting their relationship with other biological systems.

Akter *et al*. (2013) isolated and identified *Avibacterium paragallinarum*, the etiological agent of infectious coryza (IC). They investigated pathological changes that occurred in organs in layer chickens. They suggested further studies involving serological and molecular identification of the etiological agent of infectious coryza.

Adebayo *et al*. (2013) examined various parameters of poultry production, the time of the year that diseases were most observed and the rate of mortality associated with various diseases and level of vaccination of birds under village conditions. The study recommended that awareness campaign should be conducted in the villages on how they can increase their rural poultry productivity, alerting them of the causes of various diseases and the available remedy.

Sharma *et al*. (2014) estimated the seroprevalence of Newcastle disease, infectious bursal disease, chicken infectious anemia, avian pneumovirus and avian influenza in commercial chickens. This study shows that major poultry diseases are threatening the productivity of commercial chickens.

Srinivasan *et al*. (2014) investigated the prevalence of *Salmonella* species in commercial layer chicken in Namakkal poultry zone of India. Findings concluded that supplementation of contaminated fish meal in poultry feed could be the source of *Salmonella* infection in commercial layer flocks.

Sultana *et al*. (2014) recorded the prevalence of economically important viral disease in broiler and layer flocks. The broiler flocks were affected with Newcastle disease, gumboro and hydro pericardium syndrome respectively. It was noticed that prevalence of Newcastle disease in broiler and layer flocks was highest during summer season. The flocks maintained poor managemental condition such as poor ventilation; overcrowding, unvaccinated flock had high susceptibility to these viral diseases.

2.4 Meat and egg yield studies on the chicken breeds

2.4.1 Meat yield studies

A number of workers have reported their findings of meat yield studies on various chicken breeds at home and abroad. Here is the summary of some of the notable ones.

Onifade (1997) conducted an experiment using four antibiotics, namely procaine penicillin, tyrosine, streptomycin and neomycin-oxytetracycline each at 150 $mgkg^{-1}$ and four levels of dried yeast *viz*., 1.5, 3.0, 4.5 and 6.5 gkg^{-1} were incorporated into a basal high fiber diet containing 250 gkg^{-1} palm kernel meal. The investigation revealed that broilers fed antibiotics or dried yeast supplemented diets attained heavier ($P<0.05$) body weights, consumed greater ($P<0.05$) quantities of feed except on penicillin and 6.0 gkg^{-1} dried yeast, converted the feed better ($P<0.05$), and yielded heavier carcass and cut-parts than those fed the un-supplemented diet. Organ weights were similar in broilers on the treatments, except the greater ($P<0.05$) hepatic, spleenic and gizzard weights and lengthier intestinal tracts in birds fed dried yeast.

Barua and Olsen (2000) reported that the commercial source of vitamin A is an ester of retinol which is susceptible to light, oxygen, heat, moisture and pressure during processing, and in tropical climate zones like Bangladesh with high temperature and relative humidity, the storage stability of premix poultry feed containing vitamins may be limited.

Uni *et al*. (2000) studied the effect of vitamin A on the small intestine was examined in vitamin-A-deficient meat-type chickens. Vitamin A deficiency caused hyperproliferation of enterocytes, a decrease in the number of goblet cells, decreased alkaline phosphatase activity and decreased expression of 2 brush-border enzymes. The findings suggest that the absence of vitamin A interferes with the normal growth rate in chickens because it influences functionality of the small intestine by altering proliferation and maturation of cells in the small intestinal mucosa.

Sahin *et al*. (2001) conducted an experiment on Cobb-500 male broilers to evaluate the effects of vitamin E (α-tocopherol-acetate), vitamin A (retinol) and their combination on broiler performance. The birds were fed either a control diet or a control diet supplemented with either vitamin A (15000IU retinol/kg diet), vitamin E (250mg α-tocopherol-acetate/kg diet), or a combination of vitamin A and E (15000IU retinol plus 250mg of α-tocopherol-acetate/kg diet). The results of the present study show that supplementing a combination of dietary vitamin E and vitamin A offers a good management practice to reduce heat stress-related decreases.

McDowell (2004) evaluated the optimum levels of supplementary vitamin A are important for maintaining improved immune response of the poultry and have been shown to increase growth, egg production, feed efficiency and overall health by improving disease resistance.

Bhuiyan *et al*. (2004) studied the importance of vitamin A supplementation for performance of *Sonali* chickens under smallholder farm conditions. The findings recommended that the diets must be supplemented with vitamin A, at least with 1500 IU/kg feed. However, the dietary level and the stability of vitamin A need to be determined under relevant farming conditions.

Ciftci and Ceylan (2004) investigated the effects of dietary threonine and crude protein in maize–soybean meal based diets on the growth performance, carcass traits and meat composition of broiler chickens and to determine the dietary Thr requirement for optimum performance *i.e.*, weight gain and feed conversion efficiency at 0 to 3 weeks and 3 to 6 weeks of age. A significant interaction between dietary CP and Thr was found for feed intake, body weight gain and FCE. Increasing Thr supplementation improved feed intake, BW gain and FCE, especially in high CP diets in both feeding periods. Incremental increases in dietary Thr increased breast yield at both CP levels and drumstick yield only on high CP diets. Liver weight was significantly reduced by Thr supplementation; abdominal fat was not affected.

Corzo *et al*. (2005a) studied the dietary amino acid density effects on Growth and Carcass of Broilers. Outcomes of the findings are overall improvements in economically important parameters *i.e*., feed conversion and white meat yield observed after feeding an amino acid concentration greater than that typically used by some broiler integrators. Considerations for increasing current amino acid concentrations should be made on a cost-benefit basis.

Corzo *et al*. (2005b) studied the impact of amino acid density on broiler growth. Findings revealed that feeding high amino acid density diets to broilers was beneficial in feed consumption, feed conversion and abdominal fat fed for throughout the entire grow out period. Males had higher body weight, breast meat yield and lower feed conversion than females.

Quentin *et al*. (2005) evaluated the effect of increasing levels of essential amino acids (EAAs) in broiler diet. High metabolic energy and lysine concentrations in the starter diet stimulate long-term enhancement of growth performances and carcass composition of broilers.

Ahmed *et al*. (2005) studied the growth performances, nutrient utilization and carcass traits in broiler chickens fed with a normal low energy diet supplemented with inorganic chromium and a combination of inorganic chromium and ascorbic acid. Weight of the hot carcass increased ($P<0{\cdot}05$) due to chromium supplementation although dietary energy concentration did not affect this parameter. Findings concluded that inorganic chromium supplementation (0·2mg chromium/kg diet) effectively enhance the growth performance and carcass characteristics.

Dozier *et al*. (2006) examined the growth, meat yield and economic responses of broilers provided diets varying in amino acid density. The study revealed that feeding the high density amino acids regimen increased yield of breast fillet, breast tender and total breast meat yield.

Rosa *et al*. (2007) evaluated the effects of broiler genotype and of heat exposure on performance, carcass characteristics, and protein and fat accretion, six hundred one-day-old male broilers according to the following factors: genetic group and pair-feeding scheme with a total of six treatments with four replicates of 25 birds each. However, as compared to non-selected broilers, they reduced feed intake when heat exposed, which promoted significant breast-yield decrease.

Dozier *et al*. (2007) evaluated the performance of feeding the high amino acid diets in heavy broiler. Findings revealed decreased feed consumption, improved feed conversion and increased total breast meat yield in broiler. Feeding broilers the diet formulated to 3,140 kcal increased breast meat yield compared with birds provided diets containing 3,240 kcal.

Sarkar *et al*. (2008) conducted an experiment to compare the productivity and profitability of commercial broiler, cockerel and cross-bred chicks up to target body weights of 850, 1000 and 1250g. Findings revealed the feed conversion ratio was best in broilers, followed by cockerels and cross-bred chicks respectively. The highest mortality (8.3%) was found in cross-bred group. The mortality of broiler was 1.4% and no bird was died in cockerel group.

Corzo *et al*. (2010) evaluated the live performance, carcass traits, breast and thigh meat composition and feed cost efficiency in Cobb500 broiler. Findings revealed that broiler benefited greatly from being fed high amino acid density diets, particularly during the latter feeding phases of life. The benefits observed when feeding high amino acid density diets were not necessarily the most economical when feeding these throughout the entire grow-out period.

Ahmed and Abbas (2011) carried out an experiment to determine the effect of dietary methionine levels higher than NRC recommendation on broiler performance and carcass traits. The broiler chicks on methionine higher than NRC showed significant ($P<0.05$) increase in absolute and relative weight of breast and significant ($P<0.05$) decrease in abdominal fat.

Lilly *et al*. (2011) studied the effects of dietary amino acid density in broiler feed on carcass characteristics and meat quality. The findings exposed that feeding the diet with a high amino acid density during the finishing phase produced birds with excellent meat quality and carcass traits while supporting optimal broiler growth and carcass traits.

Nasr and Kheiri (2011) evaluated amino acid density in broilers to better understand the impact of increase and decrease dietary amino acids density in live weight performance. The outcome suggested that high amino acids density throughout life optimized live weight and growth, whereas reductions in amino acids density reduced growth and live weight.

Kana *et al*. (2011) studied the growth performances and carcass characteristics of broiler fed diets supplemented with graded levels of Canarium schweinfurthii Engl seed (charcoal A) or maize cob (B) were studied. Results indicated that birds fed 0.2, 0.4, and 0.6% of either charcoal A or B had significantly ($P<0.05$) higher final body weights as compared to control birds while, above 0.6% slightly depressed average final body weights Dressing percentage liver weight and abdominal fat were not significantly ($P>0.05$) affected by charcoal.

Landy *et al*. (2011) conducted an experiment to examine the effect of neem (*Azadirachta indica*) as an antibiotic growth promoter substitute on growth performance, carcass traits, and humoral immune responses in broiler chickens. The dietary treatments consisted of the basal diet (control), control+4.5 mg flavophospholipol/kg, or control+7 or 12g neem fruit powder/kg. Birds fed 7g neem/kg had the highest feed conversion ratio at 42 d, compared with other treatments. Daily feed intake, internal organ weights and carcass traits were not influenced.

Asafa *et al*. (2012) studied the performance and carcass characteristics of broiler finishers fed different levels of poultry offal meal and crayfish waste meal as replacement for fishmeal. The protein efficiency ratio and feed conversion ratio were similar for all treatments. Chicken fed diet 3 had an eviscerated weight of 84.27% which was significantly ($P=.05$) better than others.

Uchida *et al*. (2012) generated seventeen recombinant viruses by a reverse genetic technique to elucidate the pathogenicity of highly pathogenic avian influenza viruses in chickens. Survival analysis demonstrated that the exchange of a gene segment affected survivability of the chickens with statistical significance. The analysis revealed three groups of recombinants with various gene constellations that depended upon the survivability of the infected chickens.

Igbasan and Adebayo (2012) conducted an experiment with 180 one week old Arbor Acre broiler chickens to evaluate their growth response, carcass quality when fed lanthanum supplemented diets. Dietary treatments included the un-supplemented basal diets. There was no significant (P=0.05) difference in the final live weight, daily weight gain and feed conversion ratio of the birds fed the control diet and those fed lanthanum supplemented diets.

Abudabos and Aljumaah (2012) evaluated the effect of supplementation of low crude protein corn-soybean meal diets which contained low ME levels with lysine, methionine and threonine above that recommended by the National Research Council on broiler performance, carcass characteristics. Four dietary treatments: T1=Control diet (21% CP and 3150 kcal/kg ME); T2, T3 and T4 contained 19.5% CP and 115% of Lys, Met and 108% of Thr compared to the NRC requirements; T2, T3 and T4 contained 3150, 3100 and 3050 kcal of metabolizable energy/kg, respectively. Breast muscle yield followed the same trend; heavier breasts were obtained from birds which had received T2 and T3.

Kayode *et al*. (2012) studied the performance and carcass characteristics of broiler chickens fed on fungal mixed-culture (*Aspergillus niger and Penicillium chrysogenum*) fermented mango kernel cake. Six diets were formulated as Diet A had 0% MKC (control) while diets B, C, D, E and F were mixed-culture fermented MKC replacing maize at 20, 40, 60, 80 and 100% respectively. Decrease in weight gain and feed intake of the birds with increase in fermented MKC was significant (P<0.05). The weight of birds fed on diet B was higher than others, but not statistically different (P<0.05) from the control at the starter phase.

Kim *et al*. (2013) compared the effects of a poultry fat (PF) and a new corn oil blend (CO) on live performance and carcass characteristics of 49-d-old broilers. There were no significant differences in live performance for the starter phase (0–18 d). For the grower phase (19–35d), birds fed 75:25% PF:CO significantly (P≤0.05) increased BW, BW gain, and decreased feed conversion compared with the control (100:0% PF:CO). Birds fed 0:100% PF:CO also observed similar improvements in BW, BW gain, and feed conversion during the grower phase. There were no significant differences for the finisher phase (36–48d).

Tavernari *et al*. (2013) conducted a randomized block experiment with 7 treatments, each with 8 replicates of 25 starter birds and 20 finisher birds. The utilized levels of dietary digestible lysine were 10.7 and 9.40 g/kg for the starting and growing phases, respectively. During the starting phase, in broilers that were fed a higher Val/Lys ratio, weight gain, and the feed conversion ratio improved by 5.5% compared with broilers fed the basal diets. The broilers in the growing phase also had improved performance (by 7 to 8%) when the test diets had higher Val/Lys ratios.

Safarizedah and Zakeri (2013) conducted an experiment on Ross 308 chickens divided in to 12 groups in same environmental conditions. Group A, consider as control group and group B and C considers as experimental groups. Birds fed vitamin A and complex vitamin E and selenium containing diets exhibited significant difference against Newcastle disease's vaccine ($p<0.05$). Consequently, vitamin A and complex of vitamin E and selenium, improve humoral immune system in broiler chickens, but exhibited no effects on growth factor in broiler chickens.

Ekmay *et al*. (2013) determined the amino acid and protein requirements of broiler breeders at peak production. The average digestible requirements per breeder per day for both product and feed/product ratio from trials 1 and 2 for Met, Cys, TSAA, Phe, Phe + Tyr, Trp, Arg, Ile, Lys, Val, Thr, and CP were 424, 477, 901, 689, 997, 252, 1,026, 830, 916, 799, 613 mg/d, and 20.0 g/d, respectively. It is suggested that adequate dietary Lys and Ile should be provided for maximum hatching egg production but an excess may affect fertility.

Zhai *et al*. (2013) evaluated the effects of dietary amino acid (AA) density on the performance and meat yield of broilers. Findings revealed that based on the main effects of FCR, chickens are benefited greatly from being fed high-AA-density diets during the finisher feeding phases.

2.4.2 Egg yield studies

A number of workers have reported their findings of egg yield studies on various chicken breeds at home and abroad. Here is the summary of some of the notable ones.

Khan *et al*. (2006) studied the production performance of Fayoumi chicken under intensive management system. Outcome of the research include age and weight at sexual maturity, egg weight and yearly egg production of the Fayoumi chicken with amino acid diets.

Halima *et al*. (2006) reported growth performance of RIR from day-old to 20 wks of age. They found that day old weight, final body weight, body weight gain and mortality rate in RIR were 35.2 g, 1394 g, 1359 g and 18.3%, respectively. The poor growth rate in indigenous chickens, as observed in the present study, could be attributed to genetic composition of the birds.

Akhtar *et al*. (2007) compared the production potential and egg characteristics of Lyallpur Silver Black, Fayoumi and Rhode Island Red breeds. Findings concluded that the RIR birds exhibited better production potential, whereas LSB birds produced eggs with better egg quality characteristics than other breeds.

Yasmeen *et al*. (2008) compared the production performance and egg quality characteristics of pullets and spent layers. The results revealed that pullets produced more eggs and utilized their feed more efficiently than spent layers. However, egg weight in spent layers was higher than in their counterparts.

Bregendahl *et al*. (2008) studied the ideal ratios of essential amino acids relative to lysine for white leghorn-type laying hens. Outcome of the research include egg weight, egg production and egg mass and feed utilization of leghorn layer at varying level of supplementary amino acids.

Gomez and Angeles (2009) conducted an experiment to evaluate productive variables and egg component yields of laying hens that were fed a low-protein diet with increasing levels of Thr and Met. Findings revealed that egg production, egg mass and FE were greater at a Met level of 0.32% and egg weight was greater when dietary Met was 0.45% ($P<0.01$).

Applegate *et al*. (2009) studied the effect of amino acid formulation and dietary microbial supplementation on egg production and egg characteristics in laying hens. The diet reduced feed intake-to-egg mass ratio by 2.4 and 3.4% from 33 to 36 wk and 41 to 44 wk, respectively.

Bonekamp *et al*. (2010) studied the effects of amino acids on egg number and egg mass of brown and white laying hens. Findings revealed egg weight, daily egg mass production as well as feed conversion regression analysis of the experimental layers.

Panda *et al*. (2010) studied the effect of lysine supplementation to low protein diet and its influence on production performance and egg quality of White Leghorn layers. Findings suggested that the diet with 14.8% and 0.77% lysine is adequate to realize optimum performance with good albumen quality in layers during 28–44 wk of age.

Rao *et al*. (2011) conducted an experiment on White Leghorn layers to evaluate the effect of dietary ME and CP and supplementation of low-CP diets with graded concentrations lysine or methionine on layer performance. Under tropical conditions the White Leghorn layers required approximately 0.70% lysine and 0.30% methionine in diets for better performance.

Kingori (2011) studied the egg weight, shape and shell colour are external characteristics that influence egg grading, packaging, price, consumer preference and hatchability. Findings revealed that higher bodyweights are generally associated with bigger eggs. The most important nutrients for control of egg size are linoleic acid, protein and specific amino acids. Lighting programmes influence egg size by accelerating or delaying the age at which hens start to lay eggs.

Perez-Bonilla *et al*. (2012) studied the effects of energy concentration of the diet on productive performance and egg quality of brown egg-laying hens differing in initial body weight. Findings suggested that heavy hens had higher feed intake and produced heavier eggs and more egg mass than light hens. Feed and energy efficiency were better for the lighter hens.

Fouad *et al*. (2012) evaluated the role of dietary L-Arginine in poultry production. L-Arginine supplementation in poultry diets improves egg production, egg weight, modulates lipid metabolism toward reducing total body fat accumulation to improve meat quality and increases antioxidant defense under normal conditions.

Khawaja *et al*. (2012) studied the feed supplementary effect on exotic and cross-bred chicken. The results revealed that the average day old weight was highest in RIR and FIRI, intermediate in RIFI and lowest in Fayoumi chickens. The RIR breed consumed more feed and gained maximum ($P<0.05$) weight gain than those of Fayoumi and cross-bred chickens at all ages.

Burley *et al*. (2013) investigated whether reduced CP and amino acid balanced laying hen diets could maintain egg production and quality while reducing feed costs. Findings suggested that implementing reduced CP, AA-balanced diets for commercial-scale laying hen flocks would be economically beneficial without sacrificing hen performance.

Khawaja *et al*. (2013) compared the performance of cross-bred chickens under different supplementation. The crossbred derived from RIR male and Fayoumi female achieved sexual maturity earlier than both FIRI and RLH crossbred chickens with lower egg traits.

Ahmad *et al*. (2013) evaluated the effects of Canola oil and vitamin A on egg characteristics in laying hens. Higher egg weight and egg mass ($P<0.05$) were noted for the hens at the diet with 10,000 IU vitamin A /kg of diet whereas, all other egg characteristics were not influenced by increasing the supplemental level of vitamin A.

Ji *et al*. (2014) evaluated the supplemented diets with amino-acid varying in protein levels for laying hens. Findings suggested that the application of the assumed ideal AA profile can lead to reduced dietary protein level, from 18 to 16%, without affecting the production performance of laying hens during 21 to 34 wk of age.

Abdel-Wareth and Esmail (2014) studied the effects of different levels of L-threonine on some productive performance and egg quality of laying hen. Findings stated that 0.2, 0.4 and 0.6% of L-threonine has beneficial effects on productive performance of laying hen.

2.5 Research gap and the present study

Formerly, productivity and management practices and disease incidences of the chicken breeds and feed supplement experiments were done deliberately for the betterment as well as advancement of the varieties of chicken breeds but were measured independently in most of the cases. Information associated to productivity, management practices and disease incidences of the chicken breeds in the course of various feed supplement experimentation are very scanty. To author's knowledge, consequences interrelated to productivity, management practices, disease incidences and feed supplement experimentation with the chicken breeds Fayoumi, indigenous, RIR and *Sonali* (RIR♂ × Fayoumi♀) are deficient in the literature. Therefore, a study on the productivity, management practices and disease incidences of the chicken breeds in concert with feed supplement experimentation using vitamin A and essential amino acids seemed worthwhile to conduct in Rajshahi, Bangladesh.

CHAPTER THREE

GENERAL MATERIALS AND METHODS

The present research work was undertaken to study the productivity, management practices and disease incidences of the six varieties of chicken breeds *viz*., Cobb 500 (broiler), cockerel, Fayoumi, indigenous, RIR and *Sonali* that are available throughout the country. In addition, a feed supplement experiment involving vitamin A (VitA) and essential amino acids (EAAs) with an indigenous, two exotics *viz.,* Fayoumi and Rhode Island Red (RIR), and a crossbred *Sonali* (RIR♂ × Fayoumi♀) was conducted to examine the meat and egg yield efficiencies of the experimental chicken breeds. Finally, the cost-benefit components were analyzed to evaluate the profitability index (PI) of the chickens and farms under study.

Intended for this purpose the aforesaid six varieties of chicken breeds were selected from in and around Rajshahi. For the compilation of data on productivity, management practices and disease incidence, a government, ten private farms and ten houses were chosen randomly from the study area. The farms were visited to gather requisite information on productivity of the farms, management practices and disease incidence of the chicken breeds. Productivity data *i.e.,* number and varieties of chickens reared at a particular farm with profitability, management practices *i.e*., bio-safety measures adopted for the chicken breeds and disease incidences *i.e.*, bacterial, viral and fungal disease susceptibility of the chicken breeds were measured. Moreover, to carry out feed supplement experiment, the experimental chicken breeds were reared separately under four dietary treatment group *viz*., T1, T2, T3 and T4 in favour of meat and egg yield study. Data on growth performances of both types of rearing in accordance with meat and egg features were collected for analysis and evaluation among the breeds, genotypes and treatments. These have further been elaborated in respective chapters.

3.1 Selection of the study area

Ten Upazillas of Rajshahi District, namely Baghmara, Boalia, Godagari, Mohanpur, Motihar, Paba, Puthia, Rajpara, Shahmokdum and Tanor, were selected for the study (Plate 3.1). The main considerations in selecting the study area were as follows:

(a) A large number of poultry farms are raised in these areas;

(b) No study of this nature was conducted here previously;

(c) The study areas are well-communicated; and

(d) Co-operation from the farm owners was highly satisfactory.

3.2 Selection of the poultry farms and houses

A total of 21 farms consisting of one government farm, ten private farms and ten backyard chicken farms that raise indigenous chicken from the 10 Upazillas of Rajshahi District were selected for the survey. The farm owners were interviewed face-to-face and data were collected using an interview list **(Appendix 2)** with direct observation. However, the main consideration of this kind of selection was as follows:

(a) The selected poultry farms covered the Rajshahi district of Bangladesh.

(b) A large number of indigenous chickens are raised in these areas; and

(c) The indigenous, exotic and crossbred chickens are available in the selected farms.

A detailed account of the poultry farms are further discussed in **Chapter Four.**

3.3 Selection of the chicken breeds

The accessible six varieties of chicken breeds consisting of one indigenous (non-descriptive *Deshi*), four exotics *viz*., broiler, cockerel (isolated male chicken from Isa-White), Fayoumi (Egyptian breed) and RIR (Rhode Island Red) and a crossbred or hybrid *Sonali* (derived from RIR♂ × Fayoumi♀) were selected for the investigation. The selected chicken breeds were most common in both the selected farms and houses of Rajshahi district. The main consideration towards selecting the aforementioned chicken breeds was as follows:

(a) The varieties of chicken breeds are most trendy in Rajshahi.

(b) They are available in the selected poultry farms and houses; and

(c) The aforesaid six varieties of chicken breeds have appreciable customer demands.

A detailed account of the chicken breeds is further discussed in **Chapter Four**.

Plate 3.1 Map of Bangladesh showing Rajshahi District and City

A. Rajshahi District and City (Inset) **B.** Map of Bangladesh

3.4 Preparation of the survey schedule

The poultry farms were visited twice a month during the study period from July 2011 to June 2014 (**Appendix 1**). Incidences of various poultry diseases were recorded during each visit. Overall hygienic conditions and preventive measures were either observed or monitored from the beginning to the end of the research. The feed supplement experiment on the selected chicken breeds for meat and egg purpose were done separately in due time with four dietary treatment groups *viz*., T1, T2, T3 and T4, a combination of the first three treatment diets. Subsequent to the successful completion of the entire research program the recorded data from the research interests were put forwarded to a computer system for further analysis.

3.5 Preparation of the experimental houses/cages

The study was conducted in a semi-urban area of Rajshahi City Corporation, Bangladesh, in deep litter system. During the experimental period average temperature ranged from 20° to 36° C and relative humidity from 68 to 96.8%. The experimental birds were obtained from Regional Poultry Farm, Rajabarihat, Rajshahi, Bangladesh. The birds were reared in 7.0 cm depth litter of rice husk. The stocking density was 16 birds/m^2 (Thiele, 2007).

Feed supplementation: Vitamin A (VitA) as retinol acetate and seven essential amino acids (EAAs) *viz*., arginine, isoleucine, lysine, methionine, threonine, tryptophan and valine, procured from BDH, UK, were used to supplement the standard chicken feed. Four treatments included T1 (control diet), T2 (control diet+12500 IU Vit-A/kg diet), T3 (control diet+EAAs) and T4 (control diet+12500 IU Vit-A/kg diet+EAAs). The premix control diet was procured from the local market whereas the treated diets were prepared following recommendations of the National Research Council, USA (NRC, 1994). Chickens were provided with the starter, grower and finisher/layer diets as per the experimental protocol.

Brooding and lighting: Each experimental cage was provided with a 100 watt bulb hanging in for brooding the birds. During the first week room temperature exists between 29-34^{o}C. Subsequent to first week, the environmental temperature increased excessively and it was between 30-39^{o}C up to 3rd week. During the first and second week, 24 hours lighting was confirmed and it was decreased at the rate of one hour in each subsequent week.

Vaccination: All chicks were vaccinated following a programme typical of the region that included Bursine-2 against infectious bursal disease (IBD) on days 4 and 14 and baby chick Ranikhet disease vaccine (BCRDV, produced by DLS, Dhaka, Bangladesh) against Newcastle disease on day 7. However, a detailed schedule of vaccination program designed for the experimental chicken breeds are shown in **Table 3a.**

Bio-security measures: During the experimental period adequate hygienic measures and appropriate sanitation programmes were carried out. The experimental area was restricted by making fences and was kept open only to researcher, supervisor and workers related to the experiment by following special care. Before entrance into the experimental shed, special hygienic and sanitary measures were taken to avoid the entrance of diseases and germs from outside. Hands and feet were washed with soap, feet were dipped in a water bath containing disinfectant and clean apron was worn as a part of hygienic measurement. Hygienic management of feeding, watering, vaccination programs and litter management were taken during the experimental period. Disinfectants and bleaching powder were regularly sprayed on the road and surroundings of the experimental shed to prevent disease outbreak and kerosene was spread carefully to control ant. Adequate bio-safety measures were ensured throughout the experimental period (Sharma, 2010).

Table 3a: Schedule of vaccination program designed for the experimental chicken breeds

Age (day)	Vaccine	Disease	Route of administration
1	Mareks	Mareks	Run meat
7	BCRDV1	Newcastle	Two bit in two eyes
14-18	Gumboro Live	Gumboro	One bit in one eye
30	Fowl Pox	Chicken Pox	Beneath wing skin
42 and 112	Salmonella Live	Fowl Typhoid	Injection in meat
60 and 180	RDV2	Newcastle	Injection in run
63 and 70	Mycoplasma	Mycoplasmosis	Beneath neck skin
75, 90 and 180	Cholera	Fowl Cholera	Beneath neck skin
126 and 140	Gumboro Killed	Gumboro	Beneath neck skin

[1]Lentogenic F-strain Baby Chick Ranikhet Disease Vaccine (BCRDV), DLS, Dhaka, Bangladesh;
[2]Ranikhet Disease Vaccine (RDV) for adult chicken.

3.6 Parameters studied

The entire research work deals with productivity, management practices and disease incidences along with the feed supplement experimentation intended for meat and egg yield study. As a consequence, the following parameters were studied:

Productivity: Farm- as well as year-wise productivity data from the selected twenty one (21) poultry farms were recorded, calculated and analyzed during the study period. Data were collected fortnightly during the Fiscal Year: July 2011-June 2012, July 2012-June 2013 and July 2013-June 2014, respectively. The productivity data deals with the subsequent parameters such as yearly chicken production (YCP), total cost of production (TCP), total revenue (TR) etc. The parameters are further elaborated in **Chapter Four**.

Management practices: Using a five-scale scoring system, eight (8) major management practices as room temperature (RT), water source (WS), vaccination (VC), bio-safety measures (BM), boundary walls (BW), human residence (HR), chicken transportation (CT) and feeding management (FM); were considered to rank the farms under study, where score 5 was considered Excellent, 4 as Good, 3 as Satisfactory, 2 as Not good and 1 as Unacceptable. A detailed account of the parameters is spelled out in **Chapter Five**.

Disease incidences: Correspondingly by using a 5 scale scoring system, six (6) major parameters on disease incidences such as bacterial disease (BD), viral disease (VD), fungal disease (FD), disease caused by botulism (DCB), flock-wise disease commonness (FDC) and seasonal disease prevalence (SDP) were considered to rank the farms under study, where score 5 was considered Elevated, 4 as Severe, 3 as Gross, 2 as Mild and 1 as Absent. A detailed account of the parameters is further spelled out in **Chapter Six**.

Meat and egg yield studies: The crossbred *Sonali* and the exotic Fayoumi chicken of both sexs were rerared at farm conditions with a rearing period of eight (8) weeks for meat purpose. The chicken breeds were divided into four (4) dietary treatment groups *i.e.*, T1, T2, T3 and T4. The T1 group is provided with commercial ration while the T2 group was provided with commercial ration and Vitmain A; T3 group is provided with commercial ration and essential amino acids

(EAAs) and the T4 group is provided with both vitamin A (VitA) and EAAs. The meat yield efficiency of the experimental chicken breeds were studied using the following parameters as well: feed intake (FI), live weight gain (LWG), feed conversion ratio (FCR), survibability (SB), meat features (MF) [**Appendix 3]** and carcass features (CF) [**Appendix 4]**.

Concurrently, the indigenous, Fayoumi, RIR and *Sonali* chicken were rerared under farm conditions for egg purpose with a rearing period of 48 weeks. Like wise the chicken breeds were separated into four (4) dietary treatment groups *i.e*., T1, T2, T3 and T4. The egg yield efficiency of the experimental chicken were studied using the following parameters as well: growth performance (GP) [**Appendix 5]**, egg production performance (EPP) [**Appendix 6]** and egg quality performance (EQP) [**Appendix 7]**. However, both the meat and egg yield parameters are further elaborated in **Chapter Seven**.

3.7 Computation of database from field and laboratory works

Throughout the study period, comprehensive records of the data on productivity, management practices, disease incidences and feed supplement experiment intended for meat and egg yield characteristics were composed and set aside in a notebook. Soon afterwards the information was uploaded into a computer program for further analysis and processing.

3.8 Statistical analyses

Data on the productivity of the Government, private and backyard farms were compiled, tabulated and analyzed in accordance with the objectives of the entire research program. Analysis of variance (ANOVA) and significant differences among treatment means were identified by least significant difference (LSD) tests. Moreover, costs of rearing chicken breeds and their corresponding losses or benefits were calculated on farm and year basis. Microsoft Excel spread sheets (Windows 7) and SPSS (Statistical package for social sciences) for Windows 7 (version 19.0) were used for analyzing the experimental data.

CHAPTER FOUR

PRODUCTIVITY STUDIES ON THE CHICKEN BREEDS

4.1 Introduction

Bangladesh is one of the most densely populated countries in the world and due to the higher nutritional deficiencies about half of the population is unable to develop their working ability either physically or mentally. Many people, especially the rural ones, have been suffering from malnutrition which has a negative effect on immune system and consequently many diseases. They cannot contribute in the national development. We have to increase the animal protein production to make our people sound and healthy (Sumy *et al.*, 2010). However the people of our country is blessed with a variety of agricultural resources of which chicken rearing is considered to have potential both for poverty alleviation and food production, especially for the rural poor women. Globally, poultry plays an important role providing supply of animal protein as meat and egg (Sonaiya *et al*., 2012). The Food and Agriculture Organization (FAO) committed to develop family poultry through the international network on family poultry development (INFPD) as a special programme for food security (SPFS) where backyard poultry production system has been given priority (Das *et al*., 2013).

The native chicken of Bangladesh is non-descriptive and indigenous in nature. This is known as *Deshi* (Okada *et al*., 1988). The genotype, environment and genotype-environment interactions are the principal factors affecting growth performance of chicken. Feed intake, ambient temperature, relative humidity, density and flock size are the major environmental variables influencing growth of chicken (Shanawany, 1988). They are well adapted to the environmental conditions of Bangladesh such as poor management, poor nutrition and hot and humid climate (DLS, 1990). Indigenous native chickens are the principal supplier of poultry meat and egg of the country, however, their performance in term of egg and meat are comparatively poor (Khandoker *et al*., 1996). So there is enough scope of improvement of the performance of native chicken in term of egg and meat through improved management practices.

The crossbred *Sonali* derived from the RIR male and Fayoumi female has been taking place besides the indigenous hens due to their adaptability and acceptability in the climatic conditions of Bangladesh (Anisuzzaman, 1988). Such cross-bred chicken has already been proved worth in production performances in semi-scavenging system under village condition of Bangladesh (Amber *et al*., 1999). Considering the environmental factors e.g., rainfall, housing and economic traits as survivability, rapid growth of male chicks as well as female's egg production, this cross-bred was recommended to rear for small-holder poultry farming in Bangladesh (Amber, 2000).

Moreover, broiler is an important part of commercial poultry enterprise. The modern broiler chicken is fast growing, efficient and can rapidly fulfill the shortage of protein requirement since it can be produced at least possible time as compared to other meat producing animals. To reduce the shortage of animal protein in the country, broiler can play an important role. Its success and chances for further development are largely determined by the profitability of farms. A notable improvement of broiler performance was eminent in the second half of the 20th century. It was possible mainly due to genetic selection of birds for rapid growth rate (Havenstein *et al*., 2003; Renema *et al*., 2007). However, the male chicks popularly known as cockerels constitute fifty percent of day-old layer chicks. Such chicks have become an indispensable component of poultry development with the rapidly increasing trends of commercial layer chicken farming in Bangladesh (Sarkar *et al*., 2008).

Furthermore, the Fayoumi is a breed developed in Egypt to yield at a modest level, but which is particularly renowned for its genetic resistance to disease. The RIR is basically an American breed that is nowadays used as one of the parent breeds of the brown-shelled high-yielding hybrids used by most commercial producers. It has been observed that the *Sonali* is better than any other breed. This superiority is not significant for the individual traits, but in the overall gross margin the *Sonali* is significantly better than all combinations except one (FAO, 2010). From the contemporary circumstances of the productivity of the indigenous, exotics and crossbred chicken under small-scale production unit, it has become essential to get some specific conception about productivity analysis of the chicken breeds under small-scale production units that are in operation particularly in rural areas. An effective policy on this important of poultry business is urgently needed for the greater interest of the farmers. It is therefore the objective of this study was to estimate the current status of smallholder production units covering different chicken breeds and farms to determine the costs and returns at the study area.

4.2 Materials and methods

4.2.1 Study area

The productivity study was conducted by using purposive sampling method, which is the selection of sample intentionally on 21 chicken farmers from the urban, semi-urban and rural areas of Rajshahi district, Bangladesh. The overall number of farmers' samples was 21 farmers, of which 11 farmers rearing exotic and crossbred chicken and 10 farmers rearing indigenous chicken. However, out of the 21 chicken farms *i.e.*, one Government, ten private farms and ten backyard farms that reared indigenous chickens were selected for the survey. The poultry farmers were interviewed and the data were collected through interview and direct observation. Information on the selected chicken breeds was collected from the selected 21 farms, where the Government farm was Regional poultry farm which is located at Rajabari, Rajshahi. The rest 20 farms were situated at the ten Upazillas of Rajshahi district, namely Baghmara, Boalia, Godagari, Mohanpur, Motihar, Paba, Puthia, Rajpara, Shahmokdum and Tanor. A brief description of the selected poultry farms are as follows:

Government farm

Regional Poultry Farm, Rajabari is the government poultry farm of Rajshahi. The farm is located in the Rajabari village under Godagari Thana in Rajshahi District (**Plate 4.1**). The farm reared exotic Fayoumi and crossbred (*Sonali*) chickens breeds. The specialty of this farm was that it provided an opportunity for comparative study of rearing both exotic and crossbred chickens.

Private farms

The private farms in the study area generally rear both exotic and crossbred chickens, for instance, broiler, cockerel, Fayoumi, RIR and *Sonali* (**Plates 4.1 and 4.2**). The farmers rear these breeds equally for meat and egg purpose excluding broiler and cockerel that are merely intended for meat purpose. However, a location-wise and concise description of the private farms is as follows:

Baghmara: The selected farm is situated in Sreepur village under Baghmara Thana. The farm rears only the exotic breed RIR. The specialty of this farm was that it provided knowledge on small scale rearing of a popular layer breed.

Boalia: The farm is located in Mirer Chak village under Boalia Thana. The farm raises the exotic Fayoumi and crossbred *Sonali*. The specialty of this farm was that it provided knowledge on meat purpose rearing of the exotic and crossbred chicken.

Godagari: The farm is sited in Rajabari village under Godagari Thana. The farm rears simply the exotic breed RIR and it provided vast information on the exotic rearing at small scale pattern.

Mohanpur: The visited farm is located under Khoira village of Mohanpur Thana. The exotic Fayoumi and crossbred *Sonali* was the rearing breeds of this farm. The farm furnished understanding on meat purpose rearing of the exotic and crossbred chicken.

Motihar: The farm is situated in Kapasia village under Motihar Thana. The rearing breeds of this farm were the exotic broiler, cockerel and crossbred *Sonali*. This farm also bears adequate knowledge on meat purpose rearing of the exotic and crossbred chicken.

Paba: It is placed under Sayer Pukur village of Paba Thana. Rearing breed of this farm is the exotic RIR. The farm possesses a guide of rearing exotic breed for egg purpose rearing with an aim of achieving profit from poultry enterprise.

Puthia: The farm is situated in the Kajir Para village of Puthia. The farm raises the exotic Fayoumi and crossbred *Sonali*. The specialty of this farm was that it provided awareness on small-scale meat purpose rearing of the exotic and crossbred chickens.

Rajpara: The visited farm is located under Nagar Para village of Rajpara Thana. The farm usually rears cockerel and RIR breeds. The farm provides conception on both meat and egg purpose rearing of the exotic breed at a profit making approach.

Shahmokdum: The selected farm is located under Baroipara village of Shahmukdum Thana. The farm raises only the exotic RIR for egg purpose. The farm represents a manner of raising an exotic breed for earning from eggs.

Tanor: The visited farm is placed under Jeeol village of Tanor Thana. The farm rears basically the exotic breed RIR and it endows with vast information on the exotic rearing at small-scale outline with a variety of earning practices.

Plate 4.1 Selected poultry farms at the study area - I

A Government farm (Outside view)

B Government farm (Inside view)

C RIR chicken farm at Baghmara

D *Sonali* chicken farm at Boalia

E RIR chicken farm at Godagari

F Fayoumi chicken farm at Mohanpur

Plate 4.2 Selected poultry farms at the study area - II

A Cobb 500 (broiler) farm at Motihar

B RIR chicken farm at Paba

C *Sonali* chicken farm at Puthia

D Cockerel farm at Rajpara

E RIR farm at Shahmokdum

F RIR farm at Tanor

Backyard chicken farms

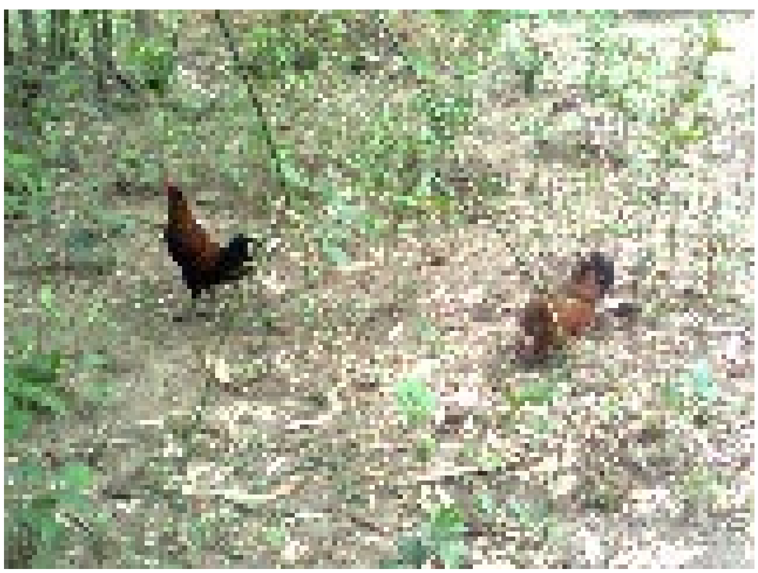
The backyard poultry houses in the study area usually rear indigenous chickens through semi scavenging system of chicken management. Basically, these are reared on semi-scavenging method (**Plate 4.3**). Therefore, the indigenous chickens are found neither in the private nor in the government farms. The small household farmers rear this breed equally for meat and egg purposes. However, the smallholders' backyard poultry houses are shown in **Plates 4.4 and 4.5**.

Baghmara: The visited house is located under Sreepur Purbopara village.
Boalia: The visited house is positioned under Mirerchak village.
Godagari: The visited house is placed under Rajabari village.
Mohonpur: The visited house is to be found under Khoira village.
Motihar: The visited house is sited under Kapasia village.
Paba: The visited house is situated under Sayerpukur village.
Puthia: The visited house is located under Kajirpara village.
Rajpara: The visited house is situated under Holdarpara village.
Shahmokdum: The visited house is situated under Baroipara village.
Tanor: The visited house is situated under Chandpur village.

The quantitative data were collected from the farmers' record as of the three successive fiscal years 2011-2012, 2012-2013 and 2013-2014, respectively at the study area.

Plate 4.3 Indigenous (*Deshi*) chicken on semi-scavenging system

A Indigenous (*Deshi*) naked neck hen with her chicks



B Chicken moving freely outside of the house

Plate 4.4 Backyard chicken farms at the study area - I

A *Deshi* chicken at Sreepur village

B *Deshi* chicken at Mirerchak village

C *Deshi* chicken at Rajabari village

D *Deshi* chicken at Khoira village

Plate 4.5 Backyard chicken farms at the study area - II

A *Deshi* chicken at Kapasia village

B *Deshi* chicken at Sayerpukur village

C *Deshi* chicken at Kajirpara village

D *Deshi* chicken at Holdarpara village

E *Deshi* chicken at Baroipara village

F *Deshi* chicken at Chandpur village

4.2.2 Experimental chicken breeds

A total of six varieties of chicken breeds among which one indigenous (*Deshi*), one crossbred *i.e.*, *Sonali* and the rest four were pure breeds, for instance, broiler, cockerel, RIR and Fayoumi were selected for the study (**Plate 4.6**). However, the selected chicken breeds possessed the following characteristic features:

Broiler (Cobb 500): The broilers are classified as the Mediterranean breeds and are originated in Italy and so far there are twelve varieties of which three popular are single comb white, single comb buff and single comb brown (**Plate 4.6 A**). Broiler meat is considered a major source of high quality animal protein, required for growth and mental development (Adetola and Simeon, 2013). This type of chicken rises especially for meat production. The standard body weight of cock is 2.3-3.0 kg, hen 1.5-2.0 kg and pullet 1.5-2.0 kg.

Cockerel: The cockerels are an isolated male chicken from the exotic breeds (**Plate 4.6 B**). They constitute 50% of day-old layer chicks. Such chicks have become an indispensable component of poultry development with the rapidly increasing trends of commercial layer farming in Bangladesh (Sarkar *et al*., 2008). It is very fast maturing and grows within eight weeks of age. The adults reach a weight of 0.5-1.0 kg. Cockerels are raises especially for meat production. Utilization of cockerels through smallholder family poultry farming helps to control environment pollution, increase nutrition, generates income and self-employment in the rural community.

Fayoumi: Fayoumi the exotic pure breed is extensively used in rural areas (**Plate 4.6 C**). This breed is from Egypt and possesses the characteristics of early sexual maturity, more egg production and low mortality (Zaman *et al*., 2008). It is a high profitable breed with low cost and farmer can easily rear this breed both in intensive and scavenging systems. It is hardy, very precisions in early maturing and has excellent flying escaping capacity. The pullets may start laying a small tinted egg when 4 months old, while the cockerels often grow at 6 weeks of age. Adult males reach a weight of 2 kg and females 1.5 kg, which produce 200 eggs per year (Das, 2005).

Indigenous: The Indigenous chickens (**Plate 4.6 D**) are reported to be derived from the *Gallus gallus* (Beede, 1931; Faruque *et al*., 1987). Among the native fowls there are some distinct categories namely Hilly, Naked Neck, Aseel, Yasine, Native dwarf and non-descriptive *Deshi*

(*Gallus domesticus*). They have an inherent scavenging habit and more resistant to diseases, less prone to predator attacks and can survive under harsh nutritional and environmental conditions and are characterized by small pea comb, head and beak is long; earlobes are small, usually red and at times admixtures with a little white. The breed possesses excellent fleshing properties and good laying abilities. The standard body weight of cock is 3.5-4.5 kg and hen 3.0-4.0 kg.

Rhode Island Red: Rhode Island Red is an American breed, originated from New England of the USA and crosses among Malay wild fowl, Leghorn and Asian local variety (Zaman *et al*., 2008). Body structure is slender, triangular and heavy weighted. They are sometimes completely red, slight yellow, white and brown in colour (**Plate 4.6 E**). Combs are single or rose but single is common. RIR cock is weighed about 4 kg; hen 3 kg, cockerel 3.4 kg and pullets are of 2.5 kg.

***Sonali*:** A crossbred of Fayoumi female and RIR male first developed in 1986 (**Plate 4.6 F**). It has specially been advocated in terms of their higher egg production rate and better adaptability in rural situation (Ahmed, 1997). Females produce about 180 eggs per year on an average. It is considered as dual purpose breed considering environmental factors such as predators, rainfall and housing and economic traits as survivability and rapid growth of male chicks as well as egg production (Amber, 2000). Body plumage, legs and ear-combs are yellowish. Therefore, this crossbred has been given an appropriate name, *Sonali*.

Plate 4.6 Broiler, Cockerel, Fayoumi, *Deshi*, RIR and *Sonali* chickens

A Broiler (Cobb 500) chicken

B Cockerel chicken

C Fayoumi chicken

D Indigenous (*Deshi*) chicken

E Rhode Island Red chicken

F *Sonali* chicken

4.2.3 Analysis on profitability

Farm- as well as year-wise productivity data from the selected 21 poultry farms were recorded, calculated and analyzed during the study period (**Table 4a**). Data were collected fortnightly during the Fiscal Year: July 2011-June 2012, July 2012-June 2013 and July 2013-June 2014, respectively. The studied parameters for productivity analysis are following to yearly chicken production, total cost of production, total revenue, net profit, cost-benefit ratio, rate of return on investment, gross ratio and profitability index. Productivity of the poultry farms were determined following the procedures of Alabi and Aruna (2005), Nworgu (2007) and Adetola and Simeon (2013) with some modifications. A detailed account of these parameters is provided below:

Yearly chicken production: Yearly chicken production (YCP) was calculated from the sum of the number of chicken raised in a particular farm in a particular year. Production numbers of the chicken breeds are analyzed farm-wise and year-wise accordingly.

Table 4a: General information of the poultry farms and breeds under study

Farm	Obs. No.	Location	Rearing breeds	Nature	Purpose
GOV	N=1	Godagari	Fayoumi & *Sonali*	EXO & CRO	Meat & Egg
PRI	N=10	1. Baghmara	RIR	EXO	Egg
		2. Boalia	Fayoumi, *Sonali*	EXO & CRO	Meat
		3. Godagari	RIR	EXO	Egg
		4. Mohanpur	Fayoumi, *Sonali*	EXO & CRO	Meat
		5. Motihar	Broiler, Cockerel & *Sonali*	EXO & CRO	Meat
		6. Paba	RIR	EXO	Egg
		7. Puthia	Fayoumi, *Sonali*	EXO & CRO	Meat
		8. Rajpara	Cockerel, RIR	EXO	Meat & Egg
		9. Shahmokdum	RIR	EXO	Egg
		10. Tanor	RIR	EXO	Egg
BCF	N=10	1. Baghmara	*Deshi*	IND	Meat & Egg
		2. Boalia	*Deshi*	IND	Meat & Egg
		3. Godagari	*Deshi*	IND	Meat & Egg
		4. Mohanpur	*Deshi*	IND	Meat & Egg
		5. Motihar	*Deshi*	IND	Meat & Egg
		6. Paba	*Deshi*	IND	Meat & Egg
		7. Puthia	*Deshi*	IND	Meat & Egg
		8. Rajpara	*Deshi*	IND	Meat & Egg
		9. Shahmokdum	*Deshi*	IND	Meat & Egg
		10. Tanor	*Deshi*	IND	Meat & Egg

Note: GOV=Government farm, PRI=Private farms and BCF=Backyard chicken farms; EXO=Exotic, CRO=Crossbred and IND=Indigenous.

Total cost of production: Total cost of production (TCP) were calculated from the sum of the amount spent for rent of land/houses, purchase of day-old chicks, feed cost, medicine cost, wages, electricity and water bills, caring cost and depreciation of the fixed costs.

Total revenue: Total revenue (TR) was calculated from the sum of the amount received from sales of day-old chicken, spent hens, table eggs and poultry waste products.

Net profit: Net profit (NP) was calculated by deducting the total cost of production from total revenue. The formula is as follows: NP = TR - TCP.

Cost-benefit ratio: Cost-benefit ratio (CBR) was estimated through dividing the total revenue by total cost of production. The formula is as follows: TR ÷ TCP.

Rate of return on investment: Rate of return on investment (RRI) were calculated from dividing the net profit by total cost of production and multiplying them with hundred. The formula is as follows: RRI = NP ÷ TCP × 100.

Gross ratio: Gross ratio (GR) was calculated through dividing the total cost of production by total revenue. The formula is as follows: GR = TCP ÷ TR.

Profitability index: Profitability index (PI) was calculated from dividing the net profit by total revenue. The formula is as follows: PI = NP÷TR

4.2.4 Statistical analyses

A statistical package for social sciences (SPSS) software version 19.0 was employed for data analysis and interpretations. The analysis considered all the subsequent parameters *viz*., total cost of production, total revenue, net profit, cost-benefit ratio, rate of return on investment, gross ratio and profitability index from different poultry farms. The parameters were calculated following the procedures of Alabi and Aruna (2005), Nworgu (2007) and Adetola and Simeon (2013).

4.3 Results

4.3.1 Farm-wise variations in productivity

Variations in chicken productivity on farm basis are presented in **Table 4b**. The findings shows that the rearing breeds of Government farm was Fayoumi, RIR and *Sonali*; whereas the rearing breeds of private farms were broiler, cockerel, Fayoumi, RIR and *Sonali*, while the rearing breed of backyard chicken farm is indigenous (*Deshi*) chicken. In the Government farm the *Sonali* breed was the highest in production number (1283.33±324.79) followed by Fayoumi (1028.67±104.11) and RIR (505.33±252.66) respectively. Like-wise in private farms the *Sonali* breed also attained the highest production number (2613.33±386.51) followed by RIR (1823.33±239.17), broiler (1473.33±400.95), cockerel (1350.00±383.69) and Fayoumi (1031.67±204.55) chicken breeds in that order.

Resting on, the indigenous chicken showed the average production number (18.27±0.69) through the backyard chicken farmers at the study area. From the findings it was frequent that the exotic Fayoumi and RIR with crossbred *Sonali* was the admired breed in both Government and private farms. The production number of chickens breeds among the farms showed highly significant difference (P<0.001) for Fayoumi, RIR, *Sonali* and indigenous. The findings are graphically presented in **Fig. 4a**.

Table 4b: Farm-wise variation of chicken productivity in Rajshahi, Bangladesh

Farms	COB	COC	FAY	RIR	SON	IND
GOV	-	-	1028.67 ±104.11	505.33 ±252.66	1283.33 ±324.79	-
PRI	1473.33 ±400.95	1350.00 ±383.69	1031.67 ±204.55	1823.33 ±239.17	2613.33 ±386.51	-
BCF	-	-	-	-	-	18.27 ±0.69
F-values P-values	7.391 **	6.776 **	13.884 ***	30.348 ***	23.735 ***	387.054 ***

Note: Data compiled from field survey, FY: 2011-12, 2012-13 and 2013-14; GOV=Government, PRI=Private and BCF=Backyard chicken farms; COB=Cobb 500 broiler, COC=Cockerel, FAY=Fayoumi, RIR=Rhode Island Red, SON=*Sonali* and IND=Indigenous chickens; [-]=indicate absent mark, All F-values were at 188 df.; **= P<0.01, ***= P<0.001.

4.3.2 Year-wise variations in productivity

The year based variations in chicken productivity are presented in **Table 4c**. The vertical analysis of the findings shows that the *Sonali* chickens attained the highest number in productivity (1585.71±444.67) followed by RIR (1190.48±285.65), cockerel (833.33±357.78), Fayoumi (642.86±204.43), broiler (523.81±297.50) and indigenous (10.76±1.54) respectively in the fiscal year 2011-2012. Similarly, in the fiscal year 2012-2013 the *Sonali* breeds also achieved the highest in production number (1416.67±342.14) followed by RIR, cockerel, broiler, Fayoumi and indigenous with average production number (785.71±206.99), (595.24±338.07), (523.81±297.50), (473.81±155.02) and (7.90±1.17) in that order. Correspondingly, the broiler breed attained the highest in production number (1057.14±419.28) followed by *Sonali* (914.29±261.25), RIR (700.76±174.63), Fayoumi (504.10±180.99), cockerel (500.00±283.98) and indigenous (7.43±1.06) respectively in the fiscal year 2013-2014.

Table 4c: Year-wise variation of chicken productivity in Rajshahi, Bangladesh

Fiscal Years	COB	COC	FAY	RIR	SON	IND
2011-12	523.81 ±297.50	833.33 ±357.78	642.86 ±204.43	1190.48 ±285.65	1585.71 ±444.67	10.76 ±1.54
2012-13	523.81 ±297.50	595.24 ±338.07	473.81 ±155.02	785.71 ±206.99	1416.67 ±342.14	7.90 ±1.17
2013-14	1057.14 ±419.28	500.00 ±283.98	504.10 ±180.99	700.76 ±174.63	914.29 ±261.25	7.43 ±1.06
F-values	0.806	0.274	0.247	1.326	0.955	1.994
P-values	ns	ns	ns	ns	ns	ns

Note: Data compiled from field survey, FY: 2011-12, 2012-13 and 2013-14; COB=Cobb 500 broiler, COC=Cockerel, FAY=Fayoumi, RIR=Rhode Island Red, SON=*Sonali* and IND=Indigenous chickens; All F-values were at 188 df.; ns=not significant.

On the contrary, the longitudinal analysis of the findings revealed that following the three succeeding fiscal years 2011-12, 2012-13 and 2013-14; the cockerel, Fayoumi, RIR, *Sonali* and indigenous chicken breeds were the highest in production number with (833.33±357.78), (642.86±204.43), (1190.48±285.65), (1585.71±444.67) and (10.76±1.54) respectively in the fiscal year 2011-12, except for broiler with the highest production number (1057.14±419.28) in the fiscal year 2013-14. Resting on, the productivity of all the chicken breeds consecutively decreased from the fiscal year 2011-12 to 2013-14 except for broiler chicken, which showed increased productivity gradually from the fiscal year 2011-12 to 2013-14 at the study area.

Commencing the findings it was frequent that the exotic broiler (1057.14±419.28) and crossbred *Sonali* (914.29±261.25) was the frequent breed in the fiscal year 2013-2014 followed by RIR (700.76±174.63), Fayoumi (504.10±180.99), cockerel (500.00±283.98) and indigenous (7.43±1.06) respectively. The production number of chickens breeds among the years demonstrated insignificant difference for all the chicken breeds ($P>0.05$). The findings are graphically presented in **Fig. 4b**.

4.3.3 Farm-wise variations in production costs and benefit

Variations in chicken production costs and benefit on farm basis are presented in **Table 4d**. The findings demonstrated that the total cost of production for the Government, private and backyard chicken farm was BDT 5930784.50, 4245769.25 and 4431.22 respectively. The cost carried out revenues was BDT 5796425.00, 4654758.84 and 12475.25 for the Government, private and backyard chicken farms correspondingly. However, the net profit was found negative for the Government farm with BDT -134359.48, while positive for the private and backyard chicken farms with BDT 408989.62 and 8044.02 in that order throughout the entire production period. The findings revealed that the Government farm bear losses for the intact production. The production parameters among the farms established highly significant difference ($P<0.001$) for all the cases. The findings are graphically presented in Figure 4c.

Table 4d: Farm-wise variation of chicken production costs and benefit in Rajshahi, Bangladesh

Farms	TCP	TR	NP	CBR	RRI	GR	PI
GOV	5930784.50	5796425.00	-134359.48	0.979	-2.082	1.021	-0.021
PRI	4245769.25	4654758.84	408989.62	1.145	14.476	0.886	0.114
BCF	4431.22	12475.25	8044.02	2.983	198.340	0.354	0.646
F-values	46.838	53.821	20.781	95.739	95.739	283.905	283.905
P-values	***	***	***	***	***	***	***

Note: Data compiled from field survey, FY: 2011-12, 2012-13 and 2013-14;, GOV=Government, PRI=Private and BCF=Backyard chicken farms; TCP=Total cost of production; TR=Total revenue; NP=Net profit *i.e.*, NP=TR-TCP; CBR=Cost-benefit ratio *i.e.*, CBR=TR÷TCP; RRI=Rate of return on investment *i.e.*, RRI=NP÷TCP×100; GR=Gross ratio *i.e.*, GR=TCP÷TR; and PI=Profitability index *i.e.*, PI=NP÷TR; All F-values were at 62 df.; ***= $P<0.001$.

On the contrary, the backyard chicken farm attained the highest cost benefit ratio 2.983, followed by private and Government farm 1.145 and 0.979 respectively. In a similar way, the rate of return on invest was found the highest for backyard farms with 198.340 and private farm with

14.476; but the Government farm shows negative values of RRI with -2.082 which mean production lose. The gross ratio specified that the backyard farms attained maximum profit than private and Government farm with the GR value 0.354, 0.886 and 1.021 respectively. Equally, the profitability index exposed that the backyard farms attained maximum profit than private farms with PI value 0.646 while the private farms shows PI value 0.114. In contrast, the Government farm shows negative PI value (-0.021) which indicates economic loses. The findings are graphically presented in **Fig. 4d**.

4.3.4 Year-wise variations in production costs and benefit

Correspondingly, the year based variations in chicken production costs and benefit are presented in **Table 4e**. The findings verified that the total cost of production for the three succeeding fiscal years 2011-12, 2012-13 and 2013-14 was BDT 2200049.66, 2557082.78 and 2161837.45 respectively. Along with the cost carried out revenues was BDT 2424889.88, 2709108.20 and 2361539.90 in that order. The results exposed that the maximum revenue was attained in the fiscal year 2012-13. Throughout the entire fiscal years net profit was found the highest in 2011-12 with BDT 224840.23 and lowest in 2012-13 with BDT 152025.45, followed by BDT 199702.46 in 2013-14. The results suggested that the fiscal year 2011-12 was the profitable year for the poultry production at the study area. The production parameters among the fiscal years established insignificant difference (P>0.05) for all the cases. The findings are graphically presented in **Fig. 4e**.

Table 4e: Year-wise variation of chicken production costs and benefit in Rajshahi, Bangladesh

Fiscal Years	TCP	TR	NP	CBR	RRI	GR	PI
2011-2012	2200049.66	2424889.88	224840.23	2.156	115.561	0.606	0.393
2012-2013	2557082.78	2709108.20	152025.45	2.179	117.928	0.633	0.367
2013-2014	2161837.45	2361539.90	199702.46	1.702	70.236	0.679	0.321
F-values	0.118	0.078	0.259	1.339	1.339	0.328	0.328
P-values	ns	ns	ns	ns	ns	ns	ns

Note: Data compiled from field survey, FY: 2011-12, 2012-13 and 2013-14; TCP=Total cost of production; TR=Total revenue; NP=Net profit *i.e.*, NP=TR-TCP; CBR=Cost-benefit ratio *i.e.*, CBR=TR÷TCP; RRI=Rate of return on investment *i.e.*, RRI=NP÷TCP×100; GR=Gross ratio *i.e.*, GR=TCP÷TR; and PI=Profitability index *i.e.*, PI=NP÷TR; All F-values were at 62 df.; ns= not significant.

Conversely, the highest cost benefit ratio (2.179) was attained in the FY 2012-13, followed by FY 2011-12 and FY 2013-14 with CBR 2.156 and 1.702 respectively. equally, the rate of return on invest was found the highest for FY 2012-13 with RRI 117.928 and FY 2011-12 with RRI 115.561; but it was the lowest in FY 2013-14 with RRI 70.236 which mean lower production profit. The gross ratio (0.606) specified that the FY 2011-12 attained maximum profits than FY2012-13 and FY2013-14 with the GR value 0.633 and 0.679 respectively. Evenly, the profitability index (0.393) shows that the FY 2011-12 achieved maximum profit than FY2012-13 and FY2013-14 with PI value 0.367 and 0.321 respectively. The findings revealed that the production profit was gradually decreased from the FY2011-12 to FY2013-14 throughout the entire production period which indicates economic instability. The findings are graphically presented in **Fig. 4f**.

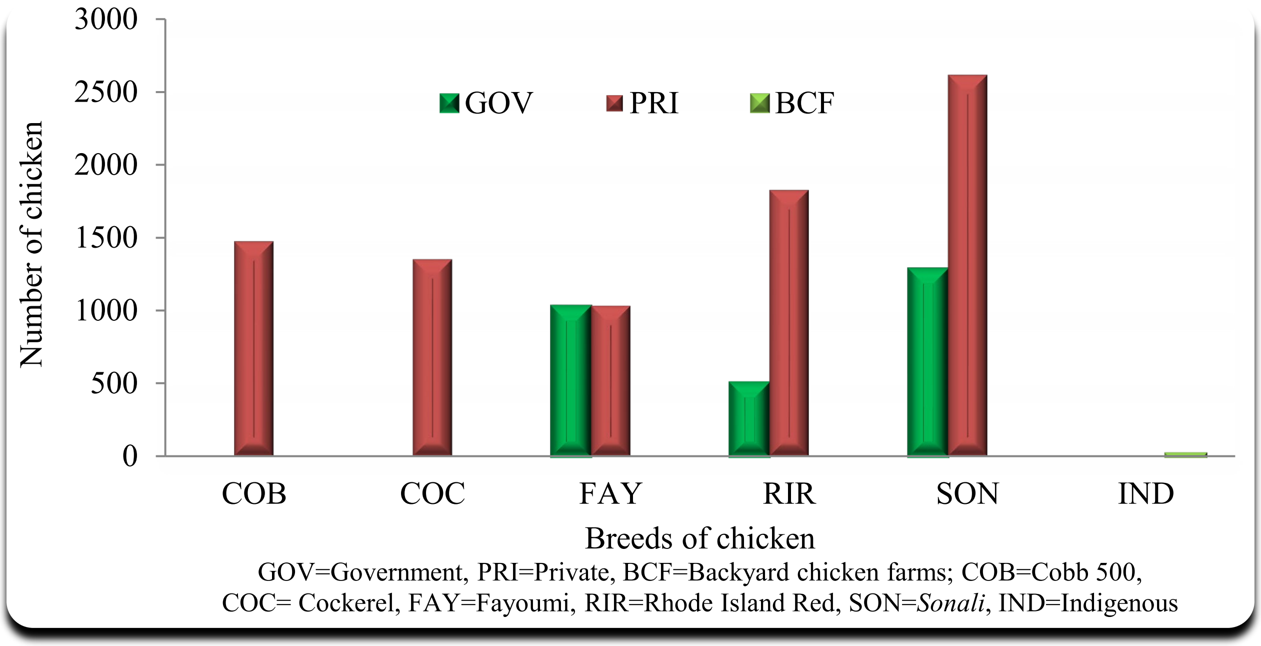


Fig. 4a: Breed-wise chicken productivity in the poultry farms of Rajshahi, Bangladesh

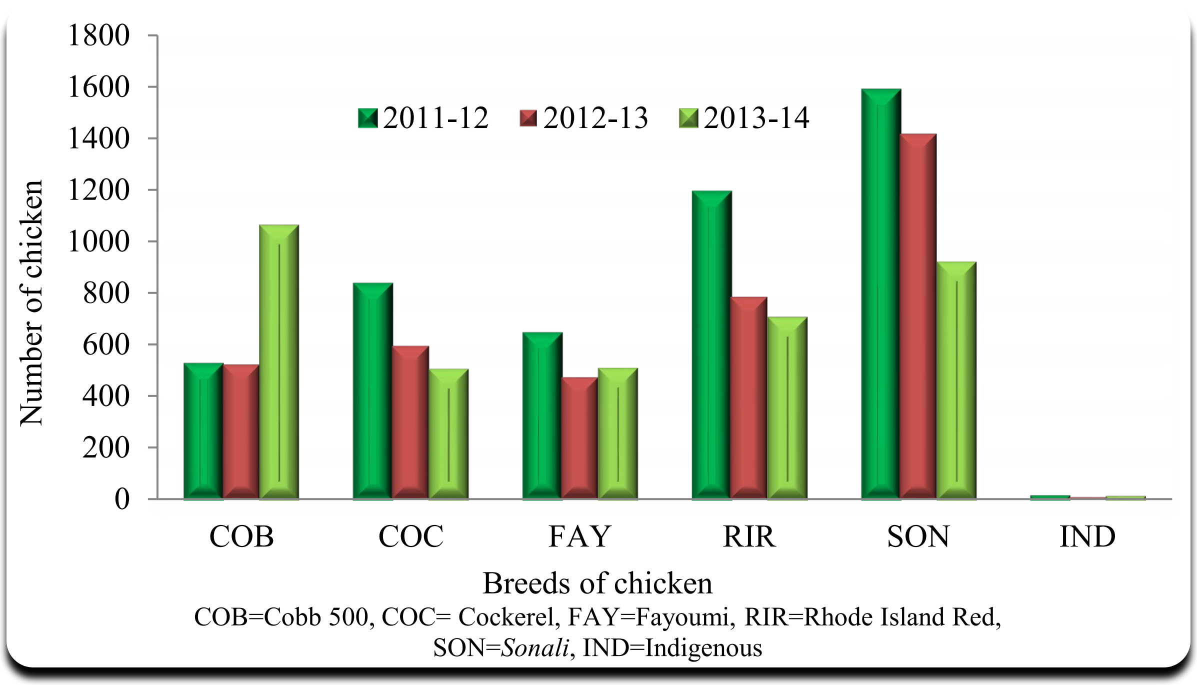


Fig. 4b: Breed-wise chicken productivity in the consecutive three fiscal years

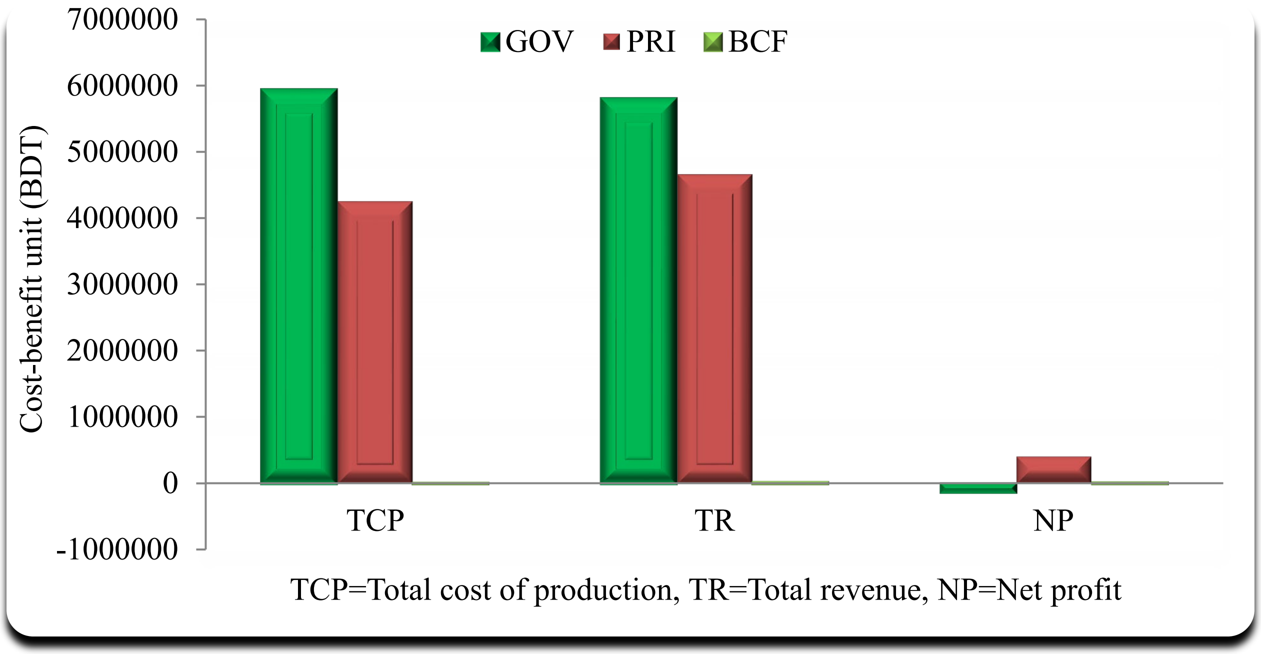


Fig. 4c: Farm-wise chicken production cost and benefit in Rajshahi, Bangladesh

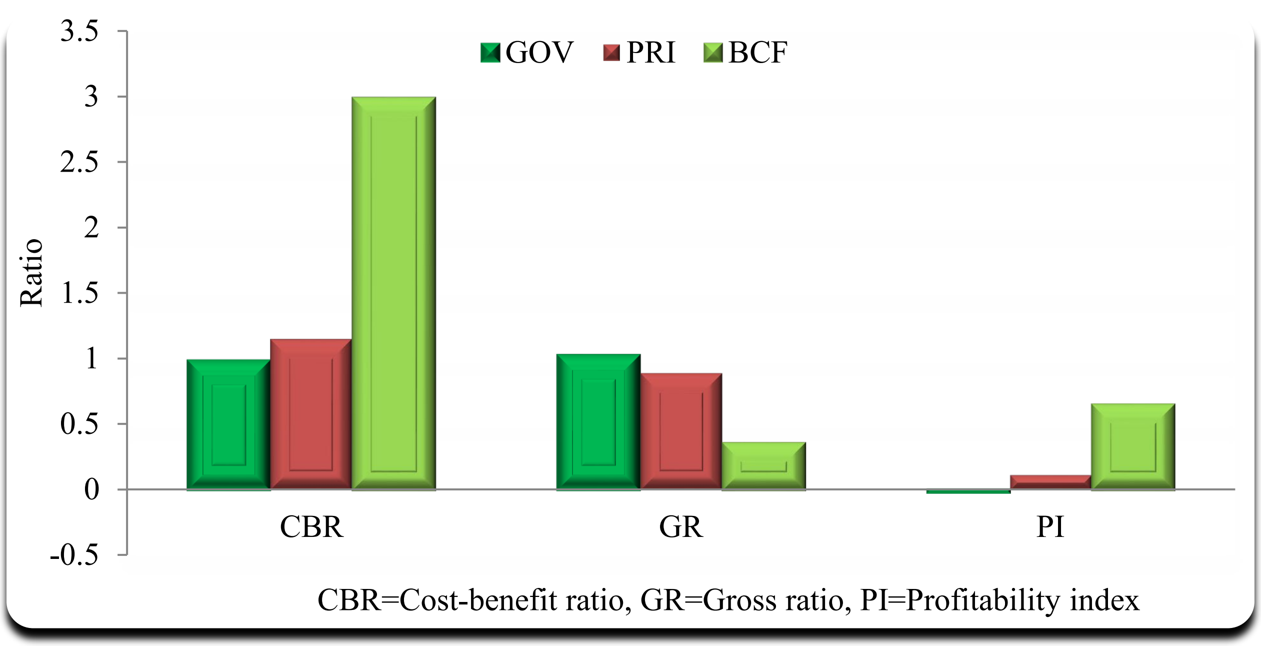


Fig. 4d: Farm-wise cost-effective performance of chicken breeds in Rajshahi, Bangladesh

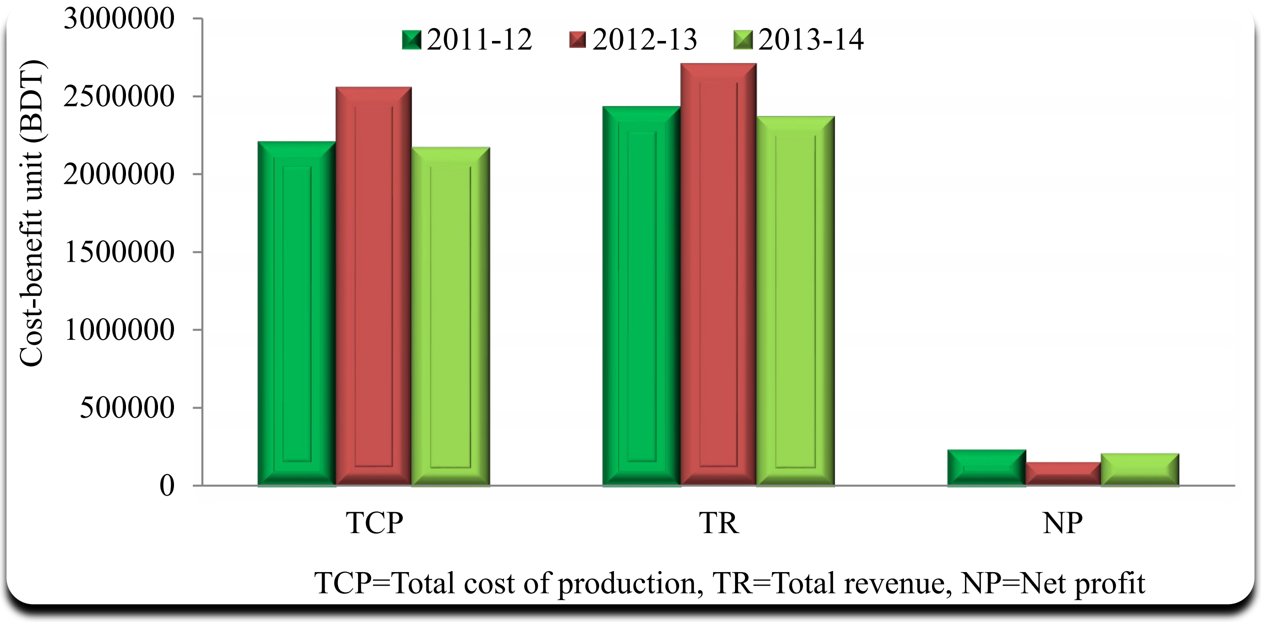


Fig. 4e: Year-wise chicken production cost and benefit in Rajshahi, Bangladesh

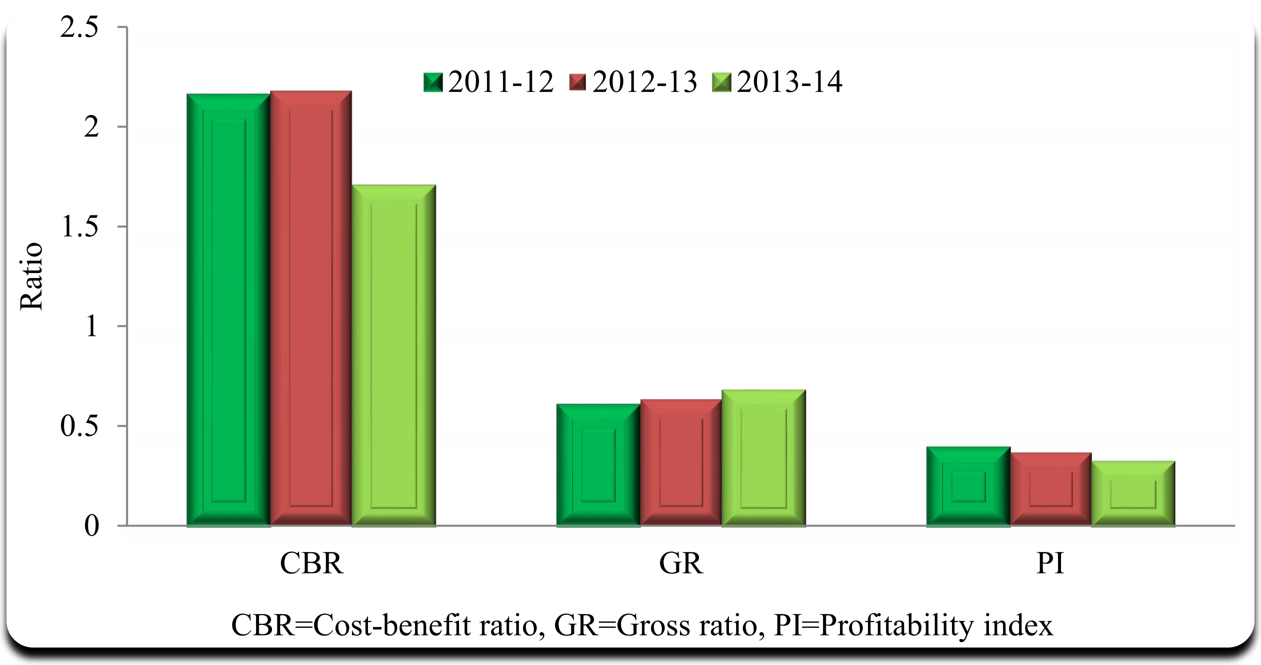


Fig. 4f: Year-wise cost-effective performance of chicken breeds in Rajshahi, Bangladesh

4.4 Discussion

Previously it has been shown that the profitability of family poultry production can be increased by the use of appropriate feed, medicine or vaccine, capital and adoption of more innovations (Alabi and Aruna, 2005). Roy *et al*. (2006) investigated the production performance and economics of producing cockerels (Shaver 579 male chicks) up to different market weights. The average cost of rearing per bird was Tk. 66.42, 62.65 and 59.72 for market weight of 500g, 750g and 1000g respectively. Nworgu (2007) studied the growth performance and economic efficiency of broiler chickens, where supplementary pumpkin leaf extracts increased growth performance and economic efficiency in terms of CBR (1.76 to 2.06), RRI (76.20 to 106.04) and PI (0.43 to 0.52), leading to higher profit margin. Sarkar *et al*. (2008) concluded that the commercial broiler, cockerel and *Sonali* chicks could be reared up to 28, 56 and 63 days, respectively to reach target weights close to 1250, 850 and 850g, respectively to obtain maximum profit. Whereas Zaman *et al*. (2008) studied profitability components of four genotypes including *Sonali*, in which the CBR was highest (5.92) at 15g feed/hen/day.

Maqbool and Bukhsh (2007) focused to estimate the percentage share of different stake holders in total profitability from poultry industry because inequitable distribution of profit share was assumed to be one of the major obstacles in the expansion of poultry industry. The results demonstrated that commission agents were earning 47% of the total profit in poultry industry, followed by retailers (28%) and producers (25%). Which indicates that to improve the contribution of poultry in total nutrients uptake of human beings without reversing the trends in profit share is unfeasible. The effect of market fluctuations in the prices of birds for slaughter on the profitability of broiler production has been observed but it has not been directly related to the flu epidemic. Because of the difficult market situation, the producers aimed to reduce the actual production costs of the factors which they were able to influence e.g. notice-able reduction of labour costs (Gumulka *et al*., 2009). Sonaiya (2009) reported that smallholder family poultry is affected by many technical factors including low bio-security, restriction to live bird markets, inadequate sources of inputs and services especially sources of technical information as well as by lack of genetically improved breeds. The free-range or scavenging system results in high chick mortality and intestinal worm infestation. The efficiency and profitability of family enterprises using indigenous poultry are limited by disease, production constraints, and external factors. The limitations caused by viral diseases, notably Newcastle disease, avian influenza, Gumboro disease and fowl pox, can be largely alleviated through the use of vaccination programmes adapted to the local prevalence of diseases (Bell, 2009).

However, the economic potentials of free range indigenous fowl reared by rural women were studied by Singh *et al*. (2009). Findings printout the average annual farm income from sale of eggs and birds were Rs. 7452, 15120 and 35625 for small, medium and large units, respectively. Profitability of Cobb 500 broiler chickens was related to increase the population density per unit of surface (m^2) and to reduce the duration of production (Mitrovic *et al*., 2010). Sumy *et al*. (2010) demonstrated that backyard chicken rearing was profitable for the farmers in the study areas, while Bano *et al*. (2011) investigated that broiler production was profitable with a profitability index of 0.24. Ike and Ugwumba (2011) verified that six variables including experience in broiler production, farming status, access to credit, labour, number of Day-old chicks and quantity of feeds exerted statistically significant influence on broiler production. In contrast, high content of fiber but low content of protein in cassava tuber meal supplement inhibited the growth performance, thereby decreasing the profitability of broiler rearing (Sultana *et al*., 2012b). Dutta *et al*. (2012a) evaluated the performance of meat purpose Cobb 500, ISA Brown, Fayoumi and *Sonali* chickens. In terms of the CBR values for meat producers, the cockerel of ISA White (1.58) was the best and the broiler of Cobb 500 (1.15) the worst. CBR for egg productivity, on the other hand, was highest in *Sonali* (1.11) followed by RIR and Fayoumi (1.10 each) and Cobb 500 (1.09). As regards the meat productivity, significant correlations existed between TC and NR for all chickens except *Sonali*, which exhibited a negative correlation between the traits.

Recent reports on family poultry profitability index (PI) in Nigeria ranged between 0.29 and 0.84 (mean 0.63) and return on investment 0.76, meaning that family poultry is highly profitable (Aboki *et al*., 2013). Adetola and Simeon (2013) estimated profitability ratios of three broiler strains *viz*., Arbor Acre, Hubbard and Marshall in which the values of CBR were 1.08, 1.10 and 1.17, respectively, that of RRI were 9.0%, 10.4% and 17.5%, respectively and that of PI were 0.08, 0.09 and 0.15, respectively. Moreover, Siyaya (2013) assessed the determinants of profitability in which profitability value was E0.40 per E1.00 of feed cost, where feed cost, market price, stock size, number of birds sold and number of birds consumed significantly affected profitability of indigenous Cobb Douglas chickens. While Kawsar *et al*. (2013) found that the farm size, training, education, farming experience and extension contact were significant factors affecting profitability of small-scale broiler farms. Income over feed cost identifies how much income that is gained after subtracted with feeding cost for a day.

Income over feed cost during production period increased protein level that was sufficiently high showed better performance and profit of layer poultry farm that used small scale feed mill production (Isbandi *et al*., 2013). Uddin *et al*. (2013) estimated the gross and net returns per household per day from native poultry rearing were estimated at Tk. 34.04 and Tk. 27.93, respectively. The undiscounted benefit cost ratio was 5.57, implying that this enterprise is highly profitable. However, Uddin *et al*. (2014) estimated that with *Sonali* chicken production the total cost for 1000 birds were estimated at Tk. 120613 per batch. Average gross margin and average net returns was calculated at Tk. 57240 and Tk. 52059 per batch. An average gross return was estimated at Tk. 172672 per batch with 1.4 BCR. Melesse (2014) reported that scavenging chicken production is a profitable enterprise that contributes to poverty reduction especially among the resource challenged rural communities in most parts of the developing world. However, owing to differences in host gene and nature of the feed supplement, the present results on the productivity components of the chicken rearing are much different from those of Nworgu (2007), Aboki *et al*. (2013) and Adetola and Simeon (2013), but similar to Sarkar *et al*. (2008), Bano *et al*. (2011) and Uddin *et al*. (2014). Therefore, the findings emphasize the use of adequate supplementation in poultry rearing towards the enhancement of productivity to the producers, marketers and policy makers for sustainable poultry farming in the country.

CHAPTER FIVE

MANAGEMENT STUDIES ON THE CHICKEN BREEDS

5.1 Introduction

Economic management is one of the main aspects in any poultry venture. Profitability of a small or large-scale production unit depends on the economic management of that particular farm. The cost-benefit ratio of a farm should be such that the farms easily run their business profitably round the year. At present it has become imperative to know the technique of scientific poultry keeping as much science as an art. It is essential to combine scientific principles with arts of poultry keeping reaping the best harvest. However, the Food and Agricultural Organization estimated poultry population to be around 156 million chickens and 13 millions ducks with a total annual production of 1,30,000 metric tons of eggs and 1,10,000 metric tons of meat in Bangladesh from poultry (FAO, 2009). According to Bangladesh Bureau of Statistics (BBS, 2012) there are about 135.10 million poultry populations in Bangladesh. Therefore, towards the economic development, poultry is one of the most important and promising industrial sectors of Bangladesh. Traditionally poultry rearing was considered as a small-scale operation and an additional source of income for the rural people of the country (Bhuyian *et al*., 2013).

Poultry dropping are a good bio-fertilizer for agricultural crops, fish food and a good source of gas for fuel produce by fermentation. Other by-products like viscera, feathers and blood have been the good sources of livestock feed, poultry feed, pet animal feed, fertilizers and industrial raw materials (Al-Amin *et al*., 2009). Lack of proper disposal of the voluminous excreta is creating environmental and health hazards and spread foul smell in the adjoining areas of the poultry farms. Sometimes local communities complain against farms, may become threat to the sustainability of poultry industries (Khaleduzzaman and Khandaker, 2009). So, layer droppings created an endangered urban life and deteriorate the daily life of people with a consequent degradation of the environment. The concept of layer droppings disposal has taken a new dimension and emphasis has been given on proper layer droppings disposal, which is not only profitable but also environment friendly. Moreover, livestock and poultry birds are major causes of zoonotic diseases transmission chain. Along with bio-security measure poultry health management is now the emerging issue. The food from livestock sources need to be free from disease causing agents to safe guard public health. Farm to fork chain must be clean and hygienic. Therefore, bio-security is foremost important to poultry farmers. It reduces losses in long terms. It promotes organic farming in rural area. Bio-security measures, poultry farm management and organic farming become sustainable development cycle in rural area (Bhattarai, 2008). Conversely, the situation is much complicated in developing countries including Bangladesh for illiteracy, unawareness and lower per capita income. The poultry farmers face various hygienic and environmental problems for poor layer droppings management.

At present environmental pollution is a great threat to poultry enterprise in the country. Layer dropping is now a factor to pollute environment. As nutrient rich products, it needed to be managed in a sustainable manner without causing environmental pollution. Layer droppings could be used as organic manure for crops, vegetables and pisciculture (Sarker *et al*., 2009). Improved management practices not only increase egg production, but also contribute to higher household income (Dutta *et al*., 2012). The most common feature of livestock and poultry operations that has not kept pace with the increase in the intensity of poultry production is manure or waste management. Poultry waste consists of droppings, wasted feed, broken eggs, feathers, dead birds and hatchery waste, all which is high in protein and contain substantial amount of calcium and phosphorus due to high level of mineral supplement in their diet. In relation to bio-security, the poultry sector requires special attention, particularly this time when bird flu is threatening the world (Mandefro *et al*., 2012). However, the improved productivity of smallholder farmers with smaller flock size depends on the adoption of disseminated management interventions package, production practices and challenges which includes housing, feeding, vaccination, brooding, and chick rearing system (Justus *et al*., 2013). However, under increased public concerns on bio-security, how to integrate the small scale poultry producers into safe and high value production chains is a key following issue in many developing countries (Wang *et al*., 2014).

From the current situation of small-scale production units, it has become essential to get some precise conception about proper scientific management of the poultry production particularly in rural areas. The purpose of this study was to evaluate the management practices of the chicken breeds and to know the problems and opinions of the poultry farm owners to raising poultry at small-scale production units to combat poultry diseases in the study area.

5.2 Materials and methods

5.2.1 Study area

Study of management practices of the farms as well as breeds were executed by using purposive sampling method, which is the selection of sample intentionally on 21 chicken farmers from the urban, semi-urban and rural areas of Rajshahi district, Bangladesh. A detailed account of the study area is spelled out in **Chapter Four**. However, the aforesaid six varieties of chicken breeds *i.e*., indigenous, broiler, cockerel, Fayoumi, RIR and *Sonali* were selected for the management study. The quantitative and qualitative data were collected from direct observations of the farmers' management as of the fiscal year July 2011 to June 2014 throughout the study area.

5.2.2 Analysis method

Using a five-scale scoring system, eight (8) major management practices as room temperature (RT), water source (WS), vaccination (VC), bio-safety measures (BM), boundary walls (BW), human residence (HR), chicken transportation (CT) and feeding management (FM); were considered to rank the farms under study, where score 5 was considered as Excellent, 4 as Good, 3 as Satisfactory, 2 as Not good and 1 as Unacceptable (Ritz, 2014). A detailed account of these management practice parameters are as follows:

Room temperature: Seasonal maintenance of room temperature, brooding, brooding facilities, management and brooding temperature of the rearing chicken breeds in different poultry farms under study were recorded. In case of *Deshi* chicken breeds the technique of brooding by broody hens under semi-scavenging system were noted during the study period.

Water source: Sources and feeding of water and water management for rearing each type of poultry breeds under study in the selected poultry farms were observed and recorded. In case of *Deshi* chicken breeds the water sources available under semi-scavenging system were noted during the survey time at the study area.

Vaccination: The nature of vaccine and the period and routine of vaccination program for rearing different chicken breeds in different poultry farms under study were recorded during the survey.

Bio-safety measures: Adopted bio-safety precautions *viz.,* use of disinfectants, disposal of dead bodies, disposal of excreta, access of wild animals and disease management practices were noted during the survey period from the poultry farms under study.

Boundary walls: The boundary walls of the poultry farms under study were investigated during the study period. The materials used for boundary walls *i.e*., bamboo, straw, bricks, net etc. and nature of protection from human and wild animals were inspected for that particular farm.

Human residence: Position of the farms and distance from human residence were recorded during the survey period. Farm location, territory of human activity and remoteness of human dwelling were scrutinized at the study area.

Chicken transportation: The mode and methods of transportation of the chicken breeds from the chicken providers or suppliers to the poultry farms and their marketing system after rearing were investigated during the study time at the study area.

Feeding management: The amount and type of feeds supplied for rearing each type of poultry breeds under study in the selected poultry farms were investigated and recorded. In case of *Deshi* breed the food available under semi-scavenging system were noted during the survey time.

5.2.3 Statistical analyses

The qualitative and quantitative data obtained from the parameters for management practices were subjected to statistical analyses for interpretations and graphical representations. As mentioned earlier, a statistical package (SPSS version 19.0) was employed for data analysis and interpretations. The analysis considered all the subsequent parameters of management practices *viz*., room temperature, water source, vaccination, bio-safety measures, boundary walls, human residence, chicken transportation and feeding management investigated and ranked accordingly from the selected poultry farms under study.

Plate 5.1 Existing poultry management practices in the study area - I

A Chick transportation at Govt. farm

B Litter management at Govt. farm

C Day-old chick collecting box at Govt. farm

D Supplying feed at Godagari farm

E Disinfectant spray at Baghmara

F Excreta management at Boalia

Plate 5.2 Existing poultry management practices at the study area – II

A Scavenging chicken at Motihar

B Broody hen at Motihar

C Incubator machine at Monhanpur

D Water supply at Rajpara

E Veterinary medicine at Shahmukdum

F Vaccinating chicken at Poba

Plate 5.3 Bio-secuity measures in poultry management at the study area – I

A Foot bath at Government farm

B Boundary wall at Government farm

C Unhygienic feeding management at Puthia

D Access of wild animal at Puthia farm

E Absence of boundary wall at Baghmara

F Absence of boundary wall at Motihar farm

Plate 5.4 Bio-secuity measures in poultry management at the study area – II

A Untrained child worker at Rajpara farm

B Farm closet to human residence at Rajpara

C Absence of boundary wall at Rajpara farm

D Improper dead body disposal at Poba farm

E Absence of foot bath at Tanor farm

F Mohanpur farm distant to human residence

5.3 Results

5.3.1 Farm-wise variations in management practices

Management practices adopted for the chicken breeds as well as farms at the study area are analyzed. Scoring results of farm based variations on adopted management practices are presented in **Table 5a**. The findings revealed that Government farm achieved highest score (4=good) for boundary wall, human residence and feeding management. Rest of the management practices acquired 3 and above scores (satisfactory to good) for room temperature, water source, vaccination, bio-safety measures and chicken transportation. However, the private farms attained highest score (3.42) for feeding management (satisfactory to good) while rest of the parameters attained below satisfactory margin. Equally, the backyard farmers also adopted a lower level to satisfactory management practices for all the parameters at the study area. The finding revealed that the adopted management practices for Government farm are better than those of the private and backyard chicken farms. Over and above both the private and backyard farms exposed similar management practices at the study area.

On the other hand, the farm based the analysis of variance among the management parameters shows highly significant difference for vaccination, boundary wall, human residence, chicken transportation and feeding management (P<0.001) except for room temperature, bio-safety measures (P<0.01) and water source (P<0.05). The farm based adopted management practices at the study area are graphically presented in **Figure 5a**.

Table 5a: Farm-wise variation of chicken management practices in Rajshahi, Bangladesh

Farms	RT	WS	VC	BM	BW	HR	CT	FM
GOV	3.33 ±0.50	3.00 ±0.00	3.44 ±0.53	3.33 ±0.50	4.00 ±0.00	4.00 ±0.00	3.11 ±0.60	4.00 ±0.00
PRI	2.74 ±0.71	2.50 ±0.50	2.69 ±0.51	2.48 ±0.69	2.69 ±0.67	2.91 ±0.32	2.69 ±0.55	3.42 ±0.54
BCF	2.58 ±0.50	2.62 ±0.49	2.23 ±0.47	2.56 ±0.62	2.52 ±0.54	2.51 ±0.55	2.43 ±0.54	2.46 ±0.50
F-values	6.898	4.949	35.941	7.079	36.426	55.728	9.141	99.594
P-values	**	*	***	**	***	***	***	***

Note: Data compiled from field survey, GOV=Government, PRI=Private and BCF=Backyard chicken farm; Score index: 5=excellent, 4=good, 3=satisfactory, 2=not good and 1=unacceptable; Scores are based on the parameters on management practices *viz*., RT=room temperature, WS=water source, VC=vaccination, BM=bio-safety measures, BW=boundary walls, HR=human residence, CT=chicken transportation and FM=feeding management; All F-values were at 188 df.; *= P<0.05, **= P<0.01, ***= P<0.001.

5.3.2 Year-wise variations in management practices

Year based variations of adopted management practices for the chicken breeds as well as farms at the study area are also investigated. Scoring results of year based variations on adopted management practices are presented in **Table 5b**. The findings exposed that the fiscal year FY2011-12 achieved marginal score (satisfactory to not good) for all the management parameters under study. The FY2012-13 acquired score 3 and above (satisfactory to good) for feeding management while rest of the management parameters attained marginal satisfactory scores on management practices. Similarly, in the FY2013-14 all the parameters on management practices acquired marginal satisfactory scores on management practices (satisfactory to not good) at the study area. The analysis of the scoring points measured from the adopted management practices for the three successive fiscal years revealed similar results for all the cases at the study area. Over and above in cooperation of the three succeeding fiscal years FY2011-12, FY2012-13 and FY2013-14 the adopted management practices were almost comparable at the study area during the course of the survey.

On the other hand, the year based the analysis of variance among the management parameters shows insignificant difference for water source, boundary wall, human residence, chicken transportation and feeding management (P>0.05) except for bio-safety measures, vaccination (P<0.05) and room temperature (P<0.01) at the study area. The year based adopted management practices at the study area are graphically presented in **Figure 5b**.

Table 5b: Year-wise variation of chicken management practices in Rajshahi, Bangladesh

Fiscal Year	RT	WS	VC	BM	BW	HR	CT	FM
2011-12	2.59 ±0.61	2.49 ±0.50	2.37 ±0.52	2.38 ±0.63	2.60 ±0.58	2.73 ±0.54	2.51 ±0.56	2.94 ±0.72
2012-13	2.90 ±0.61	2.57 ±0.50	2.62 ±0.55	2.71 ±0.66	2.65 ±0.63	2.81 ±0.59	2.62 ±0.58	3.10 ±0.76
2013-14	2.59 ±0.61	2.68 ±0.47	2.54 ±0.64	2.57 ±0.69	2.76 ±0.53	2.78 ±0.52	2.63 ±0.58	2.94 ±0.72
F-values	5.626	2.393	3.237	4.039	1.237	0.328	0.916	0.995
P-values	**	ns	*	*	ns	ns	ns	ns

Note: Data compiled from field survey, FY: 2011-12, 2012-2013 and 2013-2014; Score index: 5=excellent, 4=good, 3=satisfactory, 2=not good and 1=unacceptable; Scores are based on the parameters on management practices *viz*., RT=room temperature, WS=water source, VC=vaccination, BM=bio-safety measures, BW=boundary walls, HR=human residence, CT=chicken transportation and FM=feeding management; all F-values were at 188 df.; *= P<0.05, **= P<0.01; ns= not significant.

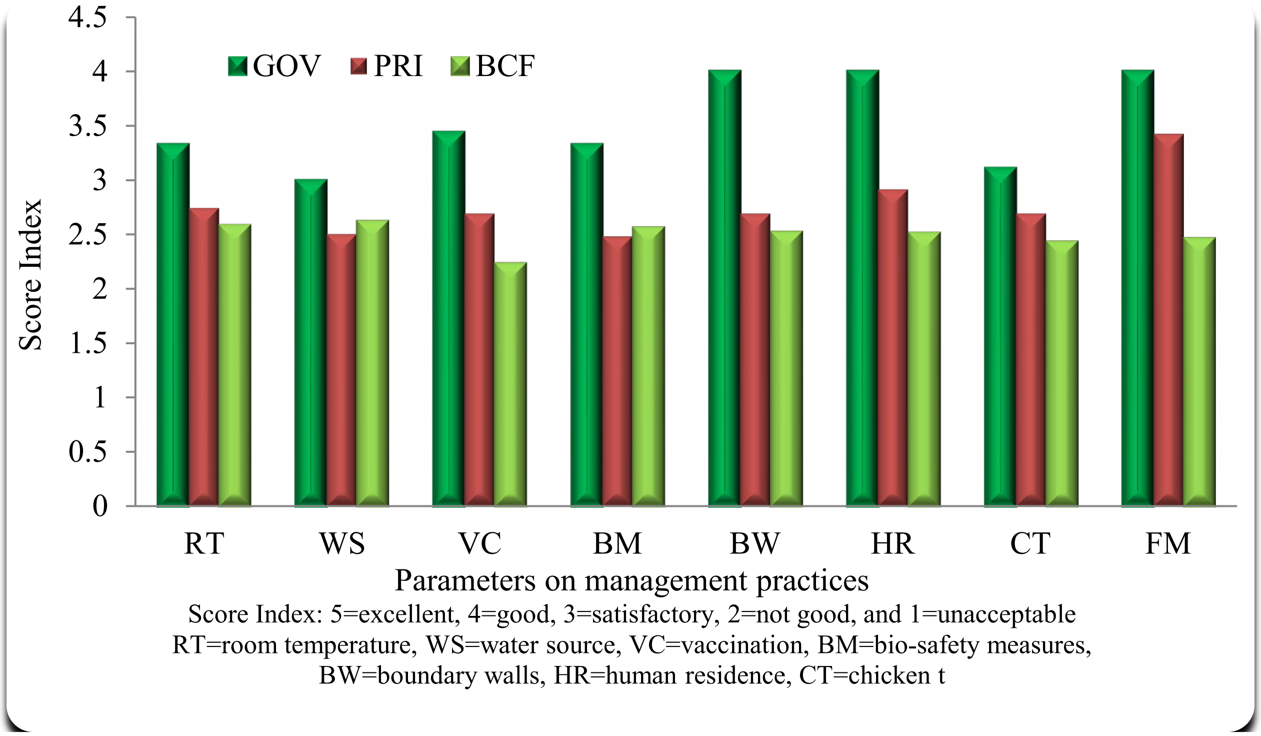


Fig. 5a: Farm based scoring of chicken management practices in Rajshahi, Bangladesh

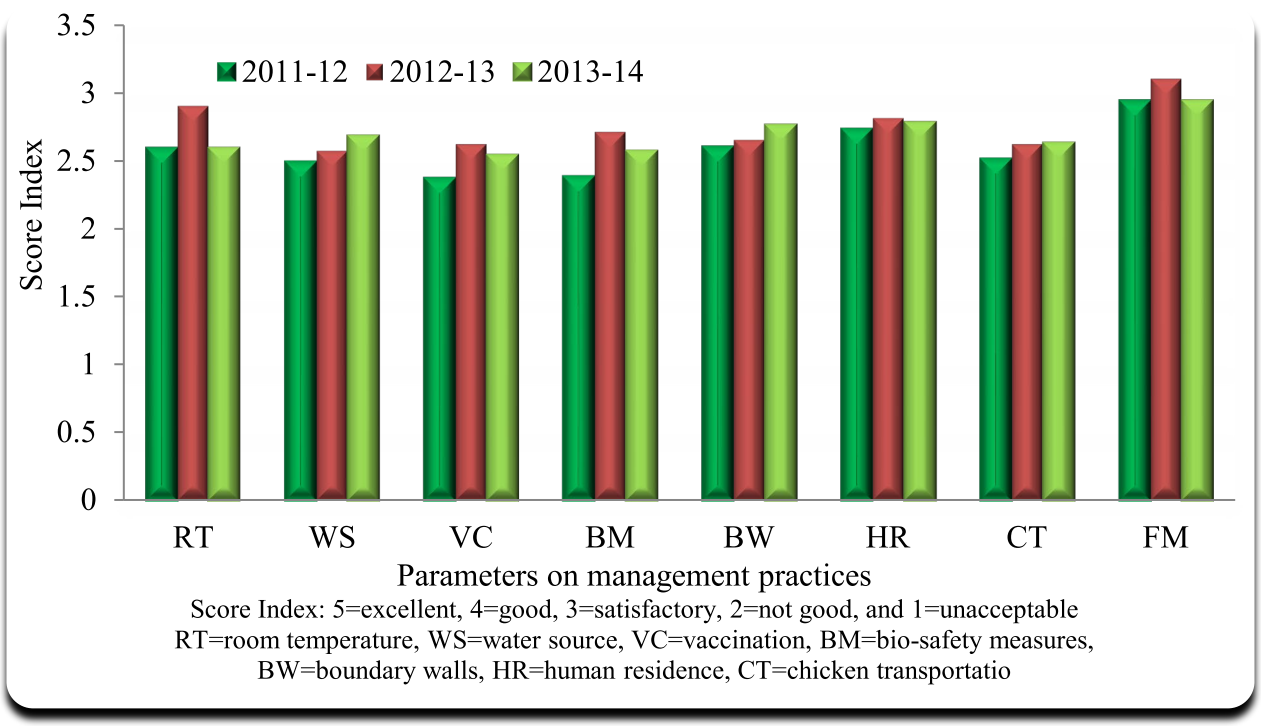


Fig. 5b: Year based scoring of chicken management practices in Rajshahi, Bangladesh

5.4 Discussion

Bio-security is necessary to control disease in effective way and it is a means of recommended practices in the farm premises that may expenses some added investment initially but it will be cheaper in the long run. Therefore, awareness and training programme in bio-security measures is prerequisites for better production results. Jacob *et al.* (2008) reported that in producer level there is almost absence of identifiable bio-security measures, such as footbaths or screens over the windows to prevent rodent or other wild animal access to the chicken flock. Majority of the producers indicated that a variety of animals, both domestic and wild, are known to interact with the meat chickens. The species included cats, dogs, opossums, rodents, raccoons, badgers, chipmunks, skunks, wild birds, guinea fowl and turkeys. Wild birds shed *Campylobacter* and *Salmonella* in their droppings. Mice are an important ongoing source of *Salmonella*, especially *Salmonella enteritidis*. Dead chickens disposed of by these methods latter could contribute to disease outbreaks on the farm. The findings are quite related with present observation. However, human activities are the main route for the spread of the virus and composting is helpful to reduce pathogen concentration and prevention of disease transmission. Therefore, a multidisciplinary and participatory approach working with producers, intermediaries, live bird market traders and for backyard poultry communities is required to developing and achieving adoption of bio-security measures (Bleich *et al*., 2009).

Disposal of poultry droppings is a real problem for aesthetic, public safety and environmental point of view. Al-amin *et al*. (2009) reported that the highest proportion of the farmers used droppings in the crop field by composting while others sold to fisheries. Nerkar *et al*. (2010) estimated that under the cleanliness of premises the excellent farms followed sprinkling of water around the poultry shed and hygienic disposal of poultry waste which was not followed by poor and optimum grade farms and also lacked fumigation of shed. Any scientific system of disposal of dead birds was not observed on any poultry farm and majority of farms lack foot bath system. The excellent sanitation farms followed sanitary measures for drinking water while the optimum and poor farms showed poor results. Excellent and optimum farms scored maximum for the disinfection of feeders and eggs collection trays during rest period. Litter management was good in excellent sanitation farm. These evaluations are comparable to the present observation with private farmers and backyard chicken farmers that possess an optimum level of bio-security.

Sharma (2010) reported that, backyard poultry raisers and small entrepreneurs will feel burden of bio-security. Though, it is helpful and cost saving mechanism for entrepreneurs in long run. As there are some important zoonotic diseases which spread from poultry to human being such as HPAI make a great concern to us and global environment. Clean poultry farm will reduce foul smelling to neighbours and disease spread. Poultry manure is good for agricultural product. Organic farming can be boosted along with poultry farming which will ultimately lead to sustainable development and clean environment. Whereas, Akidarju *et al*. (2010) observed that due to management practices the poultry industry still faces serious constraints, such as bad housing, inadequate vaccination and high mortality possibly due to multiple antibiotics resistance resulting from multiple antibiotics usage.

Shanaz *et al*. (2010) observed that every single one farmers adopted deep litter system of rearing the birds using sawdust as bedding material. Quarter to cent percent of the farmers were adopting all in all out system of rearing whereas rest of the farmers were maintaining two batches at a time. Over fifty percent of the farmers used ten different commercial brands of feed, available in the form of mash. Among the different feed additives used, below fifty percent used mineral mixture followed by Coccidiostat® to the extent of quarter percent. All the farmers fed starter ration whereas some quarter to cent percent farmers fed pre-starter and finisher ration and each bird consumed 2.7 kg of feed and marketed the birds by 45 days of age. Despite irregular power supply, majority percent farmers were able to provide 24 hours of light during rearing. More than 90% farmers vaccinated their birds against Newcastle disease and infectious bursal disease. Majority of the farmers disposed off the dead birds by throwing them in the open by itself but adopted strict rodent control measures.

However, Bolan *et al*. (2010) identified that a major problem facing the poultry industry is the large-scale accumulation of wastes including manure and litter which may pose disposal and pollution problems unless environmentally and economically sustainable management technologies are evolved. Most of the litter produced by the poultry industry is currently applied to agricultural land as a source of nutrients and soil amendment. However, environmental pollution, resulting from nutrient and contaminant leaching can occur when poultry litter is applied under soil and climatic conditions that do not favour agronomic utilization of the manure-borne nutrients. Poultry litter provides a major source of nitrogen, phosphorus and trace elements for crop production and is effective in improving physical and biological fertility, indicating that land application remains as the main option for the utilization of this valuable resource. The alternative use of poultry litter as an animal feed and fuel source is limited by contaminants and high moisture content, respectively.

Olumayowa and Abiodun (2011) observed that majority of the farmers did not treat their farm waste before or after disposal and collected their poultry waste manually using shovel and spade thereby polluting their environment. The poultry waste was not considered useful by greater part of the farmers. However, about 93.1% of the poultry farms deposited their poultry waste either on their farm, inside bush or rivers while 6.9% buried their waste inside pit. This decision causes pollution and nuisance to the environment. In addition, 76.39% of the farmers did not treat their farm waste before or after disposal while 23.61% treated it with chemical or burn during dry season to reduce air pollution, flies prevalence and disease outbreak. The results further showed that majority (63.9%) does not make economic use of the poultry waste; a few (36.1%) utilized the waste for making compost, organic manure and to feed fish while 1.4% sold the manure to gardeners and other users. Majority (70.8%) of the respondents acclaimed that the constraints to poultry waste utilization was lack of awareness and affordable technology. Other constraints include labour scarcity and high cost of disposal, high cost of chemical and difficulty to burn during wet season.

Moreover, Sultana *et al*. (2012a) reported that most of the respondents which reared Cobb-500 strain took necessary suggestions from the experienced farmers, 90% farmers regularly vaccinated their broilers and 70% farmers taken short training on broiler farming. Mandefro *et al*. (2012) revealed that there was high risk of diseases transmission and dissemination related to bio-security of live poultry markets. Parasitic and bacterial infection are highly likely and the most serious consequences of all are in breeder houses where wet litter can have a calamitous effect on the feet of the cocks causing accumulations of infected litter on the feet and subsequently leading to a fall in the level of fertility (Abubakar *et al*. 2012). Musa *et al*. (2012) reported that ammonia gas is a major product of poultry manure and to some extent green house gases. Pathogenic microorganisms can thrive in poultry wastes. These constitute environmental and health hazards to livestock and the teeming population. Economic losses due to poor litter are significantly high. Dutta *et al*. (2012b) reported that only a small proportion of poultry farms were found to maintain satisfactory management practices which must be monitored regularly to increase productivity. Ameji *et al*. (2012) observed bio-security practices evaluated by the presence of movement control was 38.8%; presence of footbath was rare (11.8%); handling of sick birds by isolation and treatment was 40%; improper disposal of dead birds in refuse dump was high (85.9%) and extensive management system was high (60.76%). The study revealed high level of awareness and readiness to report HPAI but poor knowledge and bio-security practices toward sit. The failures in bio-security measures as seen in this study will greatly enhance introduction and spread of HPAI as well as other contagious poultry diseases in the state. Knowledge directly affects readiness to report hence efforts should be made to improve poultry stakeholders' knowledge of HPAI and proper bio-security practices.

Aboki *et al*. (2013) observed that the family poultry producers are inefficient at their level of production and that their income and output can be improved if more of feeds, capital, vaccine and medicine are used and more innovation that are related to improved management are adopted. Conversely, Bhuyian *et al*. (2013) analyzed the farmers' communication exposure and knowledge in poultry farming. The research was conducted in three selected unions of Bhaluka Upazilla under Mymensingh district. Each of the six selected characteristics of poultry farmers namely age, education, family size, family education, farm size and organizational participation are the independent variables; while farmers' exposure to communication media for poultry production and farmers' knowledge on poultry were the two dependent variables. In case of farmers' exposure to communication media for poultry production, majority of the farmers (54%) had low exposure to communication media, while 46% had medium exposure and none of them had high exposure.

In the case of poultry farming knowledge, majority of the farmers (57%) had medium knowledge while 29% of them had low knowledge and only 14% had high knowledge. Tests of hypotheses indicated that education of the farmers was positively related to communication exposure for poultry production while the rest independent variables had no relationship with any of the dependent variables. In addition, indigenous chicken is largely reared in a low input-low output free-range system with only few farmers (24.2%) adopting management interventions as disseminated by extension service. To improve production and attain increased productivity, policy should focus on repackaging extension messages that considers farmers economic situations and strengthens collective action initiatives. Accessing joint input purchase and collective marketing of chicken products may further assist the farmers to increase profit margins (Justus *et al*., 2013). Moreover, an analysis identified that older farmers with larger families are more likely to adopt better bio-security in layer and broiler farms (Susilowati *et al*., 2013).

Nigatu and Bezabih (2014) reported that seasonal disease outbreak followed by predators (89%) was considered the largest threat to chicken production. Moreover, traditional management (83%), limitation of improved breed availability and lack of extension and chicken health services (86.7%) were the major constraints of chicken production. Therefore, holistic extension services such as applying breed and management improvement methods, besides to supplying chicken health service strategies are highly recommended for further improvement of chicken production under farmer's management condition. Wang *et al*. (2014) reviews the social, economic and political elements of poultry production. They discover that under increased public concerns on bio-security, integration of the small scale poultry producers into safe and high value production chains is a key political issue in developing countries.

Huque and Sarker (2014) reported that diversification and production of quality feeds and fodders, synchronization of feed production and availability to animals, strengthening feed milling capacity, conservation and improvement of new pasturage systems, mitigation of climate change impacts and domestic protection to feed safety and quality feed import are some of the options forward to increased supply of feeds and fodders help increased production and productivity of farm animals. These findings are quite analogous to the present results. Therefore, the findings emphasize the need for adequate knowledge in poultry management practices that would enhance productivity and profitability to the producers and marketers, thus suggesting for an integrated approach to strict bio-security poultry farming in the country.

CHAPTER SIX

STUDIES ON DISEASE INCIDENCES IN CHICKEN BREEDS

6.1 Introduction

The prevalence of diseases in a particular area depends on various factors like geo-climatic condition, management practices, immunization status, social awareness etc. The outbreaks of various diseases are directly or indirectly related to the management status or bio-security of the farms. So, emphasis should be given to improve the management or bio-security of the farm to check the mortality of chickens. However, poultry is essential to the national economy of Bangladesh and the welfare of human beings. Several constraints such as the diseases, poor husbandry, low productivity and shortage of feed affect the optimal performance of this industry in Bangladesh (Saha *et al*., 2012). Therefore, a thorough knowledge about the epidemiology, pathogenesis and pathology of a particular disease is the first and fundamental factor for proper diagnosis with the prevention, control and eradication of the disease (Rashid *et al*., 2013).

The impact of H5N1 virus on food security and providence of nutrition in developing countries is tremendous because main bulk of their populations depend on eggs and poultry meat as only reliable source of protein (Burgos and Burgos, 2007; Gueye, 2007; Sonaiya, 2007; Das *et al*., 2008). As an Asian country Bangladesh has experienced outbreaks of H5N1 virus since 2007 (Biswas *et al*, 2008). A single human infection by H5N1 virus has also been reported in Bangladesh (Brooks *et al*., 2009). Official and conservative estimates indicated that over 1.8 million birds have already died or killed due to H5N1 virus infection (OIE, 2011). Since 2003, infection with H5N1 virus has caused natural death or killing of over 300 million poultry. In addition, 330 human beings have died of this infection (World Bank, 2008; WHO, 2011). The international measure for controlling highly pathogenic avian influenza (HPAI) is the eradication of infected flocks, the establishing of disease outbreak declaration zones, animal movement control, surveillance and monitoring in the infected zone, and other measures such as determining the vaccination zone to stop the disease from spreading (Sarachai *et al*., 2014).

The most important source of infection in poultry appears to be contaminated feed, litter, water and the environment (Craven *et al*., 2001a). In addition, some reports about the possible vertical transmission have been published (Craven *et al*., 2001b, 2003). Several infectious agents such as viruses, bacteria, fungus and parasites are involved in intestinal disorders. These infectious agents can introduce and spread in poultry farms by different routes. At early days of age the main disease problems are related to vertically transmitted infections such as *Salmonella*, *E. coli* and improper hatchery management (Hafez, 2005; Bermudez and Stewart-Brown, 2008). The persistent virus infections or carrier states in virus infections are responsible for a wide range of human and animal diseases (Abe *et al*., 2007). The usual source of infection for healthy commercial and village chickens are infected chickens which are suffering from the disease and shedding the virus and those that are incubating the virus and shedding them at the same time (Nwanta *et al*., 2008). Recently, Martin (2010) were able to demonstrate under experimental condition, that factors such as co-infection with *Eimeria* species, genotype of chicken and the strain of *Clostridium perfringens* were the most critical factors involved in disease development. Newcastle disease is a serious and commonly fatal disease of chickens caused by a Paramyxo virus. In most developing countries Newcastle disease is the most important infectious disease affecting village chickens (Feizi and Nazeri, 2011).

Moreover, infectious bursal disease (IBD) also known as *Gumboro* disease, is highly contagious and immune suppressive to young chickens and is responsible for major economic losses in poultry industry globally (Okwor *et al*., 2012). Equally, avian coccidiosis is also thought to be one of the most expensive infectious diseases of poultry. Mechanical action of VitA may serve as new beneficial anticoccidial compounds and an essential component of alternative strategies for control of resistant *Eimeria* strains (Masood *et al*., 2013). However, the flocks that maintained poor managemental condition such as poor ventilation and overcrowding and unvaccinated flocks were found to be the highest susceptibility to viral diseases (Sultana *et al*., 2014).

The insufficiency of information on the presence and prevalence of the above diseases in backyard and commercial chickens may reflect a lack of resources for disease surveillance and control under smallholder production systems. Consequently, this study was undertaken to determine the incidences of major poultry diseases potentially affecting smallholder poultry enterprises in Rajshahi Metropolis.

6.2 Materials and methods

6.2.1 Study area

Disease prevalence studies of the farms as well as breeds were performed by using purposive sampling method, which is the selection of sample intentionally on 21 chicken farmers from the urban, semi-urban and rural areas of Rajshahi district, Bangladesh [A detailed account of the study area is spelled out in **Chapter Four**]. However, the aforesaid six varieties of chicken breeds *i.e*., indigenous, broiler, cockerel, Fayoumi, RIR and *Sonali* were selected for the disease study. The quantitative and qualitative data were collected from direct observations of the prevailing diseases at the selected farms during July 2011 and June 2014.

6.2.2 Analysis method

Using a 5 scale scoring system, six (6) major parameters on disease incidences such as bacterial diseases (BD), viral diseases (VD), fungal diseases (FD), flock-wise disease commonness (FDC) and seasonal disease prevalence (SDP) were considered to rank the poultry farms under study, where score 5 was considered as elevated, 4 as severe, 3 as gross, 2 as mild and 1 as absent (Uddin *et al*., 2010). A detailed account of the disease prevalence parameters is provided below.

Bacterial diseases: During the survey, bacterial diseases like bacillary white diarrhoea, fowl cholera and infectious coryza were under the main observation in the study area.

Viral diseases: Likewise, throughout the survey the viral diseases such as Newcastle disease, infectious bursal disease (Gumboro), fowl pox and Marek's disease (visceral leucosis) were under the foremost surveillance in the study area.

Fungal diseases: Aspergillosis (brooder pneumonia) and mycotoxicosis was the main observation in the study area as the fungal disease all through the survey period.

Flock-wise disease commonness: The poultry diseases and their commonness were observed flock-wise during the study period. The diagnosis of different diseases was done based on the history of the flock, age of affected birds, clinical signs and symptoms, postmortem lesions, gross and microscopic examinations as per farmers record.

Seasonal disease prevalence: The prevalence of seasonal diseases was also investigated during the study period. Data were collected with special emphasis on flock and season considered as measurement tools and preserved on a registered book followed by diagnostic protocol.

6.2.3 Statistical analyses

As mentioned earlier, the statistical package for social service (SPSS version 19.0) was employed for statistical analyses, where interpretations and graphical presentations of the qualitative and quantitative data obtained from the parameters for disease prevalence at the study area. The analysis considered all the succeeding parameters of disease incidences *viz*., bacterial diseases, viral diseases, fungal diseases, flock-wise disease commonness and seasonal disease prevalence scrutinized and ranked according to the scoring system during the study period.

Plate 6.1 Year-wise chicken disease incidences in Rajshahi - I

A-B Fowl cholera in Cockerel (greenish yellow feces) and in Cobb 500 (neurological sign)

C-D Infectious coryza in Cockerel (swollen sinuses) and in Cobb 500 (grown to an older age)

E-F Bacillary white diarrhoea in *Deshi* (white diarrhoea) and in Cockerel (white pasture)

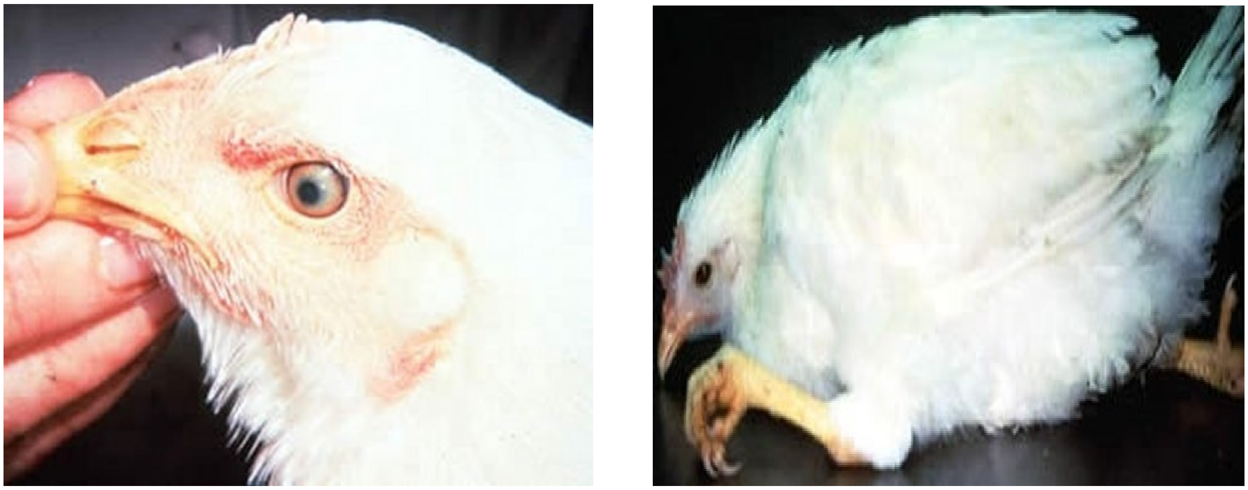
Plate 6.2 Year-wise chicken disease incidences in Rajshahi - II


A-B Fowl pox in Cobb 500 (pox lesion on eye lid) and in Cockerel (pox lesion on comb)

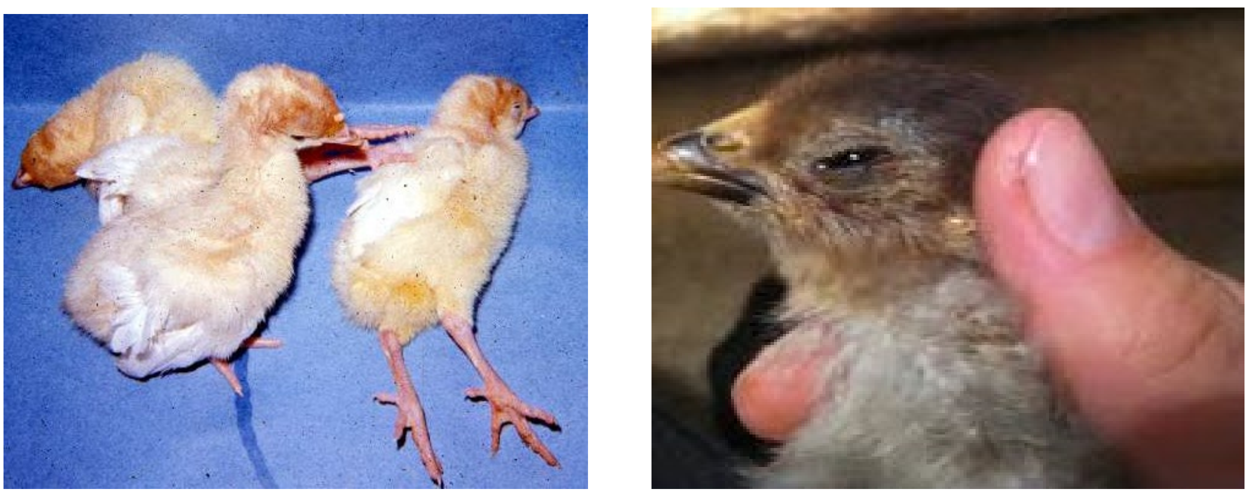

C-D Newcastle disease in RIR (birds unable to stand) and in Cobb 500 (twisted neck)


E-F Infectious bursal disease in RIR **(**ruffled feathers) and in Cobb 500 **(**decreased appetite)

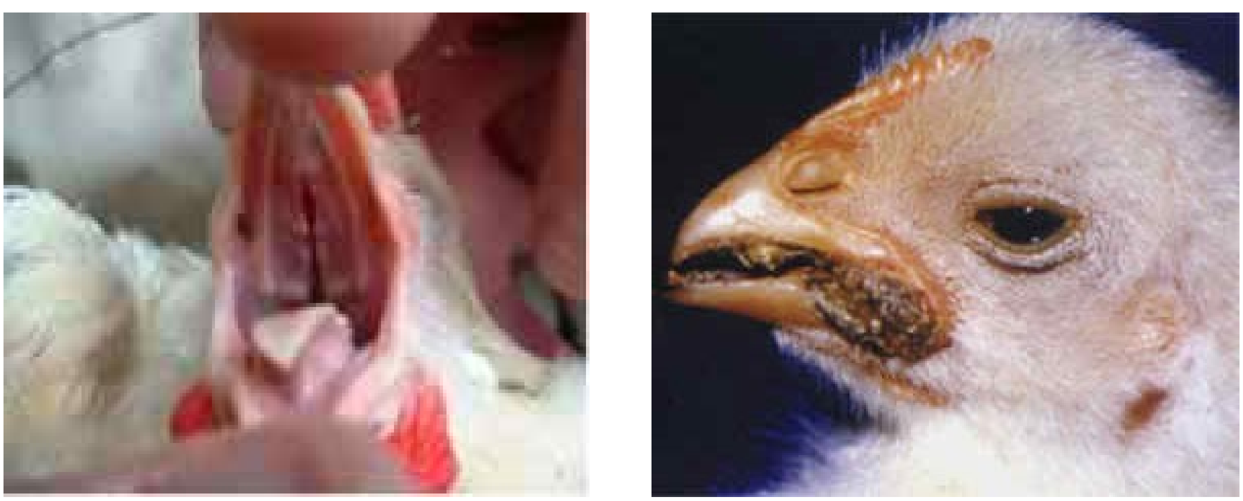
Plate 6.3 Year-wise chicken disease incidences in Rajshahi - III



A-B Marek's disease in *Deshi* (irregular pupil) and in Cobb 500 (paresis of legs)



C-D Aspergillosis in *Sonali* (CNS signs) and Fayoumi chicks (gasping chick)



E-F Mycotoxicosis in Cobb 500 (lesions in tongue) and in *Sonali* chicks (lesions on beak)

6.3 Results

6.3.1 Farm-wise variation in disease incidence

Incidences of various bacterial, viral, fungal diseases and their prevalence frequency at the study area are analyzed. Scoring results of farm based variations on disease incidences are presented in **Table 6a**. The findings revealed that Government farm achieved highest score 4.33 (severe to elevated) for seasonal disease prevalence followed by 3.44, 3.33 and 3.11 (gross to severe) for bacterial disease, flock-wise disease commonness and viral diseases respectively. However, the fungal diseases attained lowest scores 1.44 (absent to mild) at the Government farm during the entire study period.

Conversely, the private farms attained highest score 2.74 (mild to gross) for bacterial diseases followed by 2.67, 2.49 and 2.46 for viral disease, seasonal disease prevalence and flock-wise disease commonness respectively. In the same way, the fungal diseases attained lowest scores 1.10 (absent to mild) at the private farm during the study period. Evenly, the backyard farmers also reached a lower level for disease prevalence 1.06 (absent to mild) during the study period.

Disease prevalence for backyard farmers attained almost equal scores from mild to gross for all the parameters *viz*., bacterial disease, viral disease, flock-wise disease commonness and seasonal disease prevalence at the study area. The findings from disease prevalence exposed that disease susceptibility for Government farm are superior comparable to those of the private and backyard chicken farms for the case of bacterial and viral disease with flock-wise disease commonness and seasonal disease prevalence. In addition to both the private and backyard farms exposed similar disease prevalence at the study area.

On the other hand, the farm based analysis of variance among the disease incidence parameters shows highly significant difference for bacterial diseases and seasonal disease prevalence ($P<0.001$) followed by viral, fungal disease and flock-wise disease commonness ($P<0.01$). The farm based disease incidences at the study area are graphically presented in **Fig. 6a**.

6.3.2 Year-wise variation in disease incidence

Year based variations of disease incidences for the chicken breeds as well as farms at the study area are also examined. Scoring results of year based variations on disease incidences are presented in **Table 6b**. The findings exposed that the fiscal year FY2011-12 attained marginal score (mild to gross) for all the disease prevalence parameters under study except for fungal diseases that shows scores on absent too mild. Like-wise the FY2012-13 acquired score 2 and above (mild to gross) for all disease parameters except for fungal diseases that are apparent from absent to mild scores during the study period.

In the FY2013-14, on the other hand, all the parameters on disease prevalence acquired marginal satisfactory scores (mild to gross) during the study period. The analysis of the scoring points measured from the prevailed diseases for the three successive fiscal years revealed similar results for all the cases at the study area during the study period. Over and above in cooperation of the three succeeding fiscal years FY2011-12, FY2012-13 and FY2013-14, the disease prevalence was almost analogous at the study area during the course of the survey.

In a nutshell, therefore, the year-based analysis of variance among the disease prevalence parameters shows insignificant difference for the viral and fungal diseases ($P>0.05$) except for bacterial diseases, flock-wise disease commonness ($P<0.05$) and seasonal disease prevalence ($P<0.01$) at the study area. The year-based prevalence of various diseases and their incidental frequency at the study area are graphically presented in **Fig. 6b**.

Table 6a: Farm-wise variation of chicken disease incidences in Rajshahi, Bangladesh

Farms	BD	VD	FD	FDC	SDP
GOV	3.44 ±0.88	3.11 ±0.33	1.44 ±0.53	3.33 ±0.50	4.33 ±0.87
PRI	2.74 ±0.79	2.67 ±0.73	1.10 ±0.30	2.46 ±0.77	2.49 ±0.67
BCF	2.40 ±0.61	2.40 ±0.59	1.06 ±0.23	2.44 ±0.58	2.31 ±0.61
F-values	11.617	7.004	7.673	7.363	39.006
P-values	***	**	**	**	***

Note: Data compiled from Field Survey, GOV=Government farm, PRI=Private farm and BCF=Backyard chicken farm; Score index: 5=Elevated; 4=Severe; 3=Gross; 2=Mild; 1=Absent; Scores are based on the parameters on disease incidences *viz*., Bacterial diseases (BD); Viral diseases (VD); Fungal diseases (FD); Flock-wise disease commonness (FDC) and Seasonal disease prevalence (SDP); All F-values were at 47 df.; *= P<0.05, **= P<0.01, ***= P<0.001; ns= not significant.

Table 6b: Year-wise variation of chicken disease incidences in Rajshahi, Bangladesh

Fiscal Years	BD	VD	FD	FDC	SDP
2011-12	2.83 ±0.81	2.71 ±0.75	1.11 ±0.32	2.67 ±0.78	2.71 ±0.85
2012-13	2.51 ±0.82	2.44 ±0.59	1.06 ±0.25	2.32 ±0.69	2.22 ±0.73
2013-14	2.51 ±0.56	2.52 ±0.67	1.11 ±0.32	2.49 ±0.56	2.54 ±0.69
F-values	3.838	2.679	0.547	4.088	6.919
P-values	*	ns	ns	*	**

Note: Data compiled from Field Survey, FY: 2011-12, 2012-2013 and 2013-2014. Score index: 5=Elevated; 4=Severe; 3=Gross; 2=Mild; 1=Absent; Scores are based on the parameters on disease incidences *viz*., Bacterial diseases (BD); Viral diseases (VD); Fungal diseases (FD); Flock-wise disease commonness (FDC) and Seasonal disease prevalence (SDP); All F-values were at 47 df.; *= P<0.05, **= P<0.01, ***= P<0.001; ns= not significant.

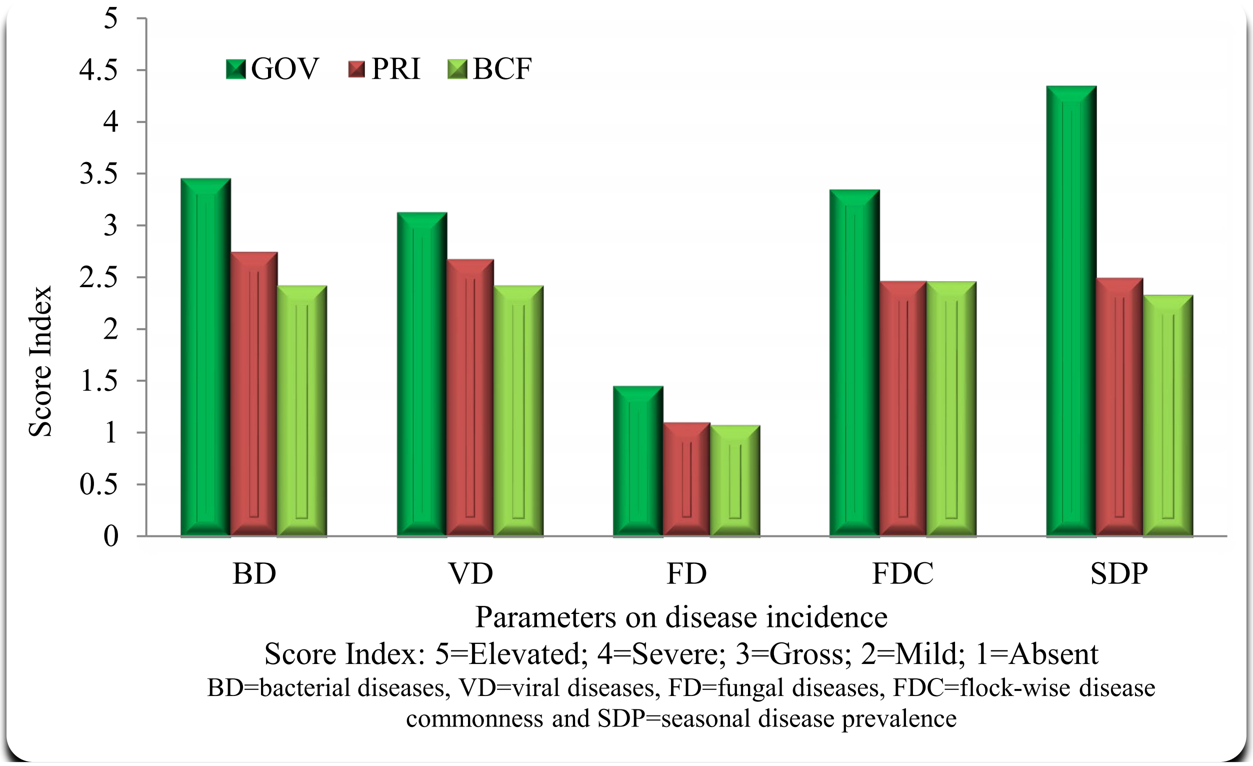


Fig. 6a: Farm-wise chicken disease incidences in Rajshahi, Bangladesh

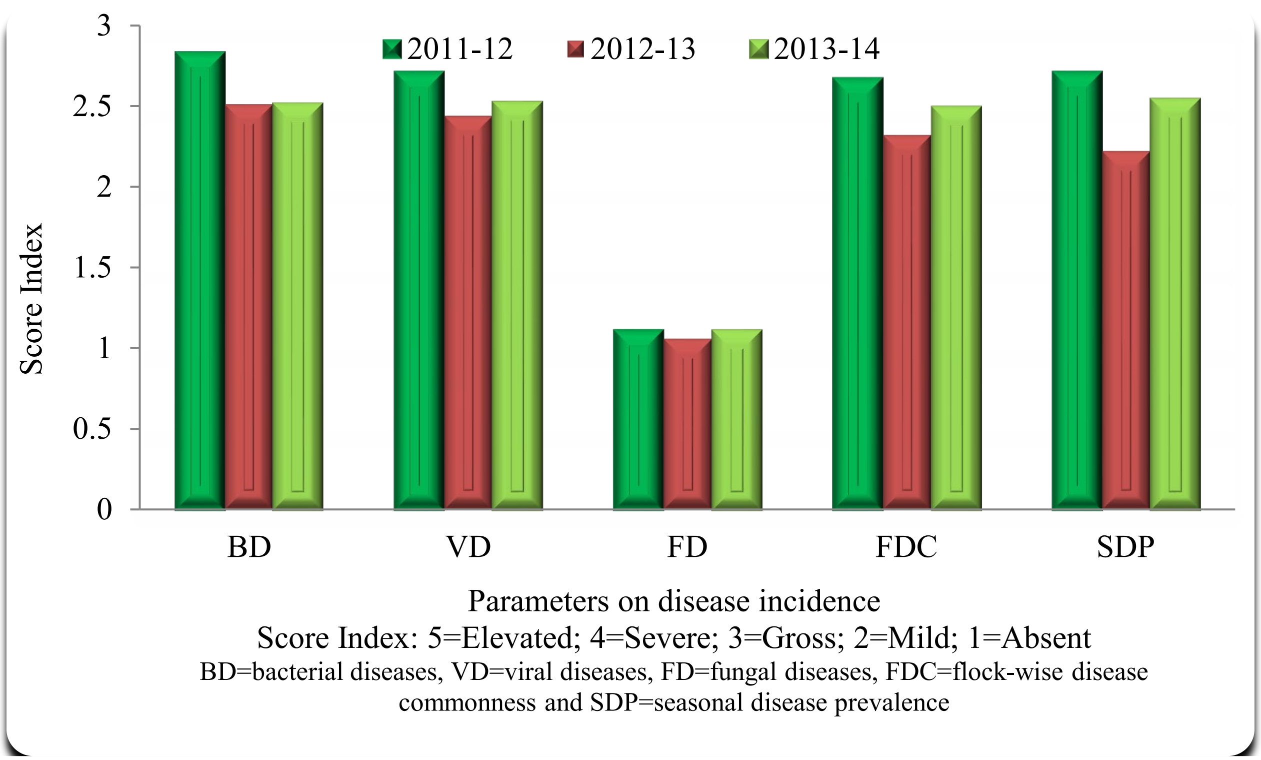


Fig. 6b: Year-wise chicken disease incidences in Rajshahi, Bangladesh

6.4 Discussion

It is obvious that continuous antibiotic supplementation and stress factors reduced antibody production in commercial chickens. An epidemiological investigation of infectious bursal disease conducted by Giasuddin *et al*. (2005) reported that clinical diseases mostly occur between 3 and 6 weeks of age. Highest morbidity and mortality were observed in cockerel (49.4% and 25.5%) followed by layer (33.4% and 17.2%) and broiler (33.0% and 16.3%) chickens. Similar morbidity and mortality were found in heavy and light birds. Contamination with *Salmonella enteritidis* (SE) is an important threat to food safety in egg production. Various risk factors exist for infection with and spreading of SE on a farm. Mollenhorst *et al*. (2005) reported that bigger flocks increased the chance of infection with SE in all housing systems. The system with the lowest chance of infection was the cage system with wet manure. An outdoor run increased the chance of infection only at farms with all hens of the same age. The presence of hens of different ages on a farm was a risk factor for deep litter systems only. The main risk factors associated with SE infection, therefore, were flock size, housing system, and farm with hens of different ages. Contaminated chicken meat remains an internationally important vehicle for human infection with *Salmonella* and *Campylobacter* species. In addition, the last 20 years has seen an international pandemic of human salmonellosis caused by the contamination of eggs with *S. enteritidis* (Humphrey, 2006).

Rahman *et al*. (2007) assessed the incidence of bacterial diseases in various age groups of different flocks of birds in different poultry farms. Findings revealed that among bacterial diseases salmonellosis was found in 53.90% of chicks followed by omphalitis (28.42%), colibacillosis (13.36%), mycoplasmosis (2.55%), necrotic enteritis (1.18%) and infectious coryza (0.59%). The bacterial diseases salmonellosis, colibacillosis, infectious coryza and necrotic enteritis were detected in 55.96, 11.93, 29.91 and 2.20% in grower stage, respectively. Omphalitis and mycoplasmosis were not found in grower. Salmonellosis was found in 53.32% of adult chicken followed by mycoplasmosis in 39.09%, infectious coryza in 6.11% and necrotic enteritis in 1.48%. Similarly this group was also not affected by omphalitis and colibacillosis. However, it has been investigated that the major prevalence of *Salmonella* in broilers was spring and in laying hens *i.e.*, winter, spring and autumn. The prevalent *Salmonella* serovars found in broilers and laying hens were *S. enteritidis* and *S. typhimurium* (Pieskus *et al*., 2008).

Moreover, vaccination against salmonellosis is widely practiced in several countries in the world to control the infection. Both live attenuated and killed vaccine have many benefits and proven results for controlling of none host-specific *Salmonella* in poultry and also in reducing the occurrence of human food born infections. Both vaccines were considered as potential to control the host specific *Salmonella* in poultry by reducing the mortality and fecal shedding to the environment (Priyantha, 2009). A logistic regression model has been indicated that free-range birds were more likely to have positivity against *Salmonella* spp., compared with caged birds (Leotta *et al*., 2010). The outbreak of colibacillosis has been reported in broiler and layer chicks reared under semi intensive and intensive system where mortality rate of the disease was 6.8% in the broiler flocks and 1.9% in the layer ones. The higher mortality rate observed in the broiler chicks than the layer was supposed to be due to the housing condition (Omer *et al*., 2008; 2010).

Uddin *et al*. (2010) determined the prevalence of poultry diseases in various age groups where infectious bursal disease was found in 24.96% followed by chronic respiratory disease or mycoplasmosis (9.87%), Newcastle disease (8.92%), aspergillosis (7.98%), salmonellosis (7.68%), coccidiosis (7.32%), colibacillosis (5.70%), infectious coryza (0.32%), fowl cholera (0.24%) and infectious bronchitis (0.24%). The etiological analysis of layer chickens by Uddin *et al*. (2011) showed that the highest mortality caused by bacterial diseases (7.08%), followed by viral diseases (5.81%) and fungal diseases (2.18%).

In most developing countries, Newcastle disease (ND) is the most common infectious disease affecting village chickens. The usual source of infection for village chickens is usually other chickens. The role of other birds as carriers to initiate outbreaks in villages is not well documented as equally epidemic and endemic forms of ND occur in village conditions (Feizi and Nazeri, 2011). The outbreaks and prevalence of ND in village chickens is thought to worsen during cold and harsh stress (Okwor and Eze, 2011). In backyard chicken *Salmonella* and mycoplasma infection were found at high levels during the summer and winter season (Xavier *et al*., 2011). The severity of coccidia infection has been reported to be highest at age group of 4–6 weeks, but number of cases was more between 6 to 8 weeks based on both litter oocyst density and oocysts per gram of faeces (Anuradha *et al*., 2011). Chaka *et al*. (2012) estimated that area and season had no significant effect on the sero-prevalence of ND and IBD indicating the widespread presence of those pathogens throughout the year in backyard chickens. Conversely, healthy carriers can serve as short term reservoirs and transmit the disease to other birds (Chukwudi *et al.,* 2012). Jatau *et al*. (2012) reported the prevalence of coccidia infection 44.3% in layers, 37.1% in broilers and 18.6% in indigenous chickens. Saha *et al*. (2012) isolated and identified *Salmonella* from ovaries of dead layer birds and from inner content of laid eggs of different poultry farms. Vaccinating the flock using live vaccines was mainly the control measure. When the live virus vaccines persisting in the poultry house environment seem to be gaining virulence and the efficacy of the vaccine to be assessed reflects the immune status of the vaccinated birds (Roy, 2012).

Seasonal influence of IBD has been observed by Rashid *et al*. (2013). Dullness, depression, anorexia, ruffled feathers, inability to move and yellowish white diarrhoea were pragmatic in affected flocks which showed a significantly ($P<0.05$) higher prevalence (13.5%) with 7.7% mortality during winter season. Patterson and Guerin (2013) found that climate change has evoked several changes in birds, including changes in avian phenology, poleward shifts in avian distributions, modification of migratory distances, direction and activity, and alterations to movement patterns and destinations will subsequently affect the spread of poultry diseases. *Avibacterium paragallinarum*, the etiological agent of infectious coryza has been isolated and identified by Akter *et al*. (2013) from the nasal swabs of dead and live chicken. In village chickens ND, fowl pox, coccidiosis and IBD is frequent and the time of the year these diseases are prevalent between September and December with highest in mortality rate through ND (Adebayo *et al*., 2013). The presence of antibodies for more than one disease agent in the same chicken indicates that several pathogens are circulating within the same premises (Sharma *et al*., 2014). Supplementation of contaminated fish meal in poultry feed could be the source of *Salmonella* infection in commercial layer flocks. It was noticed that prevalence of ND in broiler and layer flocks was highest during summer season. The flocks maintained poor management conditions such as poor ventilation, overcrowding, unvaccinated flock had high susceptibility to these diseases. The findings are in well agreement with those of Srinivasan *et al*. (2014) and Sultana *et al*. (2014). It is therefore suggested that awareness campaign should be conducted towards small-scale producers so that they can increase their productivity and alerting them concerning the causes of various diseases and the existing remedies.

CHAPTER SEVEN

MEAT AND EGG YIELD STUDIES ON THE CHICKEN BREEDS

7.1 Introduction

A number of studies have demonstrated that elevated environmental temperatures influence the amino acid (AA) needs of broilers, either as a function of reduced amino acid digestibility (Zuprizal *et al.*, 1993; Hai *et al.*, 2000) or as a result of decreased feed intake (Howlider and Rose, 1987). Many poultry nutritionists use the levels recommended by the National Research Council (NRC, 1994) as a guideline in establishing their own AA requirements, regardless of location and environmental conditions. Adequate dietary level of these AA is needed to support optimum growth and carcass yield of fast-growing commercial strains (Ojano-Dirain and Waldroup, 2002). Various research has exposed how multipurpose and high-yield strains respond to increased amino acid density (Dozier and Moran, 2001; Kidd *et al.*, 2004; Corzo *et al.*, 2004; 2005). Furthermore, researchers have emphasized the importance of optimizing dietary AA density in later feeding phases, when feed consumption is considerably increased compared with that of younger birds for optimal performance and reduction of environmental contamination due to better use of the protein of the diet and lower amount of nitrogen in the excreta (Dozier *et al.*, 2006; 2007b, Ghaffari *et al.*, 2007).

It has been reported that dietary levels of lysine (Lys), methionine (Met) and threonine (Thr) considered adequate, improves body weight and meat yield responses of commercial broilers (Tenim *et al.*, 2000). Lys is the reference amino acid in the ideal AA concept and Thr is the third limiting AA for broilers in most diets. Addition of L-Arg in poultry diets is required to avoid the harmful influences of excessive free radicals that produced during normal metabolism (Atakisi *et al.*, 2009) and to relieve the adverse effects of heat stress (Attia *et al.*, 2011). L-Arg is a substrate for biosynthesis of many molecules, including protein, nitric oxide, creatine, ornithine, glutamate, polyamines, proline, glutamine, agmatine and dimethylargininesa; thereby it serves a number of important biological and physiological functions in poultry (Khajali and Wideman, 2010). Trp another is EAA that participate in protein synthesis. The high level of Trp has positive effects on systematic immune response and growth performance in broiler chickens (Emadi *et al.*, 2010; Everett *et al.*, 2010). Deficiencies in Thr can result in superb breast meat production and carcass growth. This fact emphasizes the importance of diets having an adequate

Thr to Lys ratio. However, high AA density throughout life optimized live weight and growth, whereas reductions in AA density reduced growth and live weight (Nasr and Kheiri, 2011). The EAA levels in the diet stand out among the nutritional factors that influence characteristics such as egg size, yolk and albumen deposition, total solids percentage and internal egg quality with essentially cost effective (Figueiredo *et al*., 2012; Zhai *et al*., 2013).

Parenthetically, vitamin A (VitA) is an effective antioxidant as it can slow down the process of lipid per oxidation by breaking the chain reactions involved in this process and hence can check the process of membrane deterioration induced by the heat-stress (Sahin *et al*., 2002; Ajakaiye *et al*., 2011). Supplementation of vitamin A higher than NRC (1994) recommendations is reported to play an important role in restoration of membrane integrity and, hence, normal functioning of reproductive organs in heat-stressed laying hens (Lin *et al*., 2002; Kaya and Yildirim, 2011). Higher dietary level of VitA is reported to enhance the production performance and egg quality in the heat-stressed laying hens.

Supplemental feed-grade amino acids (AA) have been used in the diets of agricultural animals since the 1950s. Although adoption of the first limiting AA in poultry (Met) was relatively rapid, adoption of the second limiting (Lys) and third limiting (Thr) AA did not occur until the 1970s and 1990s, respectively (Kidd *et al*., 2013). Synthetic amino acids, such as Met and Lys have been used routinely for many years to provide for more efficient use of protein in diets for growing and laying chickens. As a result of using these supplements, the overall dietary crude protein may be reduced with a concomitant reduction in the excess amounts of essential amino acids (EAAs) and consequently a reduction in the amount of nitrogen excreted into the environment (Yuan *et al*., 2012). With a variety of synthetic amino acids becoming more available and affordable, this feeding strategy is becoming increasingly implemented in the poultry industry (Burley *et al*., 2013).

Therefore, the present study was conducted to evaluate the live performance, meat, egg and carcass features of indigenous, exotic and crossbred chicken fed diets with vitamin A and essential amino acid supplements in Rajshahi, Bangladesh.

7.2 Materials and methods

7.2.1 Experiment 1: Meat yield studies

Experimental breeds for meat yield study: A total of 768 day-old Fayoumi and *Sonali* chickens of both sexes divided in 16 groups each group contains 16 breeds with 3 replications were reared under 4 dietary treatments groups *viz*., T1, T2, T3 and T4 for meat yield studies (**Table 7a**). However, the T1 group is provided with premix control diet (**Table 7b**) and T2 group with control diet in addition to Vitamin A, T3 group with control diet in addition to essentials amino acids and T4 group is provided with a combination of the three dietary treatments *i.e*., T1, T2 and T3 groups (**Table 7c**).

Table 7a: Layout of the experimental breeds for meat yield study

Breed	Sex	Diet Groups[1]	Replications 1	2	3	Total
SON	Male	T1	16	16	16	192
		T2	16	16	16	
		T3	16	16	16	
		T4	16	16	16	
SON	Female	T1	16	16	16	192
		T2	16	16	16	
		T3	16	16	16	
		T4	16	16	16	
FAY	Male	T1	16	16	16	192
		T2	16	16	16	
		T3	16	16	16	
		T4	16	16	16	
FAY	Female	T1	16	16	16	192
		T2	16	16	16	
		T3	16	16	16	
		T4	16	16	16	
Grand Total		Groups=16	256	256	256	768

[1]T1 (control diet), T2 (T1 + Vit-A), T3 (T1 + EAAs) and T4 (T1 + Vit-A + EAAs)

Parameters studied: Growth performance, meat features and carcass features were calculated under meat yield studies. A detailed account of the relevant parameters is as follow:

Processing of chicken: To study the meat features the experimental chickens were slaughtered. In order to avail this process feed was withdrawn and water was supplied *ad libitum* during 12 hours of fasting prior to slaughtering and to facilitate proper bleeding. After complete bleeding, the slatured birds were immersed in pre-warmed water at 51-55°C for 120 seconds in order to facile removal of feathers. Final processing was performed by removal of the head, shank, viscera, oil gland, kidneys and lungs of the carcases. Heart and liver were removed from the remaining viscera by cutting them loose. As soon as these were removed, the gall bladder was removed the liver and the pericardial sac and arteries were excised from the heart. The gizzerd was removed by cutting it loose in front of the proventiculus an was then cutting both in coming and outgoing tracts. Then, it was splite open with knife, emptied and washed and the lining was removed by hand (Jones, 1984). However, growth performance, meat features and carcass features were calculated under meat production studies. Detailed account of the relevant parameters is as follow:

Growth performance: Feed intake (FI), live weight gain (LWG), feed conversion ratio (FCR) and survivability (SB) of the experimental chickens breeds were studied. Weekly feed intake in gram (1-8 weeks), live weight gain from day-old chick to final weight *i.e.*, deducting DOC weight from final weight, feed conversion ratio *i.e.*, dividing feed intake by live weight gain and finally survivability (in percentage) of the experimental breeds were calculated during the study period.

Meat features: Studied parameters for meat features were dressing yield (DY), total meat (TM), breast meat (BM), dark meat (DKM), drumstick meat (DM), wing meat (WM) and thigh meat (THM). All the meat yield data were converted to percent of respective live weight prior to statistical analysis. Dressing yield was calculated by subtracting the weight of blood, feathers, viscera and shank from the live weight. Dark meat was calculated as the sum of thigh meat, drumstick meat, wing meat and trimming meat. Total meat was calculated by adding together all the above parameters.

Carcass features: Studied parameters for carcass features were skin weight (SW), abdominal fat weight (AFW), neck weight (NW), head weight (HW), giblet weight (GW). Giblet weight was the total weight of liver, heart, gizzard, lung and spleen. All the measures were taken separately by using the sensitive weighing balance.

Table 7b: Premix control diet and its ingredients for meat yield study

Ingredients (%)[1]	Starter (0-20 days)	Grower (21-40 days)	Finisher (41-56 days)
Moisture	10-11	10-11	10-11
Crude protein (at least)	22-23	21-22	20-21
Crude fiber	3-4	3-4	3-4
Fat	5-6	6-7	7-8
Ash	7-8	7-8	8-9
Metabolic energy (kcal/kg)	3000	3100	3200
Calcium (at least)	1.00	0.95	0.98
Phosphorus (at least)	0.45	0.45	0.45
Vitamin-mineral premix	0.75	0.85	0.90
Lysine (at least)	1.20	1.10	1.00
Methionine (at least)	0.45	0.48	0.48

[1]Produced and supplied by the National Feed Mill Limited, Gazipur, Bangladesh

Table 7c: Essential amino acids and vitamin A supplemented feed for meat yield study

Nutrients (%)[1]	Age of chickens in days		
	0-20	21-40	41-56
Arginine	1.25	1.10	1.00
Isoleucine	0.80	0.73	0.62
Lysine	1.10	1.00	0.85
Methionine	0.50	0.38	0.32
Threonine	0.80	0.74	0.68
Tryptophan	0.20	0.18	0.16
Valine	0.90	0.82	0.70
Vitamin A[2]	12500 IU	12500 IU	12500 IU

[1]Based on NRC (1994); [2]per kg diet

Plate 7.1 Growth performance of the experimental chicken

A Feed intake at starter phase

B Feed intake at grower phase

C Feed supplying to the experimental birds

D Measuring of feed intake by digital balance

E Weighing Fayoumi at 28 days

F Weighing *Sonali* at 21 days

Plate 7.2 Meat processing of the experimental chicken

A Weighing chicken before slaughtering

B Slaughtering the experimental chicken

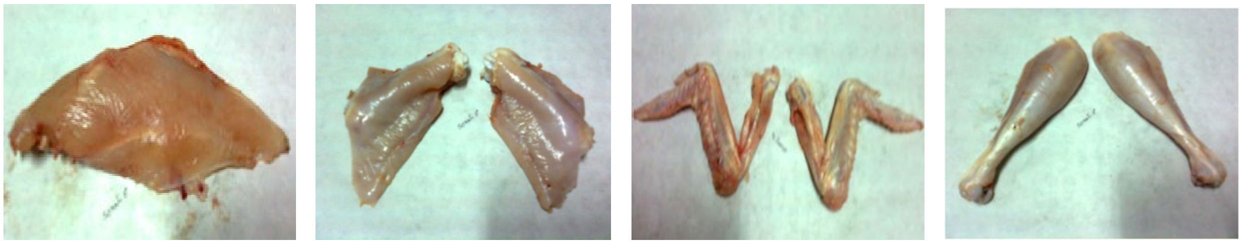
C Removing blood from the chicken

D De-feathering of the experimental chicken

E Weighing of the dressed carcass

F Removing meat from bone

Plate 7.3 Meat features of the experimental chicken

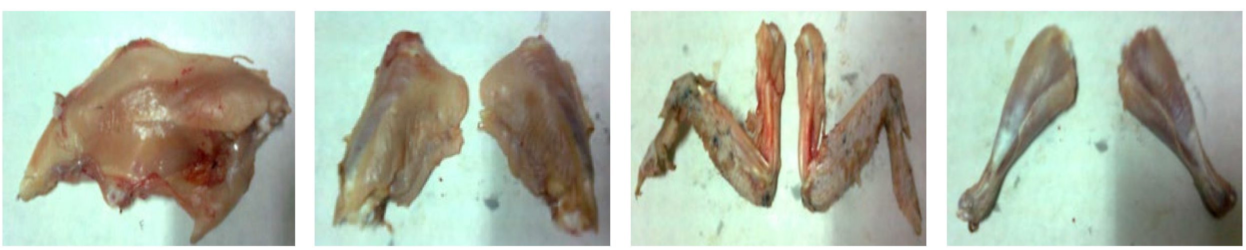


A **B** **C** **D**

A-D Breast, thigh, wing and drumstick meat of *Sonali* male chicken

E **F** **G** **H**

E-H Breast, thigh, wing and drumstick meat of *Sonali* female chicken



I **J** **K** **L**

I-L Breast, thigh, wing and drumstick meat of Fayoumi male chicken

M **N** **O** **P**

M-P Breast, thigh, wing and drumstick meat of Fayoumi female chicken

Plate 7.4 Carcass features of the experimental chicken

A Head of the male chicken

B Head of the female chicken

C Neck of the exp. chicken

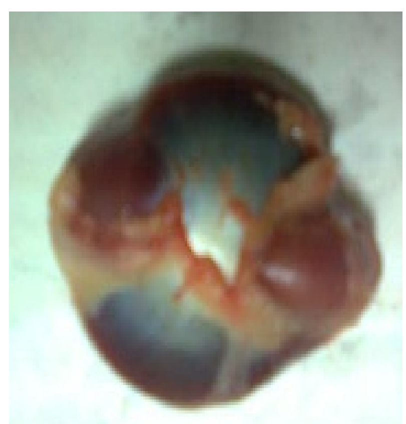
D Removed body skin

E Heart of the exp. chicken

F Liver of the exp. chicken

G Lungs of the exp. chicken

H Spleen of the exp. chicken



I Gizzard of the exp. chicken

7.2.2 Experiment 2: Egg production studies

Experimental breeds for egg yield study: A total of 384 day-old Fayoumi, indigenous, RIR and *Sonali* chickens divided in 16 groups, each group containing 8 breeds with 3 replications were reared under 4 dietary treatment groups *viz*., T1, T2, T3 and T4 for egg yield studies (**Table 7d**). However, in a similar way the T1 group is provided with premix control diet (**Table 7e**) and T2 group with control diet in addition to Vitamin A, T3 group with control diet in addition to essentials amino acids and T4 group is provided with a combination of the three dietary treatments *i.e*., T1, T2 and T3 (**Table 7f**).

Table 7d: Layout of the experimental breeds for egg production study

Breed	Diet Groups[1]	Replications			Total
		1	2	3	
Fayoumi	T1	8	8	8	96
	T2	8	8	8	
	T3	8	8	8	
	T4	8	8	8	
Indigenous (*Deshi*)	T1	8	8	8	96
	T2	8	8	8	
	T3	8	8	8	
	T4	8	8	8	
Rhode Island Red (RIR)	T1	8	8	8	96
	T2	8	8	8	
	T3	8	8	8	
	T4	8	8	8	
Sonali	T1	8	8	8	96
	T2	8	8	8	
	T3	8	8	8	
	T4	8	8	8	
Grand Total	Group=16	128	128	128	384

[1]T1 (control diet), T2 (T1 + Vit-A), T3 (T1 + EAAs) and T4 (T1 + Vit-A + EAAs)

Parameters studied: Growth performance, egg production and egg quality performance were calculated under egg yield studies. A detailed account of the relevant parameters is as follow:

Growth performance: Day-old chick weight (DW), live weight at 20 weeks (LW), live weight gain (LWG), feed intake up to 20 weeks (FI), feed conversion ratio (FCR), final live weight at 48 weeks (FLW) and survivability (SB) of the experimental chickens breeds were studied. DOC weight in gram, live weight at 20 weeks in gram, weekly feed intake in gram per bird per day (0-

20 weeks), live weight gain from day-old chick to 20 weeks of age *i.e.*, deducting DOC weight from final weight, feed conversion ratio *i.e.*, dividing feed intake by live weight gain and finally survivability (in percentage) of the experimental breeds were calculated during the study period.

Egg production performance: Egg weight (EW), age at sexual maturity (ASM), age at peak production (APP), egg production (EP), egg mass production (EMP), feed intake 21 to 48 weeks (FI) and feed conversion ratio (FCR) of the experimental chickens breeds were studied. Egg weight in gram, age at sexual maturity in days, age at peak production in days, egg production in percentage, egg mass production in gram per bird per day, feed intake from 21 to 48 weeks in gram per bird per day and feed conversion ratio of the experimental breeds were calculated during the study period. Formulae for calculating EP, EMP, FI and FCR are as follows:

$$\text{Egg production (\%)} = \frac{\text{No. of eggs produced}}{\text{Total no. of days in production} \times \text{No. of birds}} \times 100$$

$$\text{Egg mass production (g/b/d)} = \frac{\text{No. of egg production} \times \text{Average egg weight}}{\text{No. of days in production} \times \text{No. of birds}} \times 100$$

$$\text{Feed intake (g/b/d)} = \frac{\text{Feed intake in a replication up to a fixed age}}{\text{No. of hens in a replication} \times \text{Total days kept in laying}} \times 100$$

$$\text{Feed conversion ratio} = \frac{\text{Feed intake (g/b/d)}}{\text{Egg mass production (g/b/d)}} \times 100$$

Egg quality performance: From the 4 genotypes of chicken a total of 64 fresh eggs, 4 from each genotype were randomly collected to determine the external and internal qualities. Egg weight (EW), egg shape index (ESI), albumen index (AI), yolk index (YI), albumen percentage (AP), yolk percentage (YP), shell percentage (SP), shell membrane percentage (SMP), shell thickness (STH), yolk color score (YCS) and Haugh unit (HU) were studied (Chowdhury, 1988).

Formulae used for calculating the ESI (Reddy *et al*., 1979), AI (Heiman and Carver, 1936), YI (Wesley and Stadelman, 1959), AP, YP, SP and SMP are as follows:

$$\text{Egg shape index} = \frac{\text{Mean width of egg (mm)}}{\text{Length of egg (mm)}} \times 100$$

$$\text{Albumen index} = \frac{\text{Mean height of albumen (mm)}}{\text{Mean width of albumen (mm)}} \times 100$$

$$\text{Yolk index} = \frac{\text{Mean height of yolk (mm)}}{\text{Mean width of yolk (mm)}} \times 100$$

$$\text{Albumen percent} = \frac{\text{Albumen weight (gm)}}{\text{Total egg weight (gm)}} \times 100$$

$$\text{Yolk percent} = \frac{\text{Yolk weight (gm)}}{\text{Total egg weight (gm)}} \times 100$$

$$\text{Shell percent} = \frac{\text{Shell weight (gm)}}{\text{Total egg weight (gm)}} \times 100$$

$$\text{Shell membrane percent} = \frac{\text{Shell membrane weight (gm)}}{\text{Total egg weight (gm)}} \times 100$$

However, the Haugh unit was calculated from the formula; $HU = 100 \log (H + 7.57 - 1.7 W^{0.37})$ where, W= weight of egg and H= height of albumen (Haugh, 1937). The STH was measured in millimeter by using shell thickness meter (Ogawa Seiki Co-Lit. Tokyo, Japan). An average of three reading, one from waist region and rest two from both ends *i.e*., small and large end were taken from each egg shell. Finally, the YCS was determined by using Roche Yolk Colour fan (F. Hoffman-La Roche Ltd. Switzerland) depending on visual comparison (Vuilleumier, 1969).

Table 7e: Premix control diet and its ingredients for egg yield study

Ingredients (%)[1]	Starter (Crumble) (0-6 wks)	Grower (Mash) (7-18 wks)	Layer (Mash) (19-48 wks)
Moisture	12.00	12.00	12.00
Crude protein	21.50	16.50	17.50
Crude fiber	4.50	5.00	5.00
Fat	5.50	5.50	4.50
Ash	6.50	6.50	12.00
Metabolic energy (kcal/kg)	3000	2950	2850
Calcium (at least)	1.10	1.10	3.50
Phosphorus (at least)	0.50	0.50	0.42
Vitamin-mineral premix	0.50	0.50	0.50
Lysine (at least)	1.35	1.00	0.80
Methionine (at least)	0.55	0.32	0.35

[1]Produced and supplied by the City Poultry and Fish Feeds Ltd., Dhaka, Bangladesh.

Table 7f: Essential amino acids and vitamin A supplemented feed for egg yield study

Nutrients (%)[1]	Weeks of age		
	0-6	7-18	19-48
Arginine	0.94	0.78	0.72
Isoleucine	0.57	0.47	0.42
Lysine	0.80	0.56	0.49
Methionine	0.28	0.23	0.21
Threonine	0.64	0.53	0.44
Tryptophan	0.16	0.13	0.11
Valine	0.59	0.49	0.43
Vitamin A[2]	12500 IU	12500 IU	12500 IU

[1]Based on NRC (1994); [2]per kg diet

Plate 7.5 Growth performance of the experimental layers

A Experimental house for *Deshi* chicken

B Chicks with broody hen in the netted house

C Chicks with broody hen in the back-yard

D Growing phage of Fayoumi chicken

E Growing phage of RIR chicken

F Growing phage of *Sonali* chicken

Plate 7.6 Egg production traits of the experimental layers

A Egg production phase of RIR chicken

B Egg production phase of Fayoumi chicken

C Egg production phase of *Sonali* chicken

D Egg production phase of *Deshi* chicken

E Eggs laid by Fayoumi chicken at litter

F Egg laid by *Sonali* chicken at bedding litter

Plate 7.7 Determination of egg quality traits – phase I

A Weighing of trial egg by a digital balance

B Breaking of the egg by spatula

C Pouring of the egg components in a glass

D Measuring of yolk width by slide calipers

E Measuring yolk height by micrometer

F Measuring albumen width by slide calipers

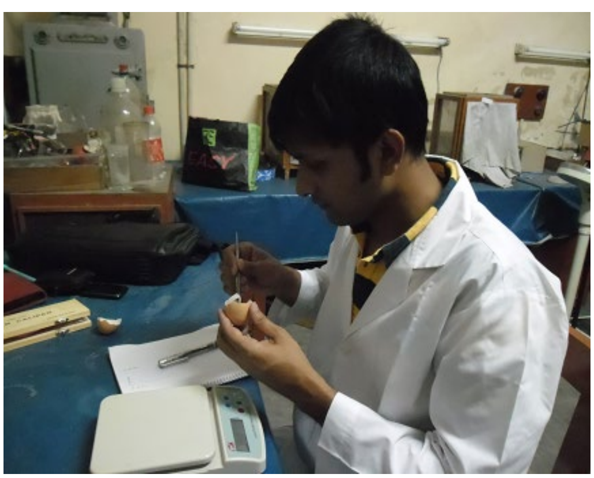
Plate 7.8 Determination of egg quality traits – phase II

A Measuring albumen height by micrometer

B Scoring of yolk colour by yolk colour fan

C Measuring shell thickness

D Taking yolk weight by a digital balance



E Removing shell membrane by forceps

F Weighing shell membrane by digital balance

7.3 Results

7.3.1 Growth performance

The impacts of breed, sex and treatment diets on the growth performance of the experimental chickens are observed and analyzed. However, the impact of breed on the growth performance of the experimental Fayoumi and *Sonali* are presented in **Table 7g**. The findings exposed that feed intake and live weight gain by the experimental Fayoumi was the highest (1771.86±57.82) and (623.38±64.14) followed by *Sonali* (1679.72±43.28) and (580.12±59.68) excluding feed conversion ratio which was found the highest for *Sonali* (3.11±0.34) followed by Fayoumi (3.05±0.33). The impact of breed on the growth performance showed highly significant difference for FI ($P<0.001$) followed by LWG ($P<0.05$). Conversely, none of parameters FCR and SB showed significant difference for the experimental chicken breeds ($P>0.05$). The findings are graphically presented in the **Fig. 7a**, **Fig. 7d** and **Fig. 7g**.

The impact of genotype or sex on the growth performance of the experimental Fayoumi and *Sonali* are presented in **Table 7h**. The findings revealed that the male chicken consumed more feed and gained more live weight (1760.22±66.19) and (638.17±56.25) than the female chicken (1691.36±52.82) and (565.33±52.15). But the feed conversion ratio was found the highest for female chicken (3.21±0.32) than the male one (2.95±0.30). The impact of genotype or sex on the growth performance as well showed highly significant difference for FI and LWG ($P<0.001$) followed by FCR ($P<0.01$). Conversely, the survivability between male and female chicken showed insignificant difference for the experimental study ($P>0.05$). The findings are graphically presented in the **Fig. 7b**, **Fig. 7e** and **Fig. 7h**.

Moreover, the impact of treatment diets on the growth performance of the experimental Fayoumi and *Sonali* are presented in **Table 7i**. The findings showed that the highest feed intake was found for the T1 group (1751.17±69.57) followed by the T2, T4 and T3 group (1732.34±65.04), (1716.74±71.57) and (1702.91±67.58) respectively. Conversely, the T1 group showed lowest live weight gain (534.38±34.27) followed by T2, T3 and T4 group (586.71±45.70), (623.03±53.57) and (662.89±46.76) in that order. On the contrary, the FCR was found the highest for T1 group (3.51±0.14) followed by T2, T3 and T4 group (3.15±0.16), (2.91±0.20) and (2.74±0.13) in correspondence. In contrast, the T4 group showed the highest survivability

(100.00±0.00) followed by T3, T2 and T1 group (95.83±4.07), (94.79±2.43) and (91.67±4.07) respectively. The growth parameters also showed highly significant difference for LWG, FCR and SB (P<0.001). Conversely, the differences in feed intake was found insignificant among the groups (P>0.05).The findings are graphically presented in **Fig. 7c**, **Fig. 7f** and **Fig. 7i**.

Table 7g: Impact of breed on growth performance of the experimental chicken

Breeds	FI	LWG	FCR	SB (%)
SON	1679.72 ±43.28	580.12 ±59.68	3.11 ±0.34	95.05 ±4.51
FAY	1771.86 ±57.82	623.38 ±64.14	3.05 ±0.33	96.09 ±4.04
t-value	-6.250	-2.419	0.622	-0.843
P-value	***	*	ns	ns

Note: FI=Feed intake, LWG=Live weight gain, FCR=Feed conversion ratio, SB=Survivability; All t-values were at 46 df; ns=not significant;*=P<0.05, ***=P<0.001.

Table 7h: Impact of sex on growth performance of the experimental chicken

Sex	FI	LWG	FCR	SB (%)
Male	1760.22 ±66.19	638.17 ±56.25	2.95 ±0.30	95.83 ±4.76
Female	1691.36 ±52.82	565.33 ±52.15	3.21 ±0.32	95.31 ±3.79
t-value	3.984	4.652	-2.856	0.419
P-value	***	***	**	ns

Note: FI=Feed intake, LWG=Live weight gain, FCR=Feed conversion ratio, SB=Survivability; All t-values were at 46 df; ns=not significant;**=P<0.01, ***=P<0.001.

Table 7i: Impact of treatment diets on growth performance of the experimental chicken

Treatment	FI	LWG	FCR	SB (%)
T1	1751.17^{a} ±69.57	534.38^{d} ±34.27	3.51^{a} ±0.14	91.67^{c} ±4.07
T2	1732.34^{a} ±65.04	586.71^{c} ±45.70	3.15^{b} ±0.16	94.79^{b} ±2.43
T3	1702.91^{a} ±67.58	623.03^{b} ±53.57	2.91^{c} ±0.20	95.83^{b} ±4.07
T4	1716.74^{a} ±71.57	662.89^{a} ±46.76	2.74^{d} ±0.13	100.00^{a} ±0.00
SEM	9.917	9.392	0.048	0.616
F-values	1.102	17.225	51.773	14.556
P-values	ns	***	***	***

Note: FI=Feed intake, LWG=Live weight gain, FCR=Feed conversion ratio, SB=Survivability; All F-values were at 47 df.; ns=not significant, ***=P<0.001; $^{a\text{-}d}$Means with different letters differ significantly (P<0.05).

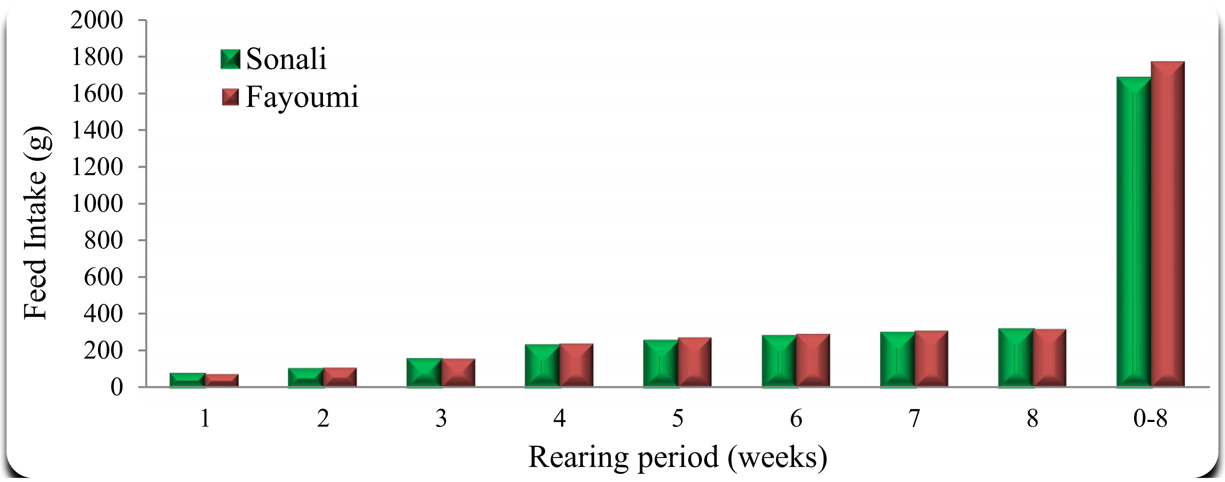


Fig. 7a: Breed-wise weekly feed intake of the experimental birds

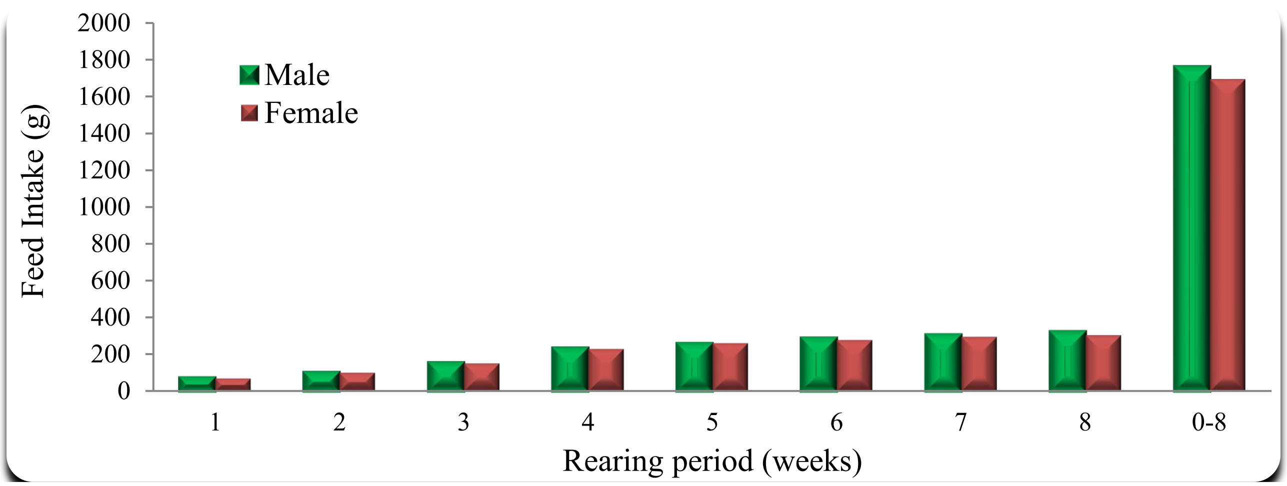


Fig. 7b: Gender-wise weekly feed intake of the experimental birds

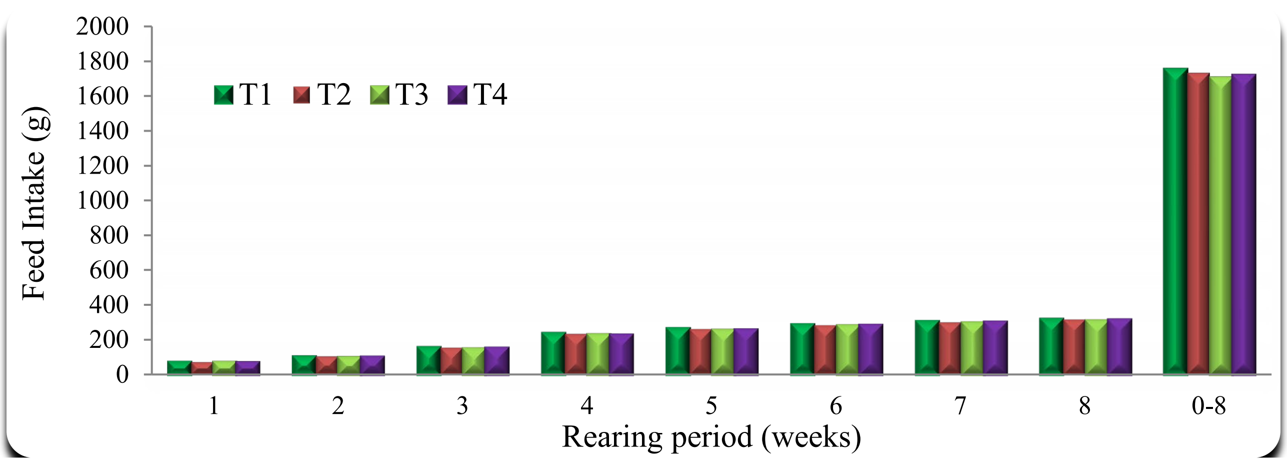


Fig. 7c: Treatment-wise weekly feed intake of the experimental birds

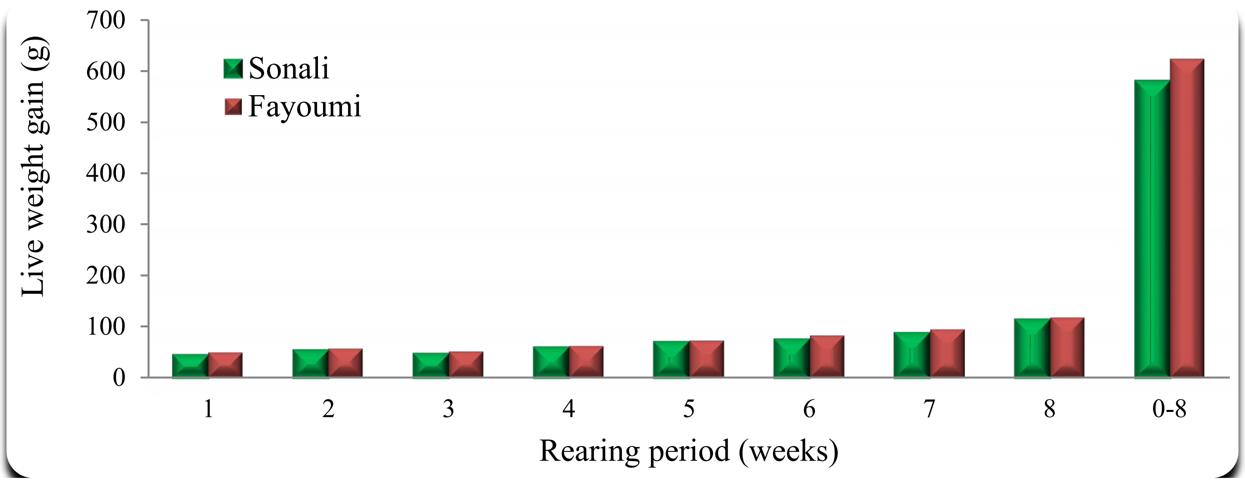


Fig. 7d: Breed-wise weekly live weight gain of the experimental birds

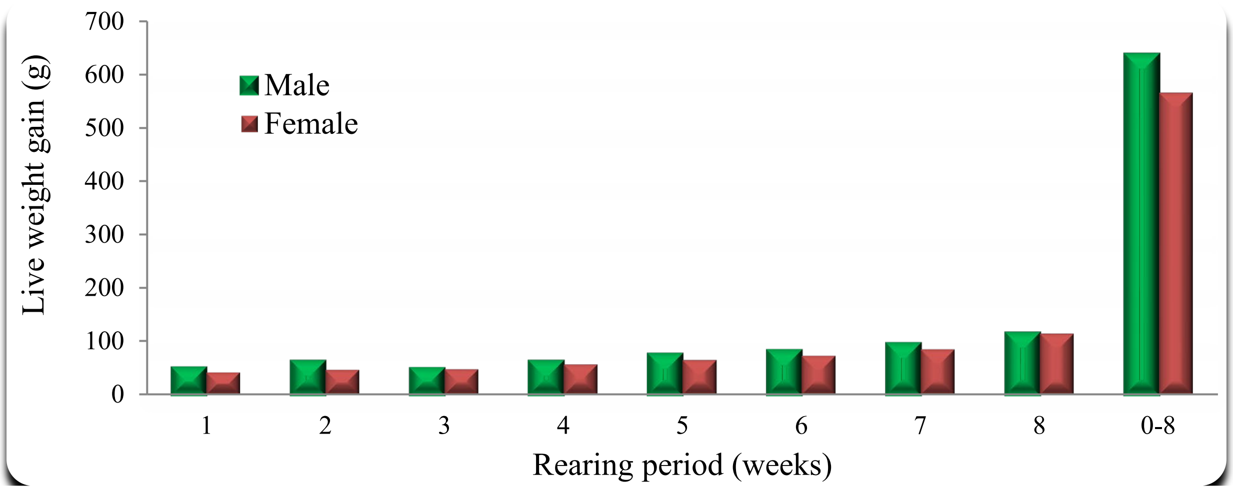


Fig. 7e: Gender-wise weekly live weight gain of the experimental birds

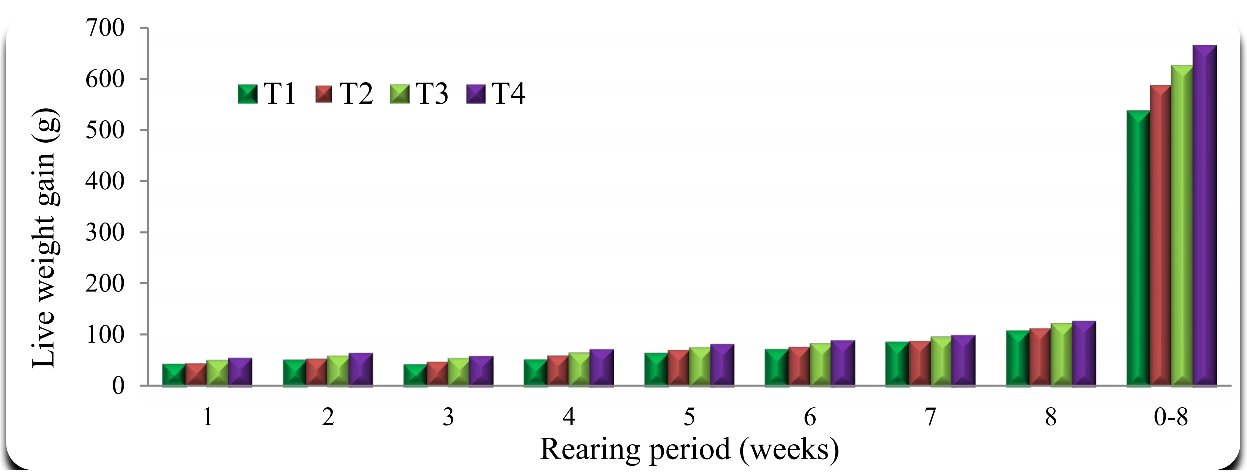


Fig. 7f: Treatment-wise weekly live weight gain of the experimental birds

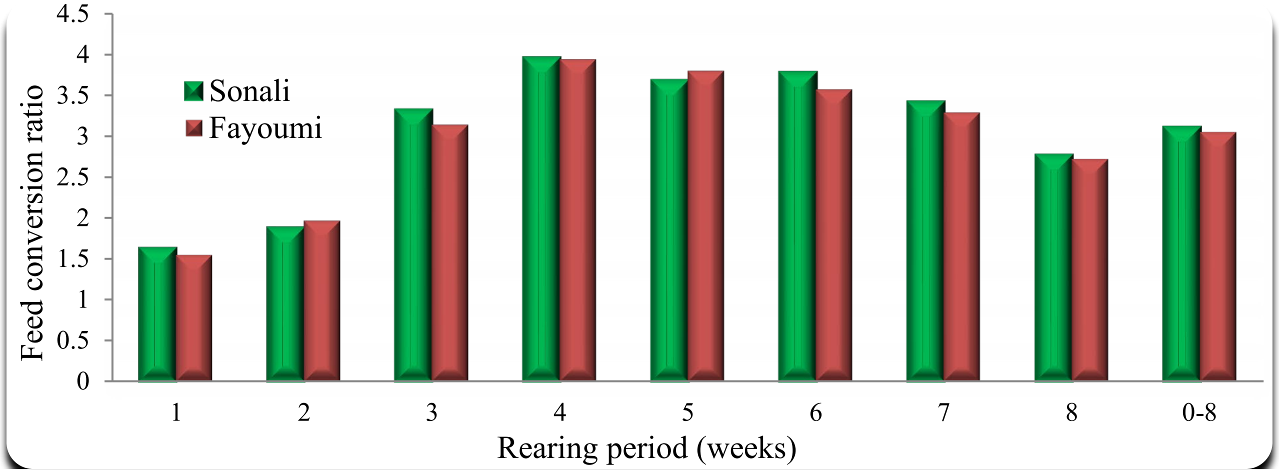


Fig. 7g: Breed-wise weekly feed conversion ratio of the experimental birds

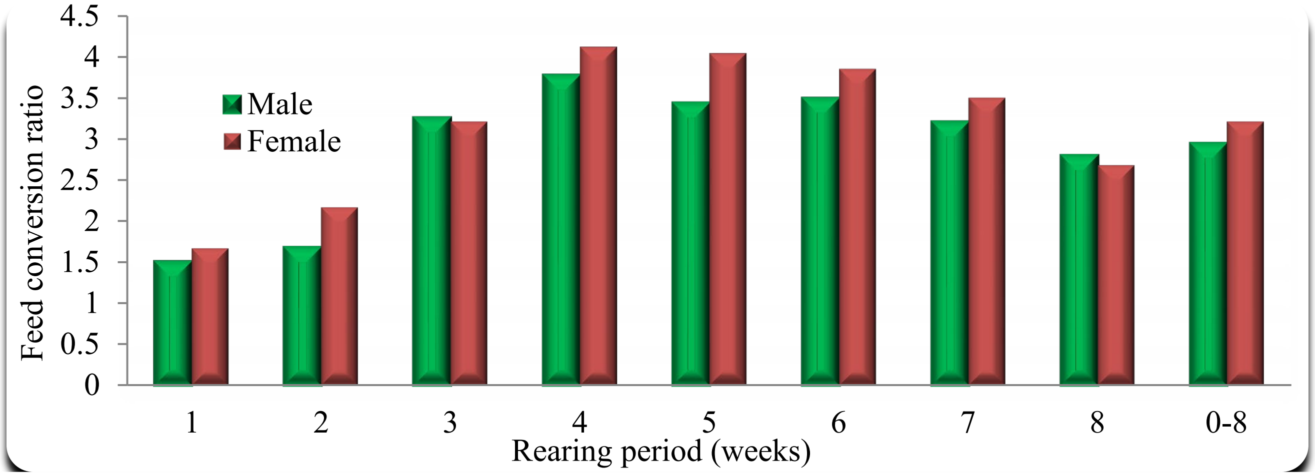


Fig. 7h: Gender-wise weekly feed conversion ratio of the experimental birds

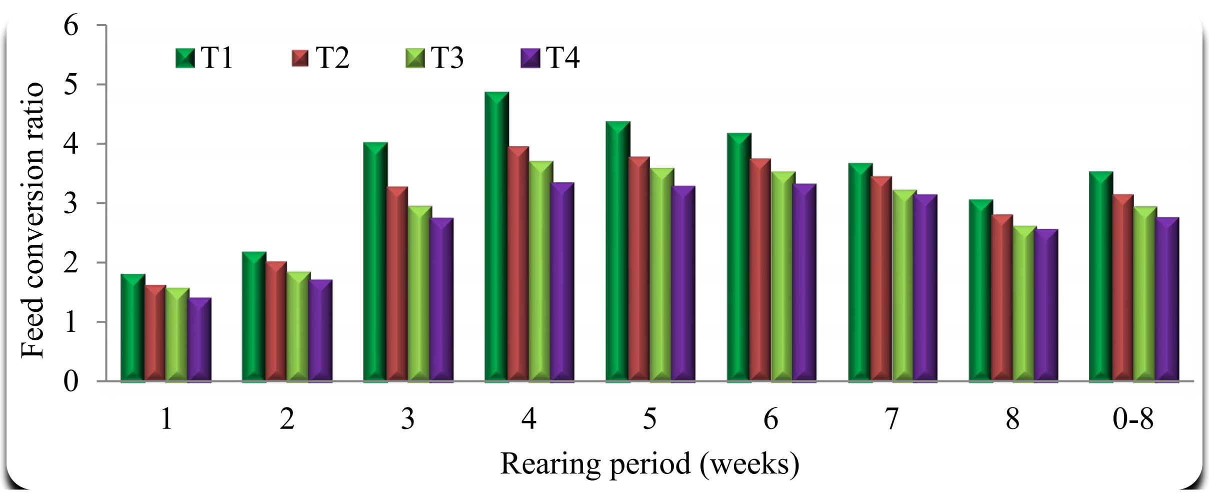


Fig. 7i: Treatment-wise weekly feed conversion ratio of the experimental birds

7.3.2 Meat features

The impacts of breed, sex and treatment diets on the meat features of the experimental chickens are observed and analyzed. However, the impact of breed on the meat features of the experimental Fayoumi and *Sonali* are presented in **Table 7j**. The findings exposed highly significant difference for wing meat and thigh meat ($P<0.001$). In addition, the dark meat and drumstick meat showed significant difference ($P<0.01$). The live weight also showed significant difference ($P<0.05$). In contrast, there is insignificant difference exists among dressing yield, total meat and breast meat ($P>0.05$). The findings are graphically presented in the **Fig. 7j**.

Moreover, the impacts of genotype or sex on meat features are presented in **Table 7k**. The findings shows that there highly significant difference exists between genotype or sex among all the parameters of meat features ($P<0.001$) except total meat ($P<0.01$). However, the breast meat showed insignificant difference between the two genotypes of chicken ($P>0.05$). The findings are graphically presented in the **Fig. 7k**.

Furthermore, the impacts of treatment diets on meat features are presented in **Table 7l**. The findings exposed highly significant difference for live weight, total meat and breast meat ($P<0.001$). On the other hand, the dark meat and wing meat showed significant difference at ($P<0.01$) and ($P<0.05$) in that order. However, there exists insignificant differences among dressing yield, drumstick meat and thigh meat of the four treatment group of chicken ($P>0.05$). The findings are graphically presented in the **Fig. 7l**.

Table 7j: Impact of breed on meat features (in %) of the experimental chicken

Breed	LW	DY	TM	BM	DKM	DM	WM	THM
SON	580.12 ±59.68	57.51 ±1.75	38.14 ±1.87	12.47 ±0.78	27.13 ±1.54	8.13 ±0.58	3.36 ±0.27	11.69 ±1.02
FAY	623.38 ±64.14	57.67 ±3.24	37.57 ±1.11	12.92 ±0.97	26.04 ±0.66	7.64 ±0.59	3.88 ±0.47	10.70 ±0.62
t-value	-2.419	-.207	1.286	-1.792	3.165	2.939	-4.777	4.074
P-value	*	ns	ns	ns	**	**	***	***

Note: LW=Live weight (g), DY=Dressing yield, TM=Total meat, BM=Breast meat, DKM=Dark meat, DM=Drumstick meat, WM=Wing meat, THM=Thigh meat; All t-values were at 46 df; ns=not significant, *=P<0.05, **=P<0.01, ***=P<0.001.

Table 7k: Impact of sex on meat features (in %) of the experimental chicken

Sex	LW	DY	TM	BM	DKM	DM	WM	THM
Male	638.17 ±56.25	59.44 ±1.85	38.39 ±1.66	12.52 ±0.77	27.36 ±1.32	8.41 ±0.34	3.33 ±0.26	11.97 ±0.74
Female	565.33 ±52.15	55.74 ±1.74	37.32 ±1.25	12.87 ±0.99	25.80 ±0.66	7.36 ±0.34	3.91 ±0.43	10.42 ±0.36
t-value	4.652	7.122	2.510	-1.373	5.187	10.689	-5.684	9.258
P-value	***	***	*	ns	***	***	***	***

Note: LW=Live weight (g), DY=Dressing yield, TM=Total meat, BM=Breast meat, DKM=Dark meat, DM=Drumstick meat, WM=Wing meat, THM=Thigh meat; All t-values were at 46 df; ns=not significant, *=P<0.05; ***=P<0.001.

Table 7l: Impact of treatment diets on meat features of the experimental chicken

Treatment	LW	DY	TM	BM	DKM	DM	WM	THM
T1	534.38^{d} ±34.27	56.03^{a} ±2.54	36.64^{c} ±1.34	11.60^{c} ±0.55	25.62^{c} ±1.18	7.54^{a} ±0.62	3.30^{d} ±0.44	10.90^{a} ±0.99
T2	586.71^{c} ±45.70	57.57^{a} ±2.81	37.33^{b} ±1.25	12.52^{b} ±0.54	26.52^{b} ±1.17	7.90^{a} ±0.62	3.68^{c} ±0.44	11.23^{a} ±0.99
T3	623.03^{b} ±53.57	58.41^{a} ±2.27	38.96^{a} ±1.24	13.23^{a} ±0.56	26.97^{b} ±1.17	7.95^{a} ±0.61	3.72^{b} ±0.43	11.28^{a} ±0.98
T4	662.89^{a} ±46.76	58.33^{a} ±2.21	38.49^{a} ±1.31	13.43^{a} ±0.56	27.24^{a} ±1.18	8.13^{a} ±0.60	3.78^{a} ±0.42	11.35^{a} ±0.98
SEM	9.392	0.372	0.224	0.130	0.187	0.091	0.067	0.140
F-values	17.225	2.391	8.184	26.526	4.360	1.986	3.044	0.491
P-values	***	ns	***	***	**	ns	*	ns

Note: LW=Live weight (g), DY=Dressing yield, TM=Total meat, BM=Breast meat, DKM=Dark meat, DM=Drumstick meat, WM=Wing meat, THM=Thigh meat; All F-values were at 47 df.; ns=not significant, *=P<0.05, **=P<0.01, ***=P<0.001; $^{a-d}$Means with different letters differ significantly (P<0.05).

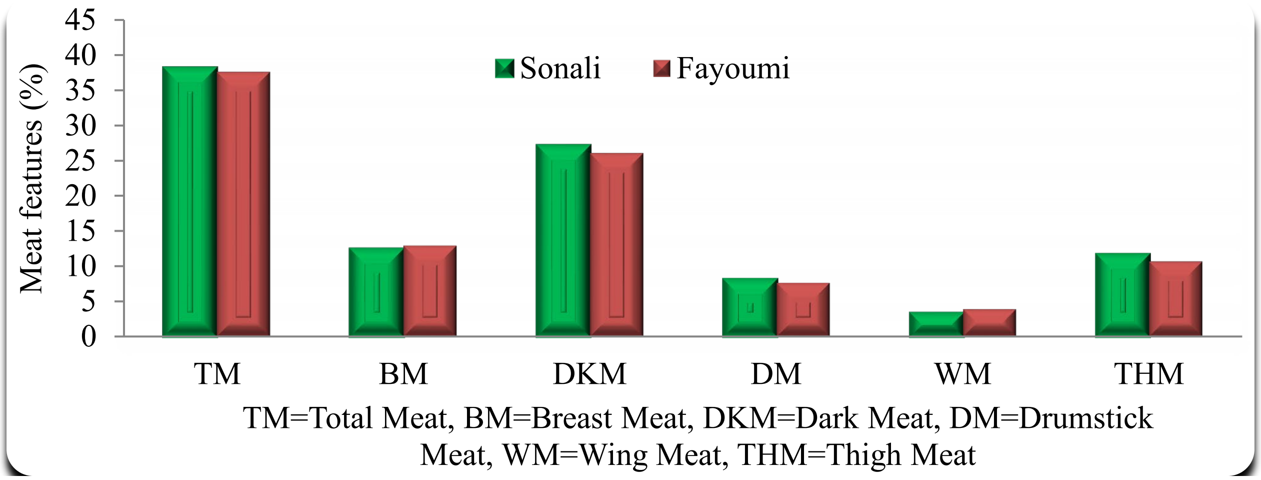


Fig. 7j: Breed-wise meat features of the experimental birds

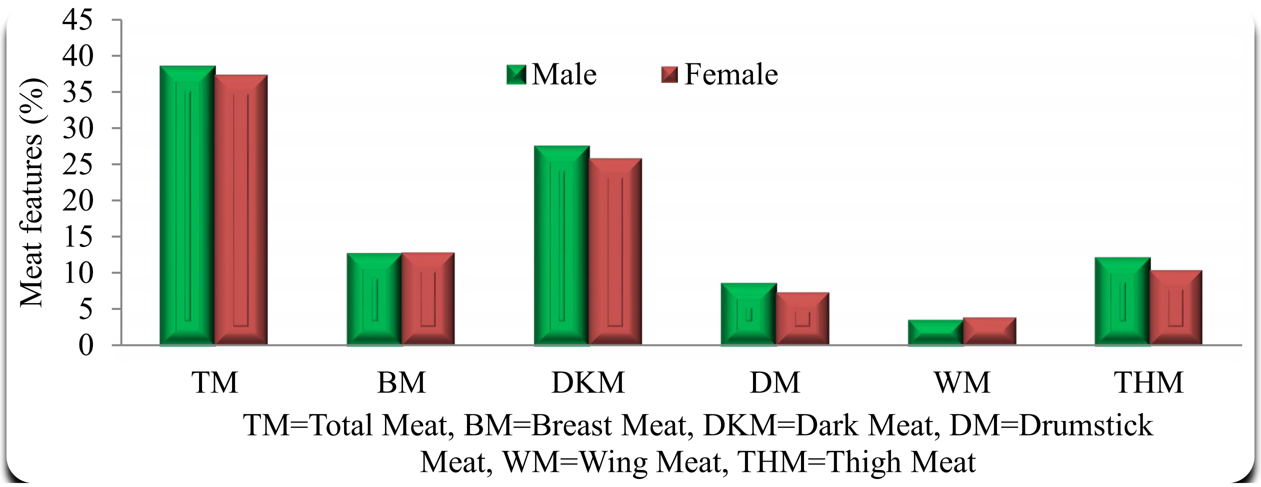


Fig. 7k: Gender-wise meat features of the experimental birds

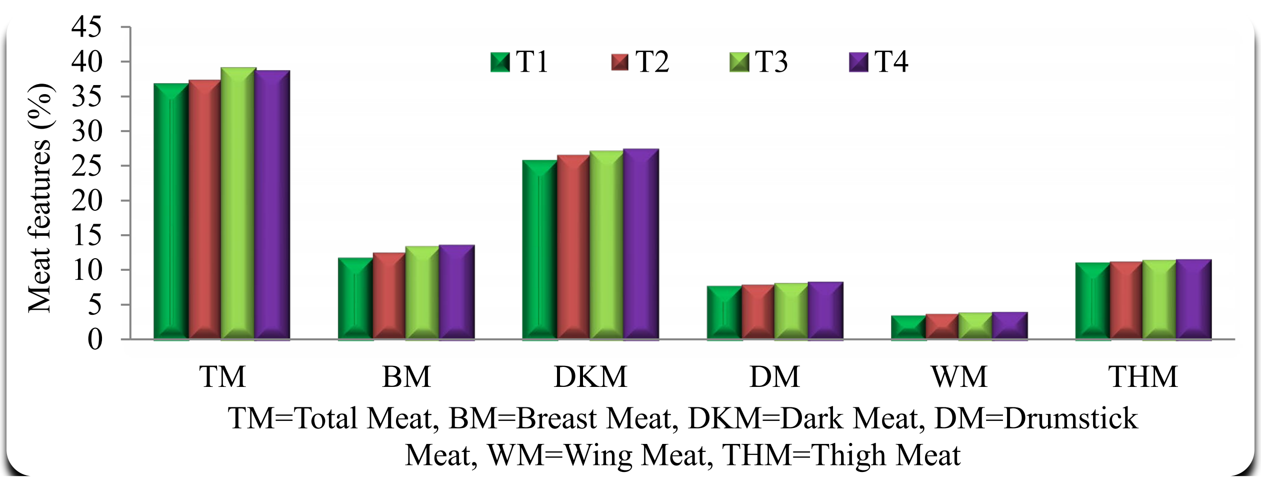


Fig. 7l: Treatment-wise meat features of the experimental birds

7.3.3 Carcass features

In a similar way, the impacts of breed, sex and treatment diets on the carcass features of the experimental chickens are observed and analyzed. However, the impact of breed on the carcass features of the experimental Fayoumi and *Sonali* are presented in **Table 7m**. The findings exposed that there is highly significant difference exists for abdominal fat weight and giblet weight (P<0.001) between two breeds. Besides, the neck weight and head weight showed significant difference (P<0.01). The live weight also showed significant difference (P<0.05). On the contrary, there is insignificant difference exists for skin weight between two varieties of chicken breeds (P>0.05). The findings are graphically presented in the **Fig. 7m**.

Additionally, the **Table 7k** presented the impacts of genotype or sex on meat features of the experimental breeds. The findings revealed that there is highly significant difference exists between genotype or sex among all the parameters of carcass features *i.e*., live weight, skin weight, neck weight and head weight (P<0.001). However, the giblet weight showed significant difference at (P<0.01) whereas the abdominal fat weight showed significant difference at (P<0.05). The findings on the impacts of sex or genotype on the carcass features of the experimental chicken breeds are graphically presented in the **Fig. 7n**.

Furthermore, the impacts of treatment diets on carcass features are tabulated in **Table 7o**. The findings exposed highly significant difference for live weight and giblet weight (P<0.001). Then again, the skin weight and abdominal fat weight showed significant difference (P<0.01). On the other hand, the neck weight and head weight showed insignificant differences among all the four treatment groups of chicken (P>0.05). The findings of the impacts of treatment diet on the carcass features of the experimental chicken breeds are graphically presented in the **Fig. 7o**.

Table 7m: Impact of breed on carcass features (in %) of the experimental chickens

Breeds	LW	SW	AFW	NW	HW	GW
SON	580.12 ±59.68	6.59 ±0.46	1.07 ±0.10	4.24 ±0.81	9.52 ±0.89	14.52 ±1.36
FAY	623.38 ±64.14	6.81 ±0.72	1.23 ±0.16	3.55 ±0.82	10.37 ±0.89	15.81 ±0.96
t-value	-2.419	-1.234	-4.321	2.935	-3.350	-3.812
P-value	*	ns	***	**	**	***

Note: SON=*Sonali,* FAY=Fayoumi; LW=live weight (g), SW=skin weight, AFW=abdominal fat weight, NW=neck weight, HW=head weight, GW=giblet weight; All t-values were at 46 df; ns=not significant, *=P<0.05, **=P<0.01, ***=P<0.001.

Table 7n: Impact of sex on carcass features (in %) of the experimental chickens

Sex	LW	SW	AFW	NW	HW	GW
Male	638.17 ±56.25	6.27 ±0.41	1.10 ±0.10	4.67 ±0.41	10.80 ±0.47	15.70 ±1.02
Female	565.33 ±52.15	7.12 ±0.44	1.19 ±0.19	3.12 ±0.41	9.09 ±0.46	14.63 ±1.41
t-value	4.652	-6.852	-2.203	13.132	12.714	3.034
P-value	***	***	*	***	***	**

Note: LW=live weight (g), SW=skin weight, AFW=abdominal fat weight, NW=neck weight, HW=head weight, GW=giblet weight; All t-values were at 46 df; *=P<0.05, **=P<0.01, ***=P<0.001.

Table 7o: Impact of treatment diets on carcass features (in %) of the experimental chickens

Treatments	LW	SW	AFW	NW	HW	GW
T1	534.38^{d} ±34.27	6.16^{d} ±0.53	1.00^{c} ±0.14	3.60^{a} ±0.89	9.71^{a} ±0.96	13.67^{d} ±0.94
T2	586.71^{c} ±45.70	6.80^{b} ±0.53	1.21^{a} ±0.13	3.87^{a} ±0.87	9.93^{a} ±1.00	15.32^{c} ±1.00
T3	623.03^{b} ±53.57	6.76^{c} ±0.52	1.17^{b} ±0.13	4.00^{a} ±0.88	10.03^{a} ±1.00	15.72^{b} ±1.05
T4	662.89^{a} ±46.76	7.09^{a} ±0.47	1.21^{a} ±0.13	4.11^{a} ±0.89	10.10^{a} ±1.04	15.95^{a} ±1.08
SEM	9.392	0.087	0.023	0.127	0.141	0.193
F-value	17.225	6.898	6.819	0.730	0.340	12.145
P-value	***	**	**	ns	ns	***

Note: LW=live weight (g), SW=skin weight, AFW=abdominal fat weight, NW=neck weight, HW=head weight, GW=giblet weight; ns=not significant, **=P<0.01, ***=P<0.001; $^{a\text{-}d}$Means with different letters differ significantly (P<0.05).

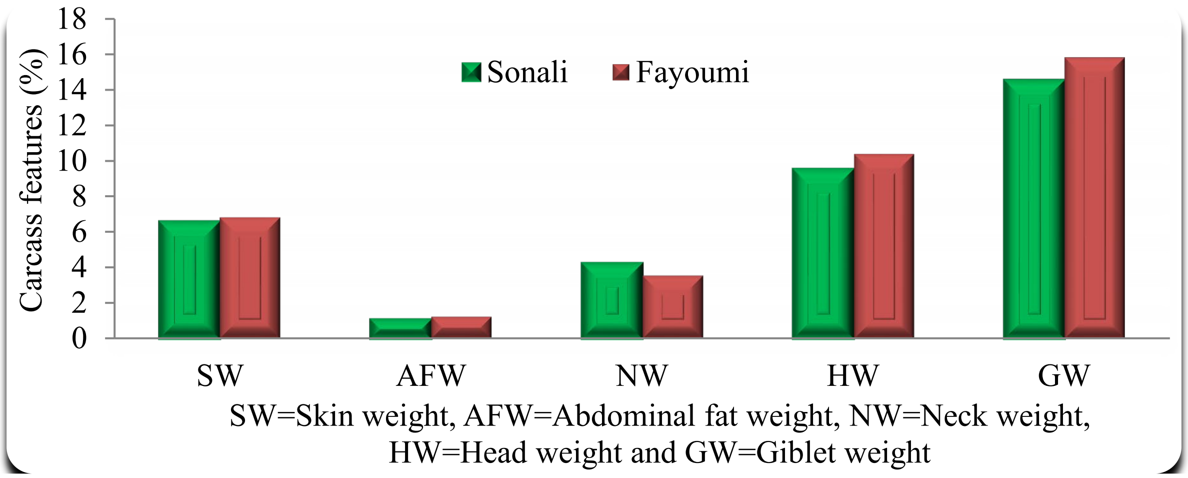


Fig. 7m: Breed-wise carcass features of the experimental birds

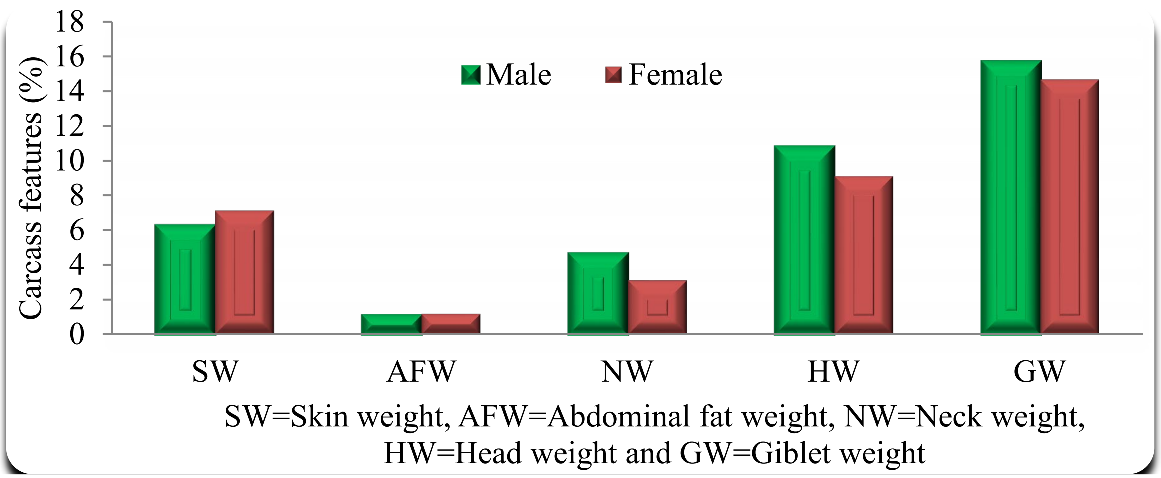


Fig. 7n: Gender-wise carcass features of the experimental birds

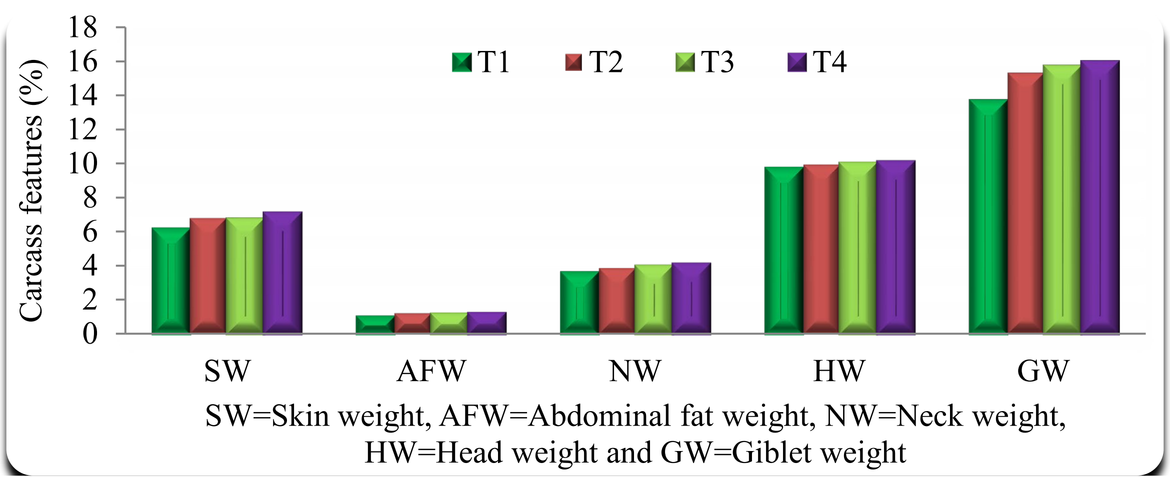


Fig. 7o: Treatment-wise carcass features of the experimental birds

7.3.4 Growth performance of the experimental layer breeds

The impacts of breed and treatment diets on the growth performance of the four genotypic experimental layer *viz*., Fayoumi, indigenous, RIR and *Sonali* are observed and analyzed. However, the impacts of breed on the growth performance of the experimental layers are presented in the **Table 7p**. The findings exposed that the RIR breed achieved the highest live weight (1364.84±39.44) and the indigenous breed achieved the lowest (800.89±65.72) live weight followed by (1278.58±28.72) and (1183.01±41.72) for *Sonali* and Fayoumi breed in that order for up to 20 weeks of age. In a similar way, the RIR breed gained the highest live weight (1326.24±39.41) followed by *Sonali*, Fayoumi and indigenous breed with LWG (1244.03±28.86), (1147.12±41.12) and (777.07±64.92) respectively.

Besides, the daily feed intake up to 20 weeks of age was found the highest for RIR breed (54.01±3.93) and the lowest for indigenous breed (43.00±1.79) followed by Sonali and Fayoumi breed with (53.39±4.15) and (51.84±2.51) respectively. However, the feed conversion ratio was found the highest for indigenous breed (7.80±0.72) followed by (6.34±0.47), (6.01±0.50) and (5.71±0.53) for Fayoumi, *Sonali* and RIR chicken breeds in that order.

Additionally, the final live weight at 48 weeks was found the highest for RIR breed with (1573.89±85.99) and the lowest for *Sonali* breed (1474.14±69.88) followed by Fayoumi and indigenous chicken breeds with (1364.54±85.09) and (924.95±100.90) in that order. Moreover, the highest survivability was found for *Sonali* breed (93.23 %) and the lowest for indigenous breed (85.94%) followed by Fayoumi and RIR breed with 91.14% and 90.62% correspondingly. Furthermore, the impact of breed on the growth performance of the experimental layer chicken breeds showed highly significant difference ($P<0.001$) for all the growth parameter *i.e*., DW, LW, LWG, FI, FCR and FLW except for SB ($P<0.05$). The findings of the impacts of breeds on the growth performance of the experimental chicken are graphically presented in the **Fig. 7p**.

Table 7p: Impact of breed on growth performance of the experimental chicken

Breeds	DW	LW	LWG	FI	FCR	FLW	SB
FAY	35.89^{b} ±2.44	1183.01^{c} ±41.72	1147.12^{c} ±41.12	51.84^{b} ±2.51	6.34^{b} ±0.47	1364.54^{c} ±85.09	91.14^{a} ±6.23
IND	23.82^{c} ±1.02	800.89^{d} ±65.72	777.07^{d} ±64.92	43.00^{c} ±1.79	7.80^{a} ±0.72	924.95^{d} ±100.90	85.94^{c} ±3.88
RIR	38.60^{a} ±0.58	1364.84^{a} ±39.44	1326.24^{a} ±39.41	54.01^{a} ±3.93	5.71^{c} ±0.53	1573.89^{a} ±85.99	90.62^{b} ±6.25
SON	34.56^{b} ±2.10	1278.58^{b} ±28.72	1244.03^{b} ±28.86	53.39^{a} ±4.15	6.01^{b} ±0.50	1474.14^{b} ±69.88	93.23^{a} ±5.63
SEM	0.854	32.058	31.267	0.790	0.141	38.083	0.871
F-values	172.011	351.591	339.997	29.787	32.366	132.226	3.648
P-values	***	***	***	***	***	***	*

Note: DW=Day-old chick wt (g), LW=Live wt at 20 weeks (g), LWG= Live wt gain (g), FI=Feed intake up to 20 weeks (g/b/d), FCR=Feed conversion ratio (FI/LWG), FLW=Final live wt at 48 weeks (g), SB=Survivability (%); All F-values were at 47 df.; *=P<0.05, ***=P<0.001; $^{a-d}$Means with different letters differ significantly (P<0.05).

Table 7q: Impact of treatment diets on growth performance of the experimental chicken

Treatment	DW	LW	LWG	FI	FCR	FLW	SB
T1	32.81^{a} ±6.44	1105.75^{a} ±249.08	1072.94^{a} ±242.78	52.14^{a} ±7.21	7.00^{a} ±1.04	1216.33^{a} ±273.99	85.94^{d} ±4.71
T2	33.71^{a} ±6.20	1148.22^{a} ±226.39	1114.51^{a} ±220.87	51.69^{a} ±5.06	6.66^{b} ±0.99	1320.45^{a} ±260.34	89.06^{c} ±4.71
T3	32.80^{a} ±5.81	1177.73^{a} ±221.07	1144.93^{a} ±215.35	49.98^{a} ±4.51	6.25^{c} ±0.88	1377.95^{a} ±258.65	91.67^{b} ±6.15
T4	33.54^{a} ±5.91	1195.62^{a} ±208.72	1162.08^{a} ±203.48	48.43^{a} ±4.55	5.94^{d} ±0.73	1422.79^{a} ±248.37	94.27^{a} ±5.63
SEM	0.854	32.058	31.267	0.790	0.141	38.083	0.871
F-values	0.074	0.360	0.375	1.169	3.064	1.405	5.360
P-values	ns	ns	ns	ns	*	ns	**

Note: DW=Day-old chick wt (g), LW=Live wt at 20 weeks (g), LWG= Live wt gain (g), FI=Feed intake up to 20 weeks (g/b/d), FCR=Feed conversion ratio (FI/LWG), FLW=Final live wt at 48 weeks (g), SB=Survivability (%); All F-values were at 47 df.; *=P<0.05, **=P<0.01, ns=not significant; $^{a-d}$Means with different letters differ significantly (P<0.05).

Likewise, the impacts of treatment diets on the growth performance of the experimental layers are presented in the **Table 7q**. The findings exposed that the T4 group chicken achieved the highest live weight (1195.62±208.72) and the T1 group chicken achieved the lowest (1105.75±249.08) live weight followed by (1177.73±221.07) and (1148.22±226.39) for T3 and T2 group chicken in that order for up to 20 weeks of age. In the same way, the T4 group chicken gained the highest live weight (1162.08±203.48) followed by T3, T2 and T1 group with LWG (1144.93±215.35), (1114.51±220.87) and (1072.94±242.78) respectively.

More to the point, the T1 group chicken consumed the highest daily feed intake (52.14±7.21) and the T4 group chicken consumed the lowest daily feed intake (48.43±4.55) followed by T3 and T2 group with FI (49.98±4.51) and (51.69±5.06) in that order up to 20 weeks of age. However, the feed conversion ratio was found the highest for T1 group (7.00±1.04) followed by (6.66±0.99), (6.25±0.88) and (5.94±0.73) for T2, T3 and T4 group correspondingly.

Moreover, the final live weight at 48 weeks was found the highest in T4 group chicken (1422.79±248.37) and the lowest in T1 group chicken (1216.33±273.99) followed by T3 and T2 group with FLW (1377.95±258.65) and (1320.45±260.34) respectively. Similarly, the highest survivability was found for T4 group (94.27%) and the lowest for T1 group (85.94%) followed by T3 and T2 group with 91.67% and 89.06% respectively. Furthermore, the impact of treatment diet on the growth performance of the experimental layer chicken breeds showed significant difference for SB ($P<0.01$) and FCR ($P<0.05$). In contrast, the rest of the growth parameter *i.e.*, DW, LW, LWG, FI and FLW showed insignificant difference ($P<0.05$) among the treatment diets. The findings of the impacts of treatment diets on the growth performance of the experimental chicken breeds are graphically presented in the **Fig. 7q**.

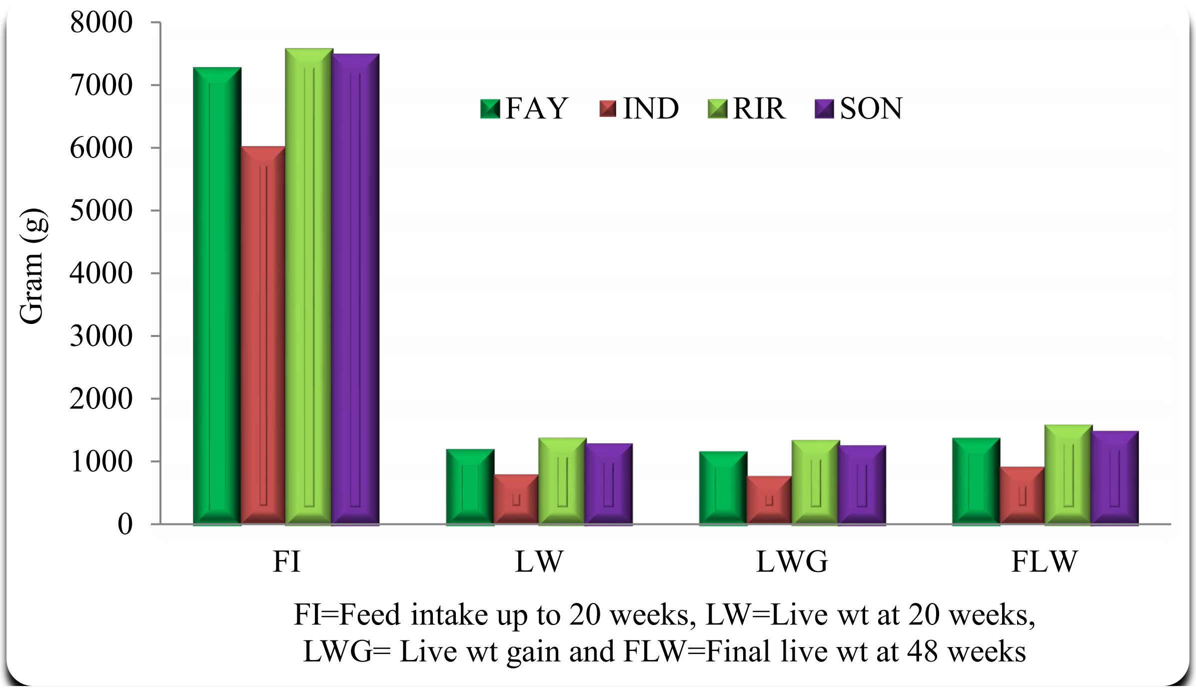


Fig. 7p: Breed-wise growth performance of the experimental birds

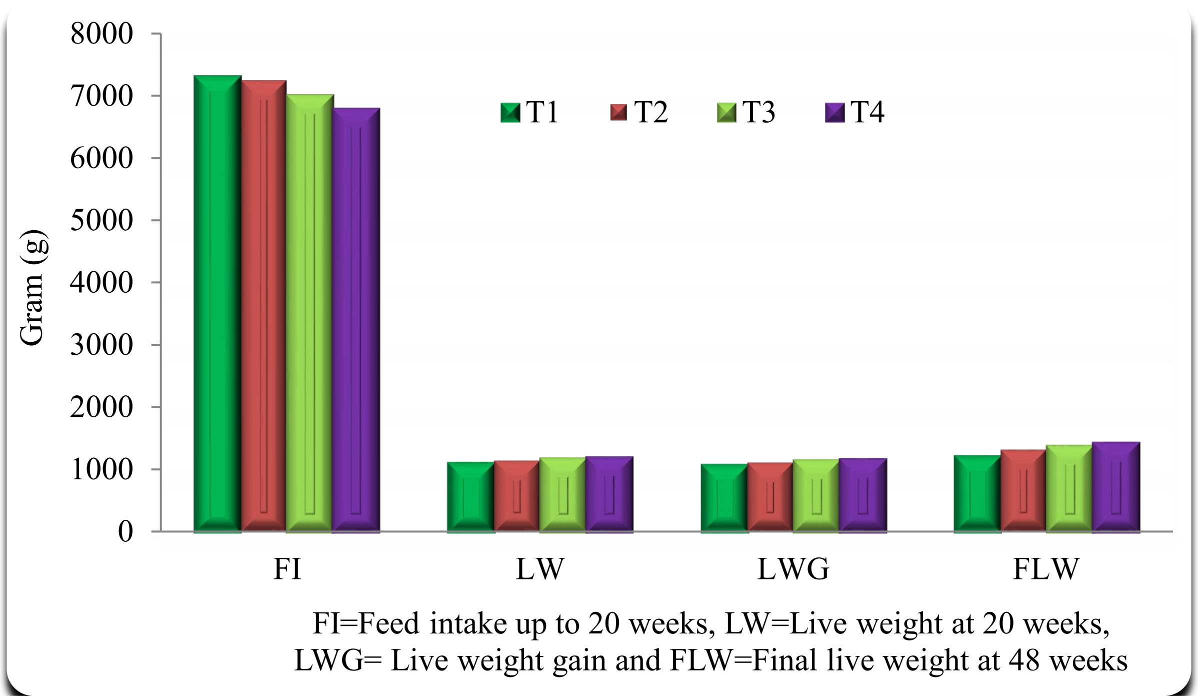


Fig. 7q: Treatment-wise growth performance of the experimental birds

7.3.5 Egg production performance

The impacts of breed and treatment diet on the egg production performance of the four genotypic experimental layers *viz*., Fayoumi, indigenous, RIR and *Sonali* are observed and analyzed. However, the impacts of breed on the egg production performance of the experimental layers are presented in the **Table 7r**. The findings exposed that the RIR egg weight was the highest (54.09±7.25) followed by *Sonali*, Fayoumi and indigenous breed with egg weight (48.26±5.99), (48.63±10.13) and (27.80±3.96) respectively. The highest egg production was found in *Sonali* breed (77.98%) and the lowest in indigenous breed (45.45%) followed by Fayoumi (75.34%) and RIR (69.15%). However, the feed intake from 21 to 48 weeks of age and egg mass production was found the highest for RIR with (101.52±3.93) and (36.29±2.97) in that order, while the lowest in indigenous breed with (90.50±1.79) and (20.84±3.34) respectively. On the other hand, the feed conversion ratio was found the highest for indigenous breeds (4.45±0.76) and the lowest for RIR (2.82±0.32) followed by (3.21±0.39) and (2.99±0.31) for Fayoumi and *Sonali* chicken breeds, respectively.

The indigenous breed attained sexual maturity with lowest production days (166.83±17.22) while the RIR breeds showed sexual maturity on highest production (181.25±15.72) days. Similar ASM was observed in both the *Sonali* and Fayoumi at (177.75±14.79) and (177.17±15.04) days respectively. Similarly, the indigenous breed showed lowest peak production age at (247.17±14.46) days while the RIR breed showed highest peak production age at (263.42±15.57) days. Both the Fayoumi and *Sonali* chicken breeds showed similar peak production age (258.08±13.79) and (257.75±12.66), respectively.

The egg production parameters showed highly significant difference for egg weight, egg production, egg mass production, feed intake and feed conversion ratio ($P<0.001$). In contrast, the age at sexual maturity and age at peak production were showed insignificant difference for the four genotypes of layer chicken breeds ($P>0.05$). The findings of the impacts of breeds on the egg production performance of the four genotypes of chicken breeds are graphically presented in the **Fig. 7r** and **Fig. 7s**.

Table 7r: Impact of breed on egg production performance of the experimental chicken

Breeds	EW	ASM	APP	EP	EMP	FI	FCR
FAY	48.63^{c} ±10.13	177.17^{a} ±15.04	258.08^{a} ±13.79	75.34^{b} ±6.28	31.27^{c} ±3.03	99.34^{c} ±2.51	3.21^{b} ±0.39
IND	27.80^{d} ±3.96	166.83^{a} ±17.22	247.17^{a} ±14.46	45.45^{d} ±6.37	20.84^{d} ±3.34	90.50^{d} ±1.79	4.45^{a} ±0.76
RIR	54.09^{a} ±7.25	181.25^{a} ±15.72	263.42^{a} ±15.57	69.15^{c} ±6.27	36.29^{a} ±2.97	101.52^{a} ±3.93	2.82^{d} ±0.32
SON	48.26^{b} ±5.99	177.75^{a} ±14.79	257.75^{a} ±12.66	77.98^{a} ±6.19	33.92^{b} ±2.59	100.89^{b} ±4.15	2.99^{c} ±0.31
SEM	1.774	2.332	2.156	2.067	0.956	0.790	0.115
F-values	31.076	1.873	2.773	66.896	62.038	29.802	28.119
P-values	***	ns	ns	***	***	***	***

Note: EW=Egg wt (g), ASM=Age at sexual maturity (d), APP=Age at peak production (d), EP=Egg production (%), EMP=Egg mass production (g/b/d), FI=Feed intake 21 to 48 weeks (g/b/d), FCR=Feed conversion ratio (FI/EMP); All F-values were at 47 df.; ns=not significant, ***=P<0.001; $^{a\text{-}d}$Means with different letters differ significantly (P<0.05).

Table 7s: Impact of treatment diets on egg production performance of the experimental chicken

Treatment	EW	ASM	APP	EP	EMP	FI	FCR
T1	36.48^{d} ±9.18	194.67^{a} ±4.73	276.25^{a} ±8.06	59.31^{c} ±13.47	26.41^{d} ±6.52	99.65^{a} ±7.22	3.99^{a} ±0.97
T2	41.20^{c} ±9.16	183.83^{b} ±6.83	259.92^{b} ±6.58	64.31^{b} ±13.47	29.93^{c} ±6.19	99.19^{a} ±5.06	3.44^{b} ±0.70
T3	48.66^{b} ±11.98	168.92^{c} ±6.40	249.33^{c} ±6.37	69.31^{b} ±13.47	32.10^{b} ±6.16	97.49^{a} ±4.51	3.14^{c} ±0.58
T4	52.44^{a} ±12.79	155.58^{d} ±6.97	240.92^{d} ±6.75	74.98^{a} ±13.59	33.87^{a} ±5.91	95.93^{a} ±4.55	2.90^{d} ±0.46
SEM	1.774	2.332	2.156	2.067	0.956	0.790	0.115
F-values	5.227	88.351	57.266	2.970	3.217	1.169	5.265
P-values	**	***	***	*	*	ns	**

Note: EW=Egg wt (g), ASM=Age at sexual maturity (d), APP=Age at peak production (d), EP=Egg production (%), EMP=Egg mass production (g/b/d), FI=Feed intake 21 to 48 weeks (g/b/d), FCR=Feed conversion ratio (FI/EMP); All F-values were at 47 df.; ns=not significant, *=P<0.05, **=P<0.01, ***=P<0.001; $^{a\text{-}d}$Means with different letters differ significantly (P<0.05).

Likewise, the impacts of treatment diet on the egg production performance of the four genotypic experimental layers *viz*., Fayoumi, indigenous, RIR and *Sonali* are observed and analyzed. However, the impacts of treatment diet on the egg production performance of the experimental layers are presented in the **Table 7s**. The findings revealed that the T4 group egg weight was the highest (52.44±12.79) followed by T3, T2 and T1 group with egg weight (48.66±11.98), (41.20±9.16) and (36.48±9.18) respectively. The highest egg production was found in T4 group (74.98%) and the lowest in T1 group (59.31%) followed by T3 (69.31%) and T2 group (64.31%). However, the feed intake from 21 to 48 weeks of age was found insignificant among the treatment groups. While, the egg mass production was found the highest for T4 group with (33.87±5.91) and the lowest in T1 group with (26.41±6.52) followed by T3 and T2 with (32.10±6.16) and (29.93±6.19) respectively. Conversely, the feed conversion ratio was found the highest for T1 group (3.99±0.97) and the lowest for T4 group (2.90±0.46) followed by (3.14±0.58) and (3.44±0.70) for T3 and T2 group chicken respectively.

The T4 group chicken attained sexual maturity with lowest production days (155.58±6.97) while the T1 group chicken showed sexual maturity on highest production days (194.67±4.73) followed by T3 and T2 group chicken breeds at (168.92±6.40) and (183.83±6.83) days respectively. In the same way, the T4 group chicken showed the lowest peak production age at (240.92±6.75) days while the T1 group chicken showed highest peak production age at (276.25±8.06) days followed by T3 and T2 group chicken breeds at (249.33±6.37) and (259.92±6.58) days respectively.

The egg production parameters showed significant difference for egg weight ($P<0.01$), egg production ($P<0.05$), egg mass production ($P<0.05$) and feed conversion ratio ($P<0.01$). While, the age at sexual maturity and age at peak production were showed highly significant difference for the four dietary treatment groups ($P<0.001$). On the contrary, there exists insignificant difference for feed intake among the four varieties of treatment diets ($P<0.05$). The findings of the impacts of treatment diets on the egg production performance of the four genotypes of chicken breeds are graphically presented in **Fig. 7t** and **Fig. 7u**.

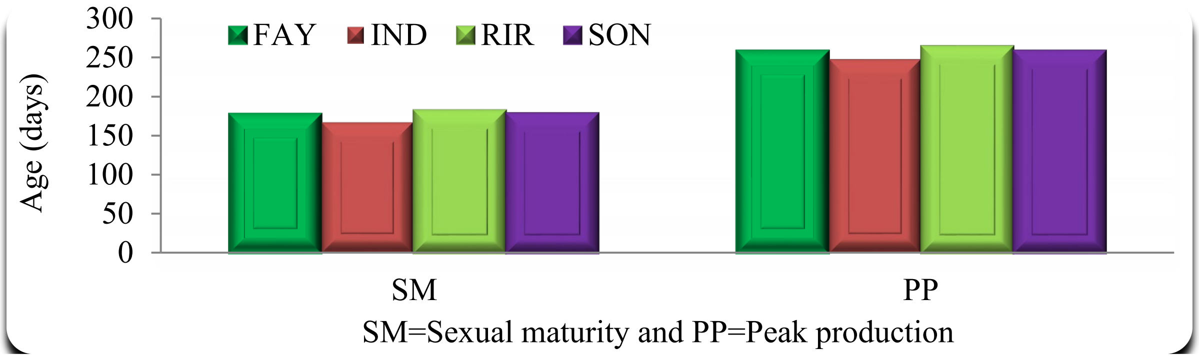


Fig. 7r: Breed-wise sexual maturity and peak production age of the experimental birds

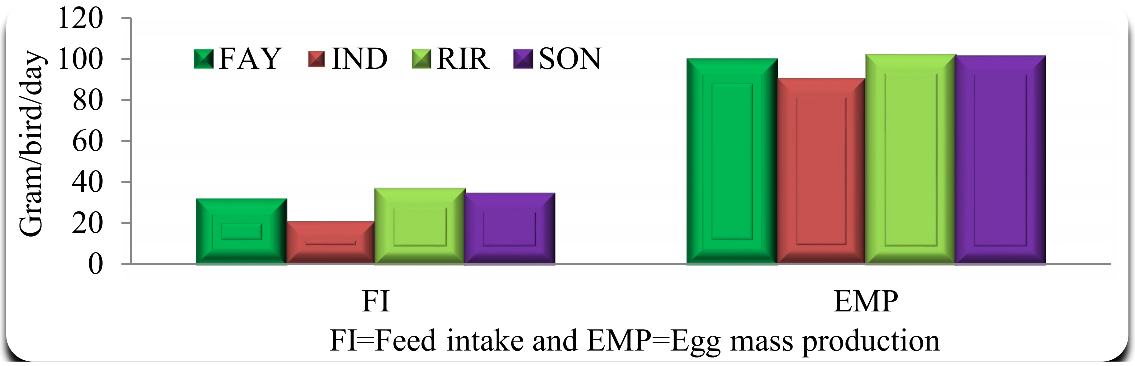


Fig. 7s: Breed-wise feed intake and egg mass production of the experimental birds

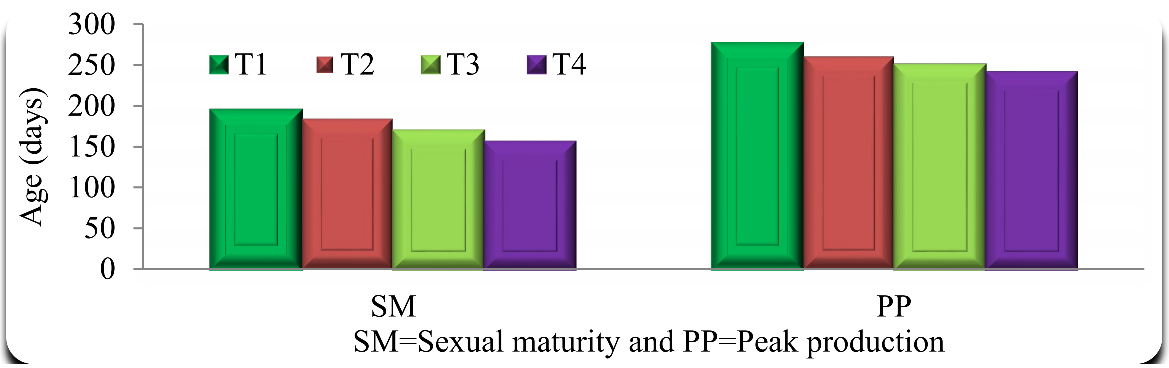


Fig. 7t: Treatment-wise sexual maturity and peak production age of the experimental birds

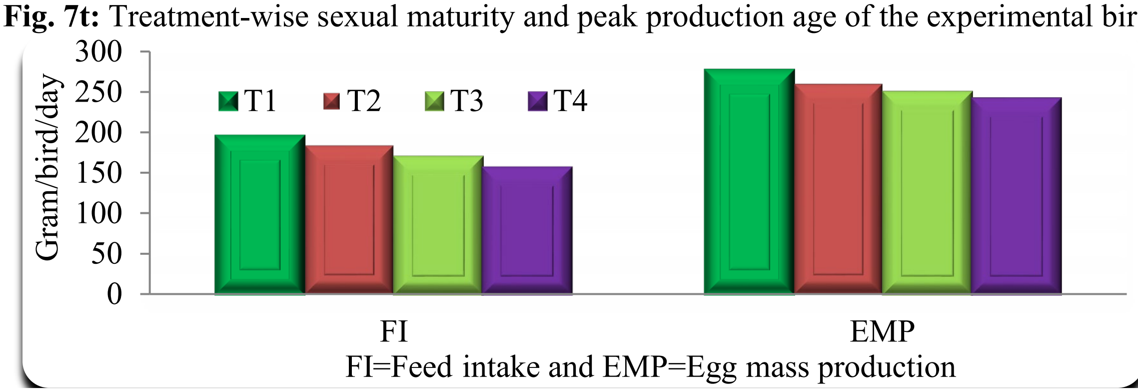


Fig. 7u: Treatment-wise feed intake and egg mass production of the experimental birds

7.3.6 Egg quality performance

The egg quality traits of four genotypes of layers *viz*., Fayoumi, indigenous, RIR and *Sonali* with the impacts of breed and treatment diet are observed and analyzed. However, the impacts of breed on the egg quality performance of the experimental layers are presented in the **Table 7t**. The findings exposed that the egg shape index was found the highest for indigenous egg (76.46±2.20) followed by (75.04±1.29), (74.31±1.46) and (73.63±1.34) for Fayoumi, *Sonali* and RIR respectively. Egg shell membrane was found the highest in indigenous (0.57%) and the lowest in Fayoumi (0.34%) followed by RIR and *Sonali* with (0.52%) and (0.47%) respectively.

The indigenous egg possessed the highest albumen percent (60.36±2.40) followed by *Sonali*, RIR and Fayoumi with albumen percent (55.42±1.01), (55.83±1.18) and (52.76±1.06) respectively. The highest yolk percent was found in Fayoumi egg (35.69±0.80) and the lowest in indigenous egg (27.33±1.92) followed by *Sonali* (33.43±0.83) and RIR (33.08±1.05). However, the egg shell percent was found the highest in indigenous egg (10.12±0.64) followed by Fayoumi, RIR and *Sonali* egg with (9.75±0.52), (9.49±0.56) and (9.47±0.51) respectively.

Egg shell thickness of the *Sonali* egg was found the highest (0.39%) and lowest in indigenous egg (0.36%) followed by RIR and Fayoumi egg with (0.38%) and (0.37%) respectively. In addition, the Haugh unit value was found the highest in indigenous egg (69.90±3.10) followed by (67.11±3.84), (62.24±5.71) and (61.70±3.10) for Fayoumi, *Sonali* and RIR egg respectively.

Moreover, the egg quality parameters of the four genotypes of chicken egg showed highly significant difference ($P<0.001$) for egg weight, egg shape index, albumen percentage, yolk percentage, shell membrane percentage, yolk index, shell thickness and Haugh unit with the exception of shell percentage ($P<0.01$). In contrast, the albumen index and yolk colour score showed insignificant difference for the four genotypes of layers ($P>0.05$). The impact of chicken breeds on egg quality parameters are graphically presented in the **Fig. 7v**, **Fig. 7w** and **Fig. 7x**.

Table 7t: Impact of breed on egg quality performance of the experimental chicken

Breeds	EW	ESI	AP	YP	SP	SMP	AI	YI	STH	YCS	HU
FAY	47.46[c] ±3.38	75.04[b] ±1.29	52.76[d] ±1.06	35.69[a] ±0.80	9.75[b] ±0.52	0.34[d] ±0.02	0.05[a] ±0.01	0.41[c] ±0.02	0.37[c] ±0.03	8.25[a] ±0.68	67.11[b] ±3.84
IND	36.15[d] ±2.68	76.46[a] ±2.20	60.36[a] ±2.40	27.33[d] ±1.92	10.12[a] ±0.64	0.57[a] ±0.17	0.05[a] ±0.01	0.45[b] ±0.02	0.36[b] ±0.02	8.63[a] ±0.50	69.90[a] ±3.10
RIR	51.86[a] ±4.52	73.63[d] ±1.34	55.83[b] ±1.18	33.08[c] ±1.05	9.49[c] ±0.56	0.52[b] ±0.05	0.05[a] ±0.01	0.46[a] ±0.02	0.38[b] ±0.02	8.44[a] ±0.63	61.70[c] ±3.10
SON	49.46[b] ±3.63	74.31[c] ±1.46	55.42[c] ±1.01	33.43[b] ±0.83	9.47[c] ±0.51	0.47[c] ±0.08	0.05[a] ±0.01	0.45[b] ±0.01	0.39[a] ±0.02	8.75[a] ±0.58	62.24[c] ±5.71
SEM	0.878	0.237	0.391	0.417	0.076	0.016	0.001	0.003	0.004	0.077	0.658
F-values	59.338	8.991	68.209	132.288	4.678	15.631	0.226	17.341	9.406	2.118	14.985
P-values	***	***	***	***	**	***	ns	***	***	ns	***

Note: EW=Egg wt (g), ESI=Egg shape index, AP=Albumen percentage (%), YP=Yolk percentage (%), SP=Shell percentage (%), SMP=Shell membrane percentage (%), AI=Albumen index, YI=Yolk index, STH=Shell thickness, YCS=Yolk color score, HU=Haugh unit; All F-values were at 63 df.; ns=not significant, **= $P<0.01$, ***= $P<0.001$; [a-d]Means with different letters differ significantly ($P<0.05$).

Table 7u: Impact of treatment-diet on egg quality performance of the experimental chicken

Breeds	EW	ESI	AP	YP	SP	SMP	AI	YI	STH	YCS	HU
T1	41.67[d] ±5.38	76.62[a] ±1.84	55.39[a] ±2.25	32.45[a] ±2.39	9.90[a] ±0.64	0.36[c] ±0.05	0.04[c] ±0.00	0.43[d] ±0.02	0.35[d] ±0.03	8.19[d] ±0.65	60.72[d] ±3.56
T2	44.98[c] ±6.14	74.98[b] ±1.91	55.92[a] ±2.92	32.55[a] ±3.08	9.99[a] ±0.62	0.46[b] ±0.08	0.05[b] ±0.00	0.44[c] ±0.02	0.37[c] ±0.02	8.31[c] ±0.60	63.10[c] ±5.79
T3	47.92[b] ±6.91	74.17[b] ±1.21	56.28[a] ±3.20	32.39[a] ±3.59	9.53[b] ±0.59	0.54[a] ±0.14	0.06[a] ±0.00	0.45[b] ±0.02	0.38[b] ±0.02	8.63[b] ±0.50	68.39[b] ±3.27
T4	50.36[a] ±6.90	73.66[c] ±1.14	56.78[a] ±4.02	32.15[a] ±4.31	9.40[c] ±0.36	0.54[a] ±0.14	0.06[a] ±0.00	0.46[a] ±0.02	0.39[a] ±0.03	8.94[a] ±0.44	68.74[a] ±3.05
SEM	0.878	0.237	0.391	0.417	0.076	0.016	0.001	0.003	0.004	0.077	0.658
F-values	5.568	10.896	0.550	0.040	4.048	9.022	161.792	6.502	8.819	5.842	15.185
P-values	**	***	ns	ns	*	***	***	**	***	**	***

Note: EW=Egg wt (g), ESI=Egg shape index, AP=Albumen percentage (%), YP=Yolk percentage (%), SP=Shell percentage (%), SMP=Shell membrane percentage (%), AI=Albumen index, YI=Yolk index, STH=Shell thickness, YCS=Yolk color score, HU=Haugh unit; All F-values were at 63 df.; ns=not significant, *= $P<0.05$, **= $P<0.01$, ***= $P<0.001$; [a-d]Means with different letters differ significantly ($P<0.05$).

Similarly, the impact of treatment diet on the egg quality traits of four genotypes of layers *viz*., Fayoumi, indigenous, RIR and *Sonali* are observed, analyzed and are presented in the **Table 7u**. The findings revealed that the egg shape index was found the highest for T1 egg (76.62±1.84) followed by (74.17±1.21), (74.98±1.91) and (73.66±1.14) for T3, T2 and T4 egg respectively. However, the albumen index was found the highest in T3 and T4 egg (0.06) followed by T2 and T1 egg with (0.05) and (0.04) in that order. While, the yolk index was found the highest in T4 egg (0.46) followed by T3, T2 and T1 egg with YI 0.45, 0.44 and 0.43 respectively. On the other hand, the egg shell membrane was found the highest in T3 and T4 egg (0.54%) followed by T2 and T1 egg with (0.46%) and (0.36%) correspondingly. Conversely, the egg shell percent was found the highest in T2 egg (9.99%) followed by T1, T3 and T4 egg with (9.90%), (9.53%) and (9.40%), respectively.

Egg shell thickness of the T4 egg was found the highest (0.39%) and lowest in T1 egg (0.35%) followed by T3 and T2 egg with (0.38%) and (0.37%) respectively. In addition, the Haugh unit value was found the highest in T4 egg (68.74±3.05) followed by (68.39±3.27), (63.10±5.79) and (60.72±3.56) for T3, T2 and T1 eggs, respectively.

Furthermore, among the egg quality parameters of the four treatment groups of chicken egg highly significant difference ($P<0.001$) was found for egg shape index, shell membrane percentage, albumen index, shell thickness and Haugh unit. While, significant difference ($P<0.01$) was found for egg weight, yolk index and yolk colour score with the exception of shell percentage ($P<0.05$). In contrast, the albumen percentage and yolk percentage showed insignificant difference for the four genotypes of layers ($P>0.05$). The impacts of treatment diets on egg quality parameters are graphically presented in the **Fig. 7y**, **Fig. 7z** and **Fig. 7z$_1$**.

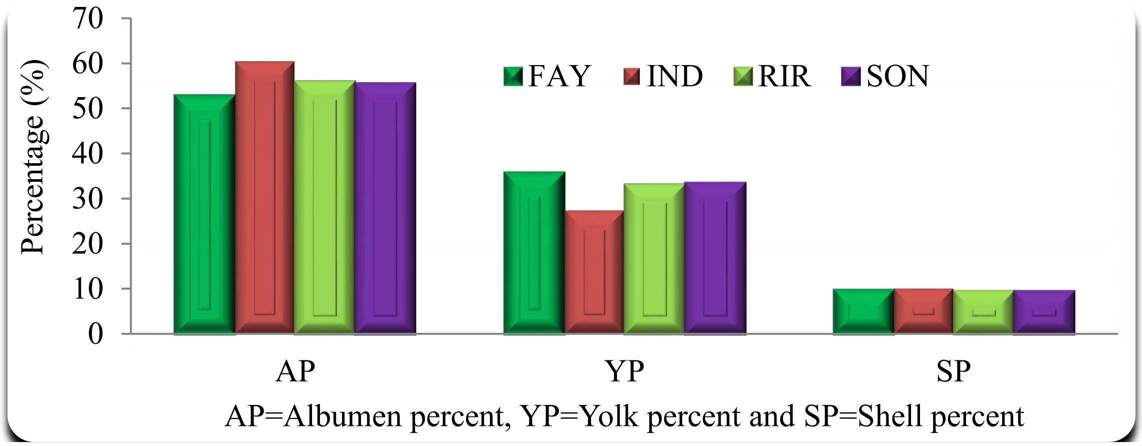


Fig. 7v: Breed-wise egg component percentage of the experimental birds

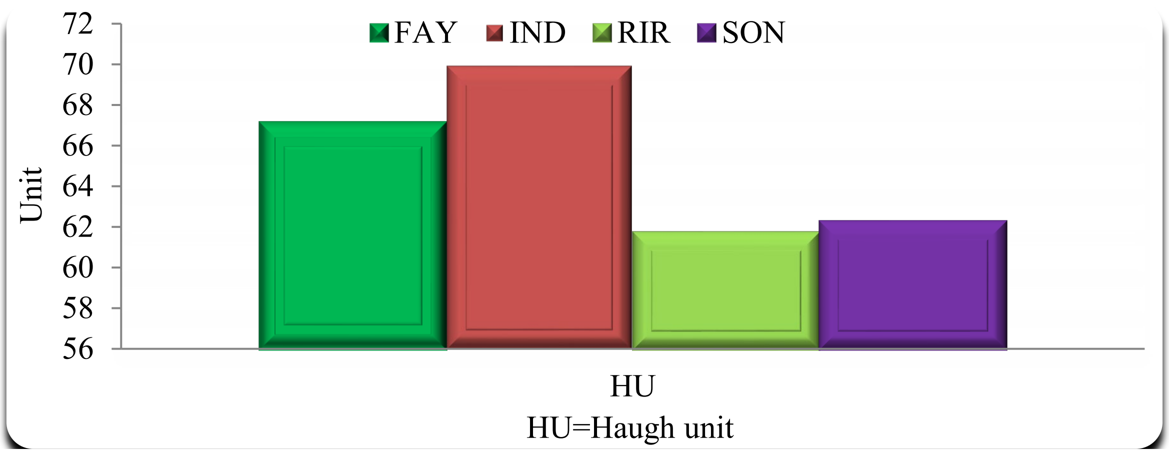


Fig. 7w: Breed-wise Haugh unit of the experimental chicken egg

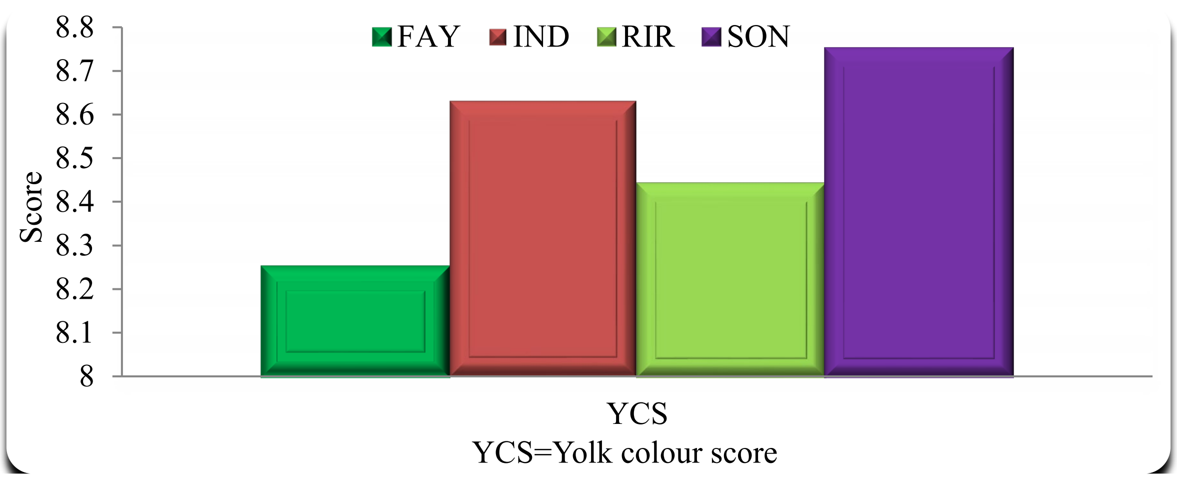


Fig. 7x: Breed-wise yolk colour score of the experimental chicken egg

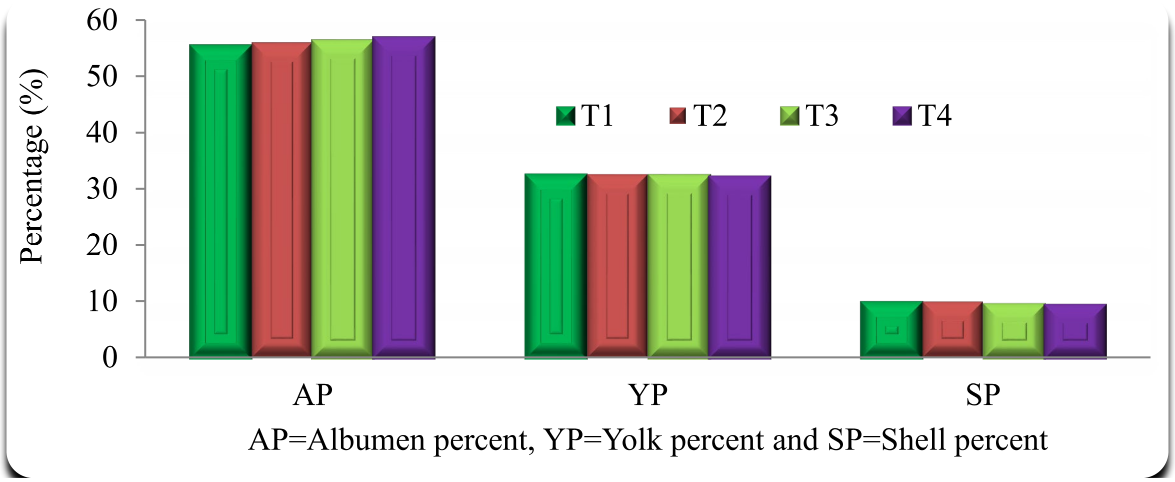


Fig. 7y: Treatment-wise egg component percentage of the experimental birds

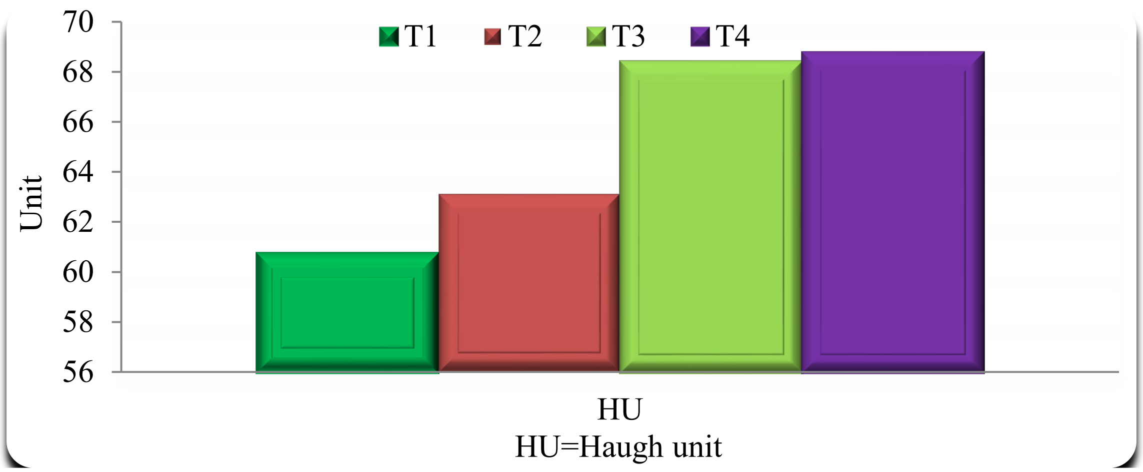


Fig. 7z: Treatment-wise Haugh unit of the experimental chicken egg

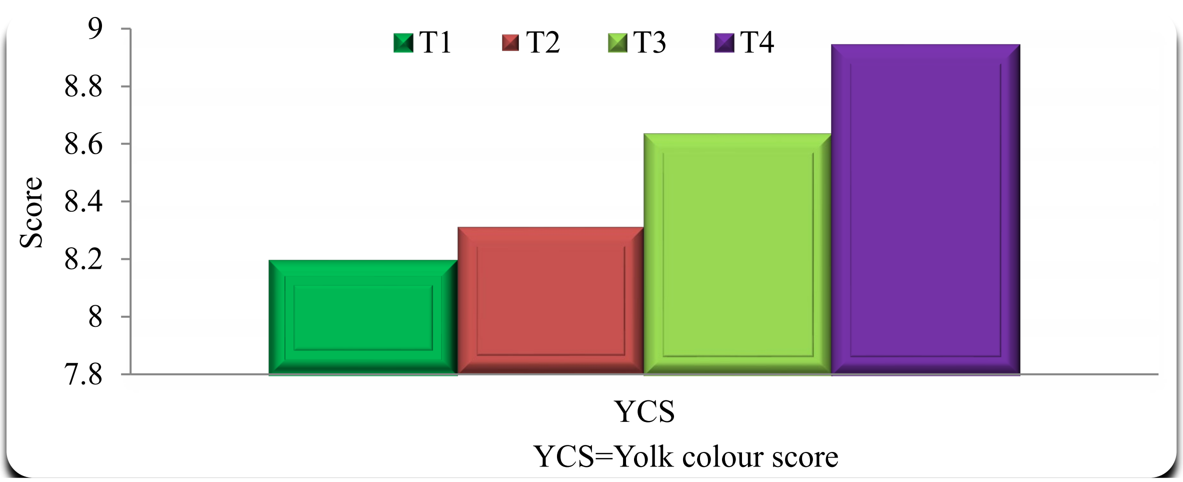


Fig. 7z1: Treatment-wise yolk colour score of the experimental chicken egg

7.4 Discussion

7.4.1 Meat yield studies

Growth performance: The commercial source of vitamin A is an ester of retinol which is susceptible to light, oxygen, heat, moisture and pressure during processing, and in tropical climate zones like Bangladesh with high temperature and relative humidity, the storage stability of premix poultry feed containing vitamins may be limited (Barua and Olsen, 2000). The optimum levels of supplementary vitamin A are important for maintaining improved immune response of the poultry and have been shown to increase growth, egg production, feed efficiency and overall health by improving disease resistance (McDowell, 2004). These facts are reflected in the present study as explained below. Similar to our results, Sahin *et al*. (2001) demonstrated that supplementation of vitamin A and E increased LWG in broiler chickens. But in contrast to Sahin *et al*. (2001), however, the present FI and FCR values gradually decreased in the treated groups. In agreement with the present findings, Bhuiyan *et al*. (2004) found FI and FCR significantly poorer in the control in comparison with the VitA-treated *Sonali* chickens. Recently, Safarizedah and Zakeri (2013) reported that VitA, VitE and selenium supplement had no effect on growth factor in Ross 308 broiler chicken, but the supplement improved immune system of the birds by exhibiting significant protection against Newcastle disease.

Previous reports on essential amino acid supplement in poultry diets showed variable results. Ciftci and Ceylan (2004) demonstrated that increasing threonine supplementation improved FI, BWG and FCR while Sarkar *et al*. (2008) reported the best FCR in broilers, followed by cockerels and *Sonali* chickens. Dietary methionine higher than NRC recommended levels showed significant increase in breast weight but significant decrease in abdominal fat (Ahmed and Abbas, 2011). Lilly *et al*. (2011) reported decreased FCR but improved carcass yield of broiler chickens as the density of dietary amino acids increased. Nasr and Kheiri (2011) found that higher amino acid density throughout life optimized live weight and growth, whereas reductions in amino acid density reduced growth and live weight in broilers. By fortifying low levels of crystalline amino acids such as lysine, methionine and threonine to growing phase broilers, growth performance and carcass characteristics of the birds were improved (Abudabos and Aljumaah (2012) while Ekmay *et al*. (2013) determined the effects of methionine, phenylalanine, arginine, isoleucine and lysine on broiler breeders at peak production, suggesting that adequate dietary amino acids should be provided for maximum hatching egg production but an excess may affect fertility. Recently, the optimal valine to digestible lysine ratio for Cobb 500 broilers was estimated, where the treatments had no significant effect on FI or carcass parameters but had a quadratic effect on LWG and FCR values (Tavernari *et al*., 2013). These variations in growth performance of the experimental chickens could be due to genetic or some extrinsic factors. The present SB data, on the other hand, appear to be consistent with the reports that survivability of poultry chicks is influenced by the absence of VitA (Uni *et al*., 2000), rearing conditions (Demeke, 2003) or genotype of the flock (Sarkar *et al*., 2008; Uchida *et al*., 2012). The present findings on the growth performance and survivability are therefore very convincing in that administration of VitA and EAAs might have resulted in a good management practice to enhance growth parameters but to reduce mortality in the experimental chickens.

Meat characteristic: Optimal return in poultry production requires a better understanding of interactions between nutrition at different ages and environmental factors. Corzo *et al*. (2005a, b) reported higher body weight and lower feed conversion in male than females, as well as higher breast meat yield values. Feeding broilers with high nutrient density diets reduced cumulative conversion and abdominal fat, but did not affect uniformity or other carcass parameters. The findings are in well agreement with the present report where the males attained the highest breast meat yield values than the female one. Quentin *et al*. (2005) observed that the first week of a broiler's life is of primary importance to determine their future growth and performances. High metabolic energy and lysine concentrations in the starter diet stimulate long-term enhancement of growth performances and carcass composition of broilers but might reduce their resistance to subsequent aggressions. Dozier *et al*. (2006) found that increasing dietary amino acid density from 36 to 59 d improved cumulative feed conversion, but did not alter final growth rate, feed consumption, and the incidence of mortality. These findings, on the other hand, appear to be inconsistent with the present reports. However, the variations in meat yield performance of the experimental chickens could be due to genetic or some extrinsic factors.

In general, increasing dietary apparent metabolizable energy decreased feed consumption and improved feed conversion but did not increase breast meat yield. Dozier *et al*. (2007a) found that feeding broilers the diet formulated to 3,140 kcal of AME/kg increased breast meat yield compared with birds provided diets containing 3,240 kcal of AME/kg. The improved breast meat yield was probably due to increased feed intake associated with the low apparent metabolizable energy diet that translated to an additional 1.3, 1.1, and 0.9 g of lysine and threonine intake. Corzo *et al*. (2010) found that based on results for live performance, breast meat yield, and abdominal fat content the Cobb × Cobb 500 broiler benefited greatly from being fed high amino acid density diets, particularly during the latter feeding phases of life. The protein and fat composition of breast meat was unaffected by the different amino acid density regimens fed. However, there was a marginal response, which we interpret to mean that feeding higher amino acid density diets may affect thigh meat composition by increasing the protein concentration at the expense of fat content. Nasr and Kheiri, (2011) found that amino acids density have a significant effect on body weight. The findings suggest that high amino acids density throughout life optimized live weight and growth, whereas reductions in amino acids density reduced growth and live weight.

Moreover, it has been found that broiler meat yield improves with the increasing of amino acid density. Breast meat derived from broilers fed diets with a low and high amino acid density were liked by a greater percentage of consumers than breast meat from diets that were deficient or excessive in amino acid density. Diets with a high or excessive amino acid density improved breast meat yield and feed conversion efficiency. Feeding the diet with a high amino acid density during the finishing phase produced birds with excellent meat quality and carcass traits while supporting optimal broiler growth and carcass traits (Lilly *et al*., 2011). Feeding increased amino acid density diet has been found significant positive effect on the yield of breast meat, wing meat, drumstick meat and thigh meat (Zhai *et al*., 2013). Moderately reliable with the above findings, the present results thus evidently signify that administration of VitA and EAAs in diet was positively correlated with various meat characteristics in the experimental chickens.

Carcass characteristics: In an earlier experiment, Onifade *et al*. (1997) used high fibre diet (palm kernel meal) supplemented with antibiotics or dried yeast and observed heavier BW, greater FI and better FCR, coupled with greater liver, spleen and gizzard weights. Inorganic chromium enhanced the growth performance (LWG and FI) and ascorbic acid was found beneficial for the carcass characteristics in broiler chickens (Ahmed *et al*., 2005). Rosa *et al*.

(2007) demonstrated that genotype of the broiler chickens, environmental temperature and FI restrictions influenced carcass characteristics and abdominal fat deposition where selected broilers showed better FCR, higher carcass characteristics and lower abdominal fat deposition, but heat exposed birds showed reduced FI and breast yield. Feed supplement of charcoal from maize cob or seed improved growth performance and some carcass characteristics in broiler chickens (Kana *et al*., 2011), in which FCR and final body weight increased but FI, DY, liver weight and abdominal fat were not affected whereas gizzard weight was reduced significantly.

Landy *et al*. (2011) used dietary Neem (*Azadirachta indica*) as an antibiotic growth promoter, which increased final body weight, enhanced FCR but FI, internal organ weight and carcass features were not influenced. The cost of dietary proteins was reduced, FCR was enhanced and the eviscerated weight was increased by both poultry offal meal and crayfish waste meal as feed supplement in Marshall Broiler chickens (Asafa *et al*., 2012). Kayode *et al*. (2012) noted that fermented mango kernel cake enhanced FI, LWG and FCR at the end of the starter phase, but no significant difference was observed in carcass characteristics where most of the parameters decreased progressively with increasing dietary supplement. Recently, Igbasan and Adebayo (2012) used feed supplement with lanthanum salts ($LaCl_3$, La_2O_3) in broiler chickens that significantly increased daily FI, although they did not have effects on final live weight, daily weight gain and FCR. In another experiment, poultry fat and corn oil lowered carcass and breast weight but increased abdominal fat; no significant difference was noticed in live performance during the starter phase (0-18 d), LW and BWG increased but FCR decreased during the grower phase (19-36 d), whereas no significant difference was recorded during the finisher phase (36-48 d) in Ross broiler chickens (Kim *et al*., 2013). Quite consistent with the above findings, the present results thus clearly indicate that administration of VitA and EAAs in poultry diet was positively correlated with various carcass characteristics in the experimental chickens.

7.4.2 Egg yield studies

Growth performance: The ideal amino acid concept is increasing by being applied to laying hens. In the earlier experiment Halima *et al*. (2006) reported growth performance of indigenous chicken from day-old to 20 wks of age. They found that day old weight, final body weight, body weight gain and mortality rate in indigenous chicken were 35.2 g, 1394 g, 1359 g and 18.3%, respectively. The poor growth rate in indigenous chickens, as observed in the present study, could be attributed to low feed intake and genetic composition of the birds. Yasmeen *et al*. (2008) studied the production performance of pullets and spent layers fed a commercial layer ration *i.e*., Metabolizeable energy (Kcal/Kg) 2802, Vitamin A (IU/Kg) 3000, Lysine (0.76%) and methionine (0.37%) at 110g/bird/day. Findings revealed that feed consumption remained unaffected due to the age. The findings are disagreement with the present report where the feed consumption of the four genotypes varied according to their age *i.e*., pullets at 20 weeks and spent at 48 weeks of age. This might be due to the supplementation of higher level of Vitamin A (12500 IU/Kg) and the additional essential amino acids like arginine, isoleucine, threonine, tryptophan and valine, which gradually increased the feed intake of the experimental birds.

Impact of treatment diet on growth performance of the experimental chicken exposed that the feed intake was gradually decreased from T4 group to T1 group chicken. The findings are in well agreement with Applegate *et al*. (2009) who found that, with the supplementation of adequate essential amino acids the feed intake of the Hyline laying hens gradually decreased. Rao *et al*. (2011) found that the final body weight increased linearly with increasing dietary lysine concentrations. While Fouad *et al*. (2012) reported that dietary L-Arg supplementation reduces ascites mortality under low ambient temperatures, attenuates the adverse effects of heat stress and high stock density, activates the immune system and enhances its responses to different common diseases in poultry farms.

Khawaja *et al*. (2012) studied the growth performance of Fayoumi, RIR and their reciprocal crosses up to 20 weeks of age. The results revealed that the average day old weight was highest in RIR, intermediate in cross-bred and lowest in Fayoumi chickens. The RIR breed consumed more feed and gained maximum ($P<0.05$) weight gain than those of Fayoumi and cross-bred chickens at all ages of growing phase. The crossbred chickens had lowest mortality ($P<0.05$)

than purebred chickens. The RIR breed consumed more feed and gained maximum weight ($P<0.05$) than those of Fayoumi and crossbred chickens at all ages of growing phase. The lowest body weight gain was recorded in Fayoumi than the RIR chickens during growing phase. These findings could be explained by the variation in chicken genotypes.

Egg production performance: Egg production is still the primary trait for the genetic-economic improvement of laying hens. Egg production is a complex metric trait showing many variations during the period of production of the pullet. Success of the poultry industry at small or large scale depends on a regular supply of day-old chicks. The production of day-old chicks is influenced by the fertility and hatchability of the eggs. Fertility and hatchability are traits that influenced by both genetic and environmental factors. Successful production of day-old chicks starts with the proper selection and management of breeding stock, proper post-lay handling of fertile eggs and the correct incubation process.

Khan *et al*. (2006) investigated that under intensive management system the age and weight at sexual maturity of Fayoumi chicken was 163.63±1.17 days and 1253.11±16.42 g, respectively. While, the yearly egg production per hen was 140.72 and the average egg weight was 45.79 g. The findings the little contradicts with the present findings this might be due to administration of supplementary diets during the rearing period. Akhtar *et al*. (2007) reported that the RIR birds exhibited better production potential. The findings noted maximum egg production and egg weight were noted in the RIR birds. RIR birds also used their feed more efficiently, both on per dozen eggs and per kg egg mass produced basis, than Fayoumi breeds. These findings are quite agreed with the present findings where the RIR breeds showed the egg mass production, feed intake and feed efficiency. Bregendahl *et al*. (2008) studied the ideal ratios of isoleucine, methionine, methionine plus cystine, threonine, tryptophan and valine relative to lysine for white leghorn-type laying hens. The findings suggested that true digestible amino acid requirements used to calculate the ideal amino acid ratio for maximum egg mass were 426 mg/d of Ile, 538 mg/d of Lys, 253 mg/d of Met, 506 mg/d of Met+Cys, 414 mg/d of Thr, 120 mg/d of Trp, and 501 mg/d of Val. Results of the research include significant variations in egg weight, egg production and egg mass and feed utilization of leghorn layer with the varying level of supplementary amino acids.

Applegate *et al*. (2009) studied the effect of amino acid formulation and dietary direct-fed microbial supplementation on egg production and egg characteristics in laying hens. The findings suggested maximum eggs laid and egg mass with the supplementation of at least 14.4 g of CP, 804 mg of Lys, 382 mg of Met, 601 mg of TSAA, 502 mg of Thr, and 609 mg of Ile consumed per hen per day. The effects of amino acids on egg number and egg mass of brown and white laying hens has been studied by Bonekamp *et al*. (2010). Findings suggested that for the light hens, an intake of 600 mg of true fecal digestible Lysine per hen per day was sufficient to maximize laying percentage. Egg weight, daily egg mass production and feed conversion ratio improved up to the highest tested true fecal digestible balanced protein intake with 800 mg of Lys per hen per day for both strains, suggesting that the optimal balanced protein intake was higher. Panda *et al*. (2010) evaluate the effect of supplemental lysine to low protein diet on egg production, egg quality and humoral immune response of White Leghorn layers. Increasing dietary concentration of lysine to 0.75% significantly ($P<0.05$) improved egg production and egg weight, humoral immune response and feed efficiency.

However, the broody hen provides the fertile eggs with optimum environmental conditions *i.e*., temperature, egg turning and humidity to stimulate embryonic development until hatching. While, the incubator is a simulated artificial design that mimics the broody hen’s role of providing fertile eggs with optimum environmental conditions to stimulate embryonic development until hatching (Kingori, 2011). Rao *et al*. (2011) conducted experiments using White Leghorn layers (Babcock) from 21 to 72 wk of age to evaluate the effect of dietary ME (2,350 and 2,600 kcal/kg) on layer performance. A higher ($P< 0.05$) rate of egg production and higher feed efficiency and egg mass were observed in groups fed 2,600 kcal of metabolic energy compared with those fed 2,350 kcal of ME/kg. Feed efficiency improved with increasing concentrations of methionine. Egg weight and egg mass increased with dietary methionine concentrations. Perez-Bonilla *et al*. (2012) reported that feed and energy efficiency were better for the lighter hens. Feed intake (114.6 *vs*. 111.1 g/hen per day), AME intake (321 *vs*. 311 kcal/hen per day), egg weight (64.2 *vs*. 63.0 g), and egg mass (58.5 *vs*. 57.0 g) were higher for the heavier than for the lighter hens ($P<0.01$). Fouad *et al*. (2012) found L-Arginine (L-Arg) supplementation in poultry diets improves egg production, egg weight, modulates lipid metabolism toward reducing total body fat accumulation to improve meat quality and increases antioxidant defense under normal conditions. Also under stress conditions L-Arg has the ability to alleviate this stress and to normalize the growth performance. Ji *et al*. (2014) conducted an experiment with a total of 540 21-week-old Hy-Line W36 hens with five dietary treatments varying in CP content (18.0, 17.5, 17.0, 16.5, and 16.0%) were formulated at a fixed dietary energy concentration of 2,825 kcal of ME/kg of feed. The crystalline amino acids, including Met, Thr, Ile, Val, Trp, and Lys, were supplemented according to an assumed ideal AA profile, and all diets contained 0.831% ideal digestible Lys. Egg production, daily egg mass, feed intake, and FCR were not affected in the low-protein groups.

Egg quality performance: Breeder factors that affect hatchability include strain, health, nutrition and age of the flock, egg size, weight and quality, egg storage duration and conditions. However, vitamin A is an effective antioxidant as it can slow down the process of lipid per oxidation by breaking the chain reactions involved in this process and hence can check the process of membrane deterioration induced by the heat-stress. Supplementation of vitamin A higher than NRC (1994) recommendations is reported to play an important role in restoration of membrane integrity and, hence, normal functioning of reproductive organs in heat-stressed laying hens. Akhtar *et al*. (2007) found that the Haugh unit values were non-significantly different amongst all the breeds. This findings are quite disagreed with the present findings where the Haugh unit of the four genotypes of layer eggs showed highly significant difference ($P<0.001$). Gomez and Angeles (2009) found that egg shell percentage decreased significantly by increasing dietary threonine and methionine levels during the second cycle of production. The findings are in well agreement with the present results where the egg shell percentages are gradually decreased with the increase of dietary supplementation of EAAs.

Panda *et al*. (2010) studied the egg quality measure such as Haugh unit score and albumen content increased, while the yolk content decreased significantly ($P<0.05$) as the dietary lysine increased from 0.6 to 0.75%. Considering 100g feed consumption per day, it is concluded that the diet with 14.8% and 0.77% lysine was adequate to realize optimum performance with good albumen quality and better immune response in layers during 28–44 wk of age. Perez-Bonilla *et al*. (2012) studied the effects of energy concentration of the diet on egg quality of brown egg-laying hens differing in initial body weight. Increased energy content of the diets from 2,650 to

2,950 kcal of metabolic energy affected performance and egg quality of the hen. An increase in energy content of the diet reduced the proportion of shell in the egg ($P<0.01$). Eggs from the heavier hens had a higher proportion of yolk and lower proportion of albumen ($P<0.01$) and shell ($P<0.05$) than eggs from the lighter hens. It is concluded that brown egg-laying hens respond with increases in egg production and egg mass to increases in AME concentration of the diet up to 2,850 kcal per kg. Heavy hens had higher feed intake and produced heavier eggs and more egg mass than light hens. Hens fed the lower energy diet (2,650 kcal of AME/kg) had an energy intake below requirements for optimal productive performance, resulting in lower egg mass production. Burley *et al*. (2013) found that reducing crude protein below normal commercial levels, with adequate amino acid supplementation, did not negatively affect large-scale hen egg production or quality.

Ahmad *et al*. (2013) showed that the egg weight, egg mass, yolk weight, Haugh unit score, shell thickness and shell weight were not influenced by increasing the supplemental level of Vit-A. Moreover, Khawaja *et al*. (2013) reported the internal egg quality parameters included yolk weight, albumen weight and albumen height was equal in all pure and crossbred chickens. The Haugh unit score is an indicator of egg freshness and is related to shelf life. The higher Haugh unit number is the better quality of the eggs with thicker whites. Evaluation of threonine supplementation has been found significant effect on the increase of Haugh unit value as the internal egg quality parameters (Abdel-Wareth and Esmail, 2014).

The findings attributed these trends to segregation and accumulation of small particle size nutrients *i.e*., vitamins, minerals and amino acid which are important for maintaining egg quality such as albumen height, Haugh unit, yolk colour score and shell thickness.

CHAPTER EIGHT

GENERAL DISCUSSION

A detailed account of productivity of the Government (GOV), private (PRI) and backyard chicken farms (BCF) that use to rear broiler, cockerel, Fayoumi, RIR, *Sonali* and indigenous chickens from the urban, semi-urban and rural areas of Rajshahi district, Bangladesh (Chapter Four), management practices of the chicken farms (Chapter Five), disease incidences of the chicken breeds (Chapter Six) and the feed supplement experimentation to study the meat and egg yield efficiencies of the experimental chicken breeds (Chapter Seven) have been presented. The impacts of the study on perspective of the chicken breeds and poultry farming at the study area are discussed in the following sections:

8.1 Productivity studies on the chicken breeds

The productivity study demonstrated that *Sonali* breed was the highest in production number both in the GOV and PRI farms. The exotic Fayoumi and RIR and the crossbred *Sonali* was the admired breeds in both the GOV and PRI farms. The production number of chicken breeds among the farms showed highly significant difference ($P<0.001$) for all the breeds except for broiler and cockerel ($P<0.01$). Moreover, the *Sonali* attained the highest number in productivity in both of the FY2011-12 and 2012-13, respectively; while, broiler attained the highest in the FY2013-14. The broiler and *Sonali* was the fashionable breeds in the FY2013-14 followed by RIR, Fayoumi, cockerel and indigenous breeds, respectively. The production numbers among the FY showed insignificant difference for all the breeds ($P>0.05$). The profitability analysis of the farms revealed that the NP was found negative for the GOV, while positive for the PRI and BCF which means that the GOV bear losses for the intact production. The production parameters among the farms established highly significant difference ($P<0.001$) for all the cases. In contrast, the BCF attained the highest CBR 2.983, followed by PRI and GOV with CBR 1.145 and 0.979, respectively. Equally, the PI exposed that the BCF attained maximum profit than PRI with PI 0.646 while the PRI showed PI 0.114. In contrast, the GOV showed negative PI (-0.021) which indicated economic losses. However, the NP was found the highest in 2011-12 with BDT 224840.23 and lowest in 2012-13 with BDT 152025.45, followed by BDT 199702.46 in 2013-14, which indicated that the FY2011-12 was the profitable year for the poultry production at the study area. The production parameters among the FY established insignificant difference

(P>0.05) for all the cases. Moreover, the highest CBR (2.179) was attained in the FY2012-13, followed by FY 2011-12 and 2013-14 with 2.156 and 1.702, respectively. The PI (0.393) showed that the FY2011-12 achieved maximum profit than FY2012-13 and 2013-14 with PI 0.367 and 0.321, respectively. The findings revealed that the production profit was gradually decreased from the FY 2011-12 to FY 2013-14 throughout the entire production period which indicated economic instability.

However, findings from the economic potentials of free-range indigenous fowl reared by rural women revealed that the average annual farm income from sale of eggs and birds were Rs. 7452, 15120 and 35625 for small, medium and large units, respectively (Singh *et al*., 2009). The backyard chicken rearing was found profitable for the farmers (Sumy *et al*., 2010). Bano *et al*. (2011) investigated that broiler production was profitable with a profitability index of 0.24. The verified six variables that exerted statistically significant influence on broiler production including experience in broiler production, farming status, access to credit, labour, number of day-old chicks and quantity of feeds (Ike and Ugwumba, 2011). Dutta *et al*. (2012a) evaluated the performance of meat purpose Cobb 500, ISA White, Fayoumi and *Sonali* chickens in terms of CBR for meat producers showed that cockerels from ISA White (1.58) was the best and the broiler of Cobb 500 (1.15) the worst. CBR for egg productivity, conversely, was highest in *Sonali* (1.11) followed by RIR and Fayoumi (1.10 each) and Cobb 500 (1.09).

Recent reports on family poultry profitability index (PI) in Nigeria ranged between 0.29 and 0.84 (mean 0.63) and return on investment 0.76, meaning that family poultry was highly profitable (Aboki *et al*., 2013). The determinants of profitability value such as feed cost, market price, stock size, number of birds sold and number of birds consumed significantly affected profitability of indigenous, Cobb and Douglas chickens (Siyaya, 2013). Also farm size, training, education, farming experience and extension contact are the significant factors affecting profitability of small-scale broiler farms (Kawsar *et al*., 2013). The gross and net returns per household per day from native poultry rearing were estimated at Tk. 34.04 and Tk. 27.93, respectively where the undiscounted benefit cost ratio was 5.57, implying that this enterprise is highly profitable (Uddin *et al*., 2013). However, Uddin *et al*. (2014) estimated that with *Sonali* chicken production the total costs for 1000 birds were estimated at Tk. 120613 per batch.

Average gross margin and average net returns was calculated at Tk. 57240 and Tk. 52059, respectively per batch. An average gross return was estimated at Tk. 172672 per batch with 1.4 BCR. However, the present results on the productivity components of the chicken rearing are similar to the above findings. Therefore, the findings emphasize the use of adequate supplementation in poultry rearing towards the enhancement of productivity to the producers, marketers and policy makers for sustainable poultry farming in the country.

8.2 Management studies on the chicken breeds

Management studies of the chicken breeds showed that the GOV farm achieved the highest score (4=good) for BW, HR and FM while rest of the parameters acquired 3 and above scores (satisfactory to good) for RT, WS, VC, BM and CT. However, the PRI farms attained the highest score (3.42=satisfactory to good) for FM while rest of the parameters attained below satisfactory margin. The BCF also adopted a lower level to satisfactory MP for all the parameters. The study showed that the adopted MP for GOV was better than those of the PRI and BCF. Besides, both the PRI and BCF had similar MP at the study area. However, the management parameters showed highly significant difference for VC, BW, HR, CT and FM ($P<0.001$) except for RT, BM ($P<0.01$) and WS ($P<0.05$). The fiscal year FY 2011-12 achieved marginal score (satisfactory to not good) for all the parameters under study. The FY 2012-13 acquired score 3 and above (satisfactory to good) for FM while rest of the parameters attained marginal satisfactory scores on MP. Similarly, in the FY 2013-14 all the parameters acquired marginal satisfactory scores on MP (satisfactory to not good) at the study area. Moreover, the analysis of variance among the management parameters showed insignificant difference for WS, BW, HR, CT and FM ($P>0.05$) except for BM, VC ($P<0.05$) and RT ($P<0.01$) during the study period.

Backyard poultry raisers and small entrepreneurs will feel burden of bio-security, though it is helpful and cost saving mechanism for entrepreneurs in long run (Sharma, 2010). Due to management practices the poultry industry still faces serious constraints, such as bad housing, inadequate vaccination and high mortality possibly due to multiple antibiotics resistance resulting from multiple antibiotics usage (Akidarju *et al.*, 2010). Every single one farmers adopted deep litter system of rearing the birds using sawdust as bedding material. Quarter to cent percent of the farmers were adopting all in all out system of rearing whereas rest of the farmers were maintaining two batches at a time. Over fifty percent of the farmers used ten different commercial brands of feed, available in the form of mash (Shanaz *et al*., 2010). However, most of the litter produced by the poultry industry is currently applied to agricultural land as a source of nutrients and soil amendment. However, environmental pollution, resulting from nutrient and contaminant leaching can occur when poultry litter is applied under soil and climatic conditions that do not favour agronomic utilization of the manure-borne nutrients. Poultry litter provides a major source of nitrogen, phosphorus and trace elements for crop production and is effective in improving physical and biological fertility, indicating that land application remains as the main option for the utilization of this valuable resource (Bolan *et al*., 2010).

Dutta *et al*. (2012b) reported that only a small proportion of poultry farms maintained satisfactory management practices which must be monitored regularly to increase productivity. The family poultry producers were inefficient at their level of production and that their income and output can be improved if more of feeds, capital, vaccine and medicine are used and more innovation that are related to improved management are adopted (Aboki *et al*., 2013). In contrast, Bhuyian *et al*. (2013) analyzed that farmers' exposure to communication media for poultry production, majority of the farmers (54%) had low exposure to communication media, while 46% had medium exposure and none of them had high exposure. Nigatu and Bezabih (2014) reported that traditional management (83%), limitation of improved breed availability and lack of extension and chicken health services (86.7%) were the major constraints to chicken production. Therefore, holistic extension services such as applying breed and management improvement methods are highly recommended for further improvement of chicken production under farmers' management condition at the study area.

8.3 Studies on disease incidences in chicken breeds

Disease incidence (DI) studies on the chicken breeds revealed that the GOV achieved the highest score 4.33 (severe to elevated) for SDP followed by 3.44, 3.33 and 3.11 (gross to severe) for BD, FDC and VD respectively. However, the FD attained lowest scores 1.44 (absent to mild) at the GOV during the entire study period. Conversely, the PRI attained the highest score 2.74 (mild to gross) for BD followed by 2.67, 2.49 and 2.46 for VD, SDP and FDC, respectively. In the same way, the FD attained lowest scores 1.10 (absent to mild) at the PRI during the study period.

Apart from this, the BCF also reached a lower level for DI 1.06 (absent to mild). The DI expressed that disease susceptibility for GOV are superior comparable to those of the PRI and BCF for the case of BD and VD with FDC and SDP. The farm based analysis of variance among the DI parameters shows highly significant difference for BD and SDP ($P<0.001$) followed by VD, FD and FDC ($P<0.01$). Moreover, the findings also exposed that the FY 2011-12 attained marginal score (mild to gross) for all the DI parameters under study except for FD that shows scores on absent too mild. Like-wise the FY 2012-13 acquired score 2 and above (mild to gross) for all disease parameters except for FD that are evidenced for absent to mild during the study period. Correspondingly, in the FY 2013-14 all the parameters on DI acquired marginal satisfactory scores (mild to gross). Analysis of the scoring points measured from the prevailed diseases revealed similar results for all the cases. Over and above in cooperation of the three succeeding fiscal years FY 2011-12, FY 2012-13 and FY 2013-14 the DI was almost analogous. Conversely, the year based analysis among the DI parameters shows insignificant difference for VD and FD ($P>0.05$) except BD, FDC ($P<0.05$) and SDP ($P<0.01$).

Newcastle disease (ND) was the most common infectious disease affecting village chickens in most of the developing countries. The usual source of infection for village chickens is usually other chickens (Feizi and Nazeri, 2011). The outbreaks and prevalence of ND in village chickens is thought to worsen during cold and harsh stress (Okwor and Eze, 2011). In backyard chicken *Salmonella* and mycoplasma infection were found at high levels during the summer and winter season (Xavier *et al*., 2011). The severity of coccidia infection has been reported to be highest at age group of 4–6 weeks, but number of cases was more between 6 to 8 weeks based on both litter oocyst density and oocysts per gram of faeces (Anuradha *et al*., 2011). Healthy carriers can serve as short term reservoirs and transmit the disease to other birds (Chukwudi *et al.,* 2012). Vaccinating the flock using live vaccines is mainly the control measure. When the live virus vaccines persisting in the poultry house environment seem to be gaining virulence and the efficacy of vaccine to be assessed reflects the immune status of the vaccinated birds (Roy, 2012).

Seasonal influence of infectious bursal disease (IBD) with the symptoms like dullness, depression, anorexia, ruffled feathers, inability to move and yellowish white diarrhoea were pragmatic in affected flocks that showed significantly ($P<0.05$) higher prevalence (13.5%) with

7.7% mortality during winter season (Rashid *et al*., 2013). Climate change has evoked several changes in birds, including changes in avian phenology, poleward shifts in avian distributions, modification of migratory distances, direction and activity, and alterations to movement patterns and destinations will subsequently affect the spread of poultry diseases (Patterson and Guerin, 2013). In village chickens ND, fowl pox, coccidiosis and IBD is frequent and the time of the year these diseases are prevalent between September and December with highest in mortality rate through ND (Adebayo *et al*., 2013). The presence of antibodies for more than one disease agent in the same chicken indicates that several pathogens are circulating within the same premises (Sharma *et al*., 2014). Supplementation of contaminated fish meal in poultry feed could be the source of *Salmonella* infection in commercial layer flocks. It was noticed that prevalence of ND in broiler and layer flocks was highest during summer season. The flocks maintained poor management conditions such as poor ventilation, overcrowding, unvaccinated flock had high susceptibility to these diseases. These findings are in well agreement with the present studies. Consequently, the findings suggested that awareness campaign should be conducted towards small-scale producers so that they can increase their productivity and alerting them concerning the causes of various diseases and the existing remedies.

8.4 Meat yield studies on the chicken breeds

Growth performance: The impacts of breed, sex and treatment diets on the growth performance of the experimental chickens *viz*., Fayoumi and *Sonali* were observed and analyzed. The findings showed that Fayoumi was the highest for FI and LWG while, *Sonali* was the highest for FCR. Significant difference were observed for FI ($P<0.001$) and LWG ($P<0.05$). The FCR and SB was found insignificant ($P>0.05$). Conversely, the impact of sex revealed that male chickens showed the highest FI and LWG but the lowest for FCR than the female ones. Highly significant difference were observed for FI and LWG ($P<0.001$) followed by FCR ($P<0.01$) except SB ($P>0.05$). Additionally, the impact of treatment diets showed that the highest FI was found in the T1 group followed by T2, T4 and T3 groups, respectively. Conversely, the T1 group showed lowest LWG followed by T2, T3 and T4 group in that order. On the contrary, the FCR was found the highest in T1 followed by T2, T3 and T4 in that order. In contrast, the T4 group showed the highest SB followed by T3, T2 and T1 groups, respectively. The LWG, FCR and SB showed highly significant difference ($P<0.001$) except FI ($P>0.05$).

Studies by McDowell (2004) demonstrated that the optimum levels of supplementary VitA are important for maintaining improved immune response of the poultry and have been shown to increase growth, egg production, feed efficiency and overall health by improving disease resistance. These facts are reflected in the present study as explained. In agreement with the present findings, Bhuiyan *et al*. (2004) found FI and FCR significantly poorer in the control in comparison with the VitA-treated *Sonali* chickens. Lilly *et al*. (2011) reported decreased FCR but improved carcass yield of broiler chickens as the density of dietary amino acids increased. Nasr and Kheiri (2011) found that higher amino acid density optimized live weight and growth, whereas reductions reduced growth and live weight in broilers. The present SB data, on the other hand, appear to be consistent with the reports that survivability of poultry chicks is influenced by the absence of VitA (Uni *et al*., 2000), rearing conditions (Demeke, 2003) or genotype of the flock (Sarkar *et al*., 2008; Uchida *et al*., 2012). The present findings are therefore very convincing in that administration of VitA and EAAs might have resulted in a good management practice to enhance growth parameters and survivability of the experimental chickens at the study area.

Meat features: The impact of breed on the meat features exposed significant difference for WM and THM ($P<0.001$), DKM and DM ($P<0.01$) and LW ($P<0.05$). In contrast, the DY, TM and BM was found insignificant ($P>0.05$). The meat features showed highly significant difference among all the parameters ($P<0.001$) except BM ($P>0.05$) between genotypes. Furthermore, the impacts of treatment diets on meat features exposed significant difference for LW, TM and BM ($P<0.001$), DKM ($P<0.01$) and WM ($P<0.05$) but DY, DM and THM was insignificant ($P>0.05$). In most cases, increasing dietary apparent metabolizable energy decreased feed consumption and improved feed conversion. Dozier *et al*. (2007a) found that feeding broilers the diet formulated to 3,140 kcal of AME/kg increased breast meat yield compared with birds provided diets containing 3,240 kcal of AME/kg. The improved breast meat yield was probably due to increased feed intake associated with the low apparent metabolizable energy diet that translated to an additional 1.3, 1.1, and 0.9 g of lysine and threonine intake. Nasr and Kheiri, (2011) found that amino acids density have a significant effect on body weight. The findings suggest that high amino acids density throughout life optimized live weight and growth, whereas reductions in amino acids density reduced growth and live weight.

Moreover, it has been found that broiler meat yield improves with the increasing of amino acid density. Breast meat derived from broilers fed diets with a low and high amino acid density were liked by a greater percentage of consumers than breast meat from diets that were deficient or excessive in amino acid density. Diets with a high or excessive amino acid density improved breast meat yield and feed conversion efficiency. Feeding the diet with a high amino acid density during the finishing phase produced birds with excellent meat quality and carcass traits while supporting optimal broiler growth and carcass traits (Lilly *et al*., 2011). Feeding increased amino acid density diet has been found significant positive effect on the yield of breast meat, wing meat, drumstick meat and thigh meat (Zhai *et al*., 2013). From the above findings, the present results thus evidently signify that administration of VitA and EAAs in diet was positively correlated with various meat characteristics in the experimental chickens.

Carcass features: The impacts of breeds on the carcass features exposed significant difference for AFW and GW ($P<0.001$), NW, HW ($P<0.01$) and LW ($P<0.05$). Insignificant difference exists for SW between two varieties of chicken breeds ($P>0.05$). Additionally, significant difference exists between genotypes among all the parameters of carcass features *i.e*., LW, SW, NW, HW ($P<0.001$) and GW ($P<0.01$) except AFW ($P<0.05$). Furthermore, the impacts of treatment diets on carcass features exposed significant difference for LW and GW ($P<0.001$), SW and AFW ($P<0.01$) except NW and HW ($P>0.05$) among the treatment groups of chicken. High fibre diet supplemented with antibiotics or dried yeast and observed heavier BW, greater FI and better FCR, coupled with greater liver, spleen and gizzard weights (Onifade *et al*., 1997). Rosa *et al*. (2007) demonstrated that genotype of the broiler chickens, environmental temperature and FI restrictions influenced carcass characteristics and abdominal fat deposition where selected broilers showed better FCR, higher carcass characteristics and lower abdominal fat deposition, but heat exposed birds showed reduced FI and breast yield. Feed supplement of charcoal from maize cob or seed improved growth performance and some carcass characteristics in broiler chickens (Kana *et al*., 2011). Experiment showed that, poultry fat and corn oil lowered carcass and breast weight but increased abdominal fat (Kim *et al*., 2013). Relatively consistent with the above findings, the present results thus clearly indicate that administration of VitA and EAAs in poultry diet was positively correlated with various carcass characteristics in the experimental chickens.

8.5 Egg yield studies on the chicken breeds

Growth performance of the layers: The impacts of breed and treatment diets on the growth performance of the Fayoumi, indigenous, RIR and *Sonali* are observed and analyzed. The FCR was found the highest for indigenous followed by Fayoumi, *Sonali* and RIR. The highest SB was found for *Sonali* and the lowest for indigenous followed by Fayoumi and RIR. In addition, the growth performance were highly significant ($P<0.001$) for DW, LW, LWG, FI, FCR and FLW except for SB ($P<0.05$). Conversely, FCR was found the highest for T1 group followed by T2, T3 and T4 group. Moreover, the FLW at 48 weeks and SB were found the highest in T4 group chicken and the lowest in T1 group followed by T3 and T2. The growth parameters were significant only for SB ($P<0.01$) and FCR ($P<0.05$) among the treatment groups.

In the present study, the poor growth rate in indigenous chickens, as observed, could be attributed to low feed intake and genetic composition of the birds. Yasmeen *et al*. (2008) studied the production performance of pullets and spent layers fed a commercial layer ration *i.e*., metabolizeable energy (Kcal/Kg) 2802, vitamin A (IU/Kg) 3000, lysine (0.76%) and methionine (0.37%) at 110g/bird/day. Findings revealed that feed consumption remained unaffected due to the age of the chickens. The findings are in disagreement with the present report where the feed consumption of the four genotypes varied according to their age *i.e*., pullets at 20 weeks and spent at 48 weeks of age. This might be due to the supplementation of higher level of Vitamin A (12500 IU/Kg) and the additional essential amino acids gradually increased the feed intake of the experimental birds. Supplementation of adequate essential amino acids gradually decreased the feed intake of the Hyline laying hens (Applegate *et al*., 2009). Rao *et al*. (2011) found that the final body weight increased linearly with increasing dietary lysine concentrations. Studied results from the growth performance of Fayoumi, RIR and their reciprocal crosses up to 20 weeks of age revealed that the average day-old weight was highest in RIR, intermediate in crossbred and lowest in Fayoumi chickens. The RIR breed consumed more feed and gained maximum weight ($P<0.05$) than those of Fayoumi and crossbred chickens at all ages of growing phase. The lowest body weight gain was recorded in Fayoumi than the RIR chickens during growing phase (Khawaja *et al*., 2012). These findings could be explained by the variation in chicken genotypes.

Egg production performance: The impacts of breed and treatment diets on the egg production performance exposed that *Sonali* was the highest in EP and indigenous the lowest followed by Fayoumi and RIR. The indigenous breed attained ASM and APP at lowest production days while RIR at the highest production days. Both the Fayoumi and *Sonali* showed similar ASM and APP. Egg production parameters were highly significant for EW, EP, EMP, FI and FCR ($P<0.001$). Conversely, the highest EP was found in T4 group and the lowest in T1 group followed by T3 and T2 group. The T4 group chicken attained ASM and APP at lowest production days while T1 group at the highest followed by T3 and T2 group. The ASM and APP were highly significant among the four dietary treatment groups ($P<0.001$). The effects of amino acids on egg number and egg mass of brown and white laying hens were studied by Bonekamp *et al*. (2010). Findings suggested that for the light hens, an intake of 600 mg of true fecal digestible lysine per hen per day was sufficient to maximize laying percentage. Panda *et al*. (2010) evaluated the effect of supplemental lysine to low protein diet on egg production, egg quality and humoral immune response of White Leghorn layers. Increasing dietary concentration of lysine to 0.75% significantly ($P<0.05$) improved egg production and egg weight, humoral immune response and feed efficiency. However, the broody hen provided the fertile eggs with optimum environmental conditions *i.e*., temperature, egg turning and humidity to stimulate embryonic development until hatching. While, the incubator is a simulated artificial design that mimics the broody hen's role of providing fertile eggs with optimum environmental conditions to stimulate embryonic development until hatching (Kingori, 2011).

A higher ($P<0.05$) rate of egg production and higher feed efficiency and egg mass was observed by feeding 2,600 kcal of metabolic energy compared with those fed 2,350 kcal of ME/kg. Feed efficiency improved with increasing concentrations of methionine. Egg weight and egg mass increased with dietary methionine concentrations (Rao *et al*., 2011). Perez-Bonilla *et al*. (2012) reported that feed and energy efficiency were better for the lighter hens. Feed intake (114.6 *vs*. 111.1 g/hen per day), AME intake (321 *vs*. 311 kcal/hen per day), egg weight (64.2 *vs*. 63.0 g), and egg mass (58.5 *vs*. 57.0 g) were higher for the heavier than for the lighter hens ($P<0.01$). These findings are in well agreement with the present results which suggested that adequate supplementation of VitA and EAAs might ensure better performance of the layers.

Egg quality performance: The impacts of breeds and treatment diets on the egg quality performance expressed that ESI was found the highest in indigenous egg followed by Fayoumi, *Sonali* and RIR egg. The indigenous egg possessed the highest AP followed by *Sonali*, RIR and Fayoumi. The highest YP was found in Fayoumi egg and the lowest in indigenous egg followed by *Sonali* and RIR. Highly significant difference were observed for EW, ESI, AP, YP, SMP, YI, STH and HU ($P<0.001$). Conversely, the ESI was found the highest for T1 egg followed by T3, T2 and T4 egg. However, the AI was found the highest in T3 and T4 egg followed by T2 and T1 egg. While, the YI was found the highest in T4 egg followed by T3, T2 and T1 egg. Highly significant difference was found for ESI, SMP, AI, STH and HU ($P<0.001$).

The egg shell percentage decreased significantly by increasing dietary threonine and methionine levels during the second cycle of production (Gomez and Angeles, 2009). The findings are in well agreement with the present results where the egg shell percentages gradually decreased with the increase of dietary supplementation of EAAs. The egg quality measure such as Haugh unit score and albumen content increased, while the yolk content decreased significantly ($P<0.05$) as the dietary lysine increased from 0.6 to 0.75%. Considering 100g feed consumption per day, it is concluded that the diet with 14.8% and 0.77% lysine was adequate to realize optimum performance with good albumen quality and better immune response in layers during 28-44 wk of age (Panda *et al*., 2010). However, the effect of energy concentration of the diet on egg quality of brown egg-laying hens differing in initial body weight revealed that increased energy content of the diets from 2,650 to 2,950 kcal of metabolic energy affected performance and egg quality of the hen. An increase in energy content of the diet reduced the proportion of shell in the egg ($P<0.01$). Eggs from the heavier hens had a higher proportion of yolk and lower proportion of albumen ($P<0.01$) and shell ($P<0.05$) than eggs from the lighter hens (Perez-Bonilla *et al*., 2012). Moreover, the internal egg quality parameters including yolk weight, albumen weight and height were found equal in all pure and crossbred chickens (Khawaja *et al*., 2013). Threonine supplementation had a significant effect on the increase of Haugh unit as the internal egg quality parameters (Abdel-Wareth and Esmail, 2014). The findings recognized that segregation and accumulation of vitamins and amino acids are important for maintaining egg quality traits such as albumen height, Haugh unit, yolk colour score and shell thickness of the experimental layers.

8.6 Summary

A detailed account of the productivity of the government (GOV), private (PRI) and backyard chicken farms (BCF) that use to rear Cobb 500 (broiler), cockerel, Fayoumi, RIR, *Sonali* and indigenous chickens were assessed from the urban, semi-urban and rural areas of Rajshahi District, Bangladesh. The study revealed that *Sonali* breed was the highest in production number in both the GOV and PRI. Moreover, *Sonali* attained the highest production in the FY 2011-12 and 2012-13. The BCF attained maximum profit (PI=0.646) than PRI (PI=0.114) while the GOV showed negative PI (-0.021) which indicated economic losses. The production profit was gradually decreased from the FY 2011-12 to FY 2013-14 which indicated economic instability.

Management studies of the chicken breeds were performed on the chicken farms from the urban, semi-urban and rural areas of Rajshahi district, Bangladesh. Management practices (MP) that existed at the study area were analyzed using a five-scale scoring system, where score 5 was considered as excellent, 4 as good, 3 as satisfactory, 2 as not good and 1 as unacceptable. Eight major parameters on MP such as room temperature (RT), water source (WS), vaccination (VC), bio-safety measures (BM), boundary walls (BW), human residence (HR), chicken transportation (CT) and feeding management (FM) were considered to rank the farms under study. The study exposed that the GOV showed good MP for BW, HR and FM (score 4). The PRI achieved the highest score (3.42=satisfactory to good) for FM while the BCF adopted a lower level to satisfactory MP for all the parameters. The study showed that MP for GOV was better than those of the PRI and BCF. Besides, both the PRI and BCF showed similar MP at the study area.

Disease incidence (DI) studies on the chicken breeds were performed from the urban, semi-urban and rural areas of Rajshahi District, Bangladesh. Using a five scale scoring system, six (6) major parameters on DI such as bacterial diseases (BD), viral diseases (VD), fungal diseases (FD), flock-wise disease commonness (FDC) and seasonal disease prevalence (SDP) were considered to rank the poultry farms under study, where score 5 was considered as elevated, 4 as severe, 3 as gross, 2 as mild and 1 as absent. The study showed that the GOV achieved the highest score of 4.33 (severe to elevated) for SDP. The PRI attained the highest score of 2.74 (mild to gross) for BD consistently, the BCF also reached at 1.06 (absent to mild). The DI indicated that disease susceptibility of the GOV was superior to those of the PRI and BCF in the case of BD, VD, FDC and SDP. The DI parameters showed highly significant difference for BD and SDP ($P<0.001$).

The impacts of breed, sex and treatment diets on the growth, meat and carcass performance of the experimental chickens *viz*., Fayoumi and *Sonali* were observed and analyzed. Findings revealed that Fayoumi was the highest for FI and LWG, while *Sonali* was the highest for FCR. Male chickens showed the highest FI and LWG but the lowest for FCR than the female ones. The T4 group chicken showed the highest SB followed by T3, T2 and T1 groups, respectively. Highly significant difference was observed for LW, TM, BM, LW and GW ($P<0.001$) among the treatment groups of chicken. In addition, the impacts of breed and treatment diets on the growth, egg production (EP) and egg quality performance of the Fayoumi, indigenous, RIR and *Sonali* were observed and analyzed. The study showed that *Sonali* was the highest in EP and indigenous the lowest followed by Fayoumi and RIR breeds. The indigenous attained ASM and APP at the lowest production days while RIR at the highest. Conversely, the highest EP was found in T4 group and the lowest in T1 group. The T4 group chickens attained ASM and APP at the lowest production days while T1 group at the highest followed by T3 and T2 groups.

8.7 Conclusions

Productivity study revealed that *Sonali* breed was the highest in production number in both the GOV and PRI. Moreover, *Sonali* attained the highest production in the FY2011-12 and 2012-13. The BCF attained the maximum profit (PI=0.646) than PRI (PI=0.114) while the GOV showed negative PI (-0.021) which indicated economic losses. The production profit was gradually decreased from the FY2011-12 to FY2013-14 which indicated economic instability. However, management studies of the chicken breeds among the farms exposed that the GOV showed good management practices (MP) for BW, HR and FM (score 4). The PRI achieved the highest score (3.42=satisfactory to good) for FM while the BCF adopted a lower level to satisfactory MP for all the parameters. The study showed that adopted MP for GOV is better than those of the PRI and BCF. Besides, both the PRI and BCF exposed similar MP at the study area. In addition, disease incidence (DI) studies showed that the GOV achieved the highest score 4.33 (severe to elevated) for SDP. The PRI attained the highest score 2.74 (mild to gross) for BD consistently, the BCF also reached at 1.06 (absent to mild). The DI indicated that disease susceptibility of the GOV was superior in comparison to those of the PRI and BCF in the case of BD, VD, FDC and SDP. The DI parameters showed highly significant difference for BD and SDP ($P<0.001$). Moreover, the meat yield studies revealed that Fayoumi was the highest for FI and LWG while, *Sonali* was the highest for FCR. Male chickens showed the highest FI and LWG but the lowest for FCR than the females. The T4 group chicken showed the highest SB followed by T3, T2 and T1 groups. Highly significant difference was observed for LW, TM, BM, LW and GW ($P<0.001$) among the treatment groups. Furthermore, the egg yield studies showed that *Sonali* was the highest in EP and indigenous the lowest followed by Fayoumi and RIR. The indigenous attained ASM and APP at lowest production days while RIR at the highest. Conversely, the highest EP was found in T4 group and the lowest in T1 group. The T4 group attained ASM and APP at lowest production days while T1 group at the highest followed by T3 and T2 groups.

Finally, it is concluded that the smallholder poultry farmers in the region might ensure sustainable production of their chickens which, in turn, might improve the economic conditions of the growers and nutritional status of the consumers. Owing to their smaller size, popular meat characteristics, low cost and suitability for rearing under prevailing environment, the crossbred *Sonali* chickens appeared to be commercially viable poultry birds in the study area.

8.8 Recommendations for further studies

Information on productivity, management practices and disease incidences revealed that under prevailing conditions the raising of smallholder poultry farms in urban, semi-urban and rural areas of Rajshahi, Bangladesh, appeared to be an efficiently feasible enterprise which requires better understanding of the socio-economic aspects of the small-scale poultry farmers. The study further indicated that there are great potentials for the improvement of indigenous chicken productivity in the urban, semi-urban and rural areas of the country. In addition, from the feed supplement experimentation on meat and egg yield efficiencies, since there is no detrimental effects of the feed supplement on the experimental birds, it is therefore recommended that administration of the suitable doses of VitA and EAAs to available poultry feed would result in enhanced growth, survivability, carcass characteristics, egg production and egg quality. However, supplement of EAAs only to the feed would contribute to the increase in productivity parameters of the chicken breeds under study. Therefore, further experiments designed to look into the mechanisms and feasibility of the supplementary diets is highly solicited.

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APPENDICES

Appendix 1 Preparation of the survey schedule and experimental module

- Survey and selection of Poultry houses, Government and Private farms:
  - Poultry Houses: Started: 26th of August Ended: 30th August 2011.
  - Government farm: Started: 31st of August Ended: 1st September 2011 and
  - Private farms: Started: 3rd of September Ended: 7th September 2011.
- Study on productivity, management practices and disease incidences at the study area:
  - First survey: (1st Phase) Started: 25th of October Ended: 31st October 2011.
  - Second survey: (1st Phase) Started: 23rd of February Ended: 29th February 2012 and
  - Third survey: (1st Phase) Started: 24th of June Ended: 30th June 2012.
- Study of the feed supplement experiment for meat purpose rearing (1st Phase):
  - Feed supplement experiment for Group T1 [Control diet]**:**
    - Batch 1**:** *Sonali* Started: 2nd March Ended: 26th April 2012.
  - Feed supplement experiment for Group T2 [Control diet + Vitamin A]**:**
    - Batch 1**:** *Sonali* Started: 2nd March Ended: 26th April 2012.
  - Feed supplement experiment for Group T3 [Control diet + Essential Amino acids]**:**
    - Batch 1**:** *Sonali* Started: 2nd March Ended: 26th April 2012.
  - Feed supplement experiment for Group T4 [Control diet + Vit-A + EAAs]**:**
    - Batch 1**:** *Sonali* Started: 2nd March Ended: 26th April 2012.
- Study on productivity, management practices and disease incidences at the study area:
  - First survey: (2nd Phase) Started: 26th of October Ended: 1st November 2012.
  - Second survey: (2nd Phase) Started: 22nd of February Ended: 1st March 2013 and
  - Third survey: (2nd Phase) Started: 24th of May Ended: 30th May 2013.
- Study of the feed supplement experiment for meat purpose rearing (2nd Phase):
  - Feed supplement experiment for Group T1 [Control diet]**:**
    - Batch 2**:** Fayoumi Started: 4th of May Ended: 28th June 2012.
  - Feed supplement experiment for Group T2 [Control diet + Vitamin A]**:**
    - Batch 2**:** Fayoumi Started: 4th of May Ended: 28th June 2012.
  - Feed supplement experiment for Group T3 [Control diet + EAAs]**:**
    - Batch 2**:** Fayoumi Started: 4th of May Ended: 28th June 2012.
  - Feed supplement experiment for Group T4 [Control diet + Vit-A + EAAs]**:**
    - Batch 2**:** Fayoumi Started: 4th of May Ended: 28th June 2012.

Appendix 1 (Contd.) Preparation of the survey schedule and experimental module

- Study on productivity, management practices and disease incidences at the study area:
  - First survey: (3rd Phase) Started: 30th of August Ended: 5th September 2013.
  - Second survey: (3rd Phase) Started: 27th of December Ended: 4th January 2014 and
  - Third survey: (3rd Phase) Started: 25th of April Ended: 1st May 2014.
- Study of the feed supplement experiment for egg purpose rearing:
  - Feed supplement experiment for Group T1 [Control diet]**:**
    - Batch 1**:** Fayoumi Started: 31st of May 2013 Ended: 2nd May 2014.
    - Batch 2**:** Indigenous Started: 1st of June 2013 Ended: 3rd May 2014.
    - Batch 3**:** RIR Started: 2nd of June 2013 Ended: 4th May 2014.
    - Batch 4**:** *Sonali* Started: 3rd of June 2013 Ended: 5th May 2014.
  - Feed supplement experiment for Group T2 [Control diet + Vitamin A]**:**
    - Batch 1**:** Fayoumi Started: 4th of June 2013 Ended: 6th May 2014.
    - Batch 2**:** Indigenous Started: 5th of June 2013 Ended: 7th May 2014.
    - Batch 3**:** RIR Started: 6th of June 2013 Ended: 8th May 2014.
    - Batch 4**:** *Sonali* Started: 7th of June 2013 Ended: 9th May 2014.
  - Feed supplement experiment for Group T3 [Control diet + EAAs]**:**
    - Batch 1**:** Fayoumi Started: 8th of June 2013 Ended: 10th May 2014.
    - Batch 2**:** Indigenous Started: 9th of June 2013 Ended: 11th May 2014.
    - Batch 3**:** RIR Started: 10th of June 2013 Ended: 12th May 2014.
    - Batch 4**:** *Sonali* Started: 11th of June 2013 Ended: 13th May 2014.
  - Feed supplement experiment for Group T4 [Control diet + Vit-A + EAAs]**:**
    - Batch 1**:** Fayoumi Started: 12th of June 2013 Ended: 14th May 2014.
    - Batch 2**:** Indigenous Started: 13th of June 2013 Ended: 15th May 2014.
    - Batch 3**:** RIR Started: 14th of June 2013 Ended: 16th May 2014.
    - Batch 4**:** *Sonali* Started: 15th of June 2013 Ended: 17th May 2014.

Appendix 2 Questionnaire designed for field survey

1. Farm description (location/type?) : ____________________
2. Breed description (IND/EXO/CRO?) : ____________________
3. Production period (meat/egg/week?) : ____________________
4. Yearly chicken production (No.) : ____________________
5. Breed-wise production costs (BDT) : ____________________
6. Breed-wise total revenue (BDT) : ____________________
7. Brooding facilities (temp./humidity) : ____________________
8. Hatching facilities (incubator/hen) : ____________________
9. Water source and supply (where/how) : ____________________
10. Vaccination schedule (disease-wise) : ____________________
11. Farm boundary wall (made by?) : ____________________
12. Ventilation (exhaust fan/type?) : ____________________
13. Human residence (distance?) : ____________________
14. Chicken transportation (vehicle?) : ____________________
15. Feeding management (type/timing?) : ____________________
16. Storage techniques (feed/drugs/how) : ____________________
17. Litter management (day's interval?) : ____________________
18. Uses of disinfectants (kind?) : ____________________
19. Disposal of dead bodies (how?) : ____________________
20. Disposal of farm excreta (how?) : ____________________
21. Access of wild animal (yes/no/type) : ____________________
22. Veterinary services (training/contact?) : ____________________
23. Bio-safety (gloves, mask, boot, apron?) : ____________________
24. Bacterial diseases (name/event?) : ____________________
25. Viral diseases (name/event?) : ____________________
26. Fungal diseases (name/event?) : ____________________
27. Flock-wise disease commonness : ____________________
28. Seasonal disease prevalence (name?) : ____________________
29. Previous disease record (name/event?) : ____________________

Researcher's signature, date and time

Appendix 3 Meat features (%) of the experimental Fayoumi and *Sonali* chickens

Breeds	**Sex**	**Diet**	**LW (g)**	**DY**	**TM**	**BM**	**DKM**	**WM**	**THM**	**DM**
SON	M	T1	547	58.25	38.31	11.74	27.56	2.84	12.22	8.32
SON	M	T1	551	55.17	37.84	11.33	27.41	2.77	12.42	8.41
SON	M	T1	556	57.47	39.21	11.81	27.63	2.92	12.51	8.25
SON	F	T1	495	56.45	35.23	11.27	24.82	3.25	10.27	7.27
SON	F	T1	487	53.36	34.77	10.85	24.65	3.16	10.45	7.36
SON	F	T1	481	55.65	36.15	11.34	24.86	3.29	10.56	7.19
FAY	M	T1	570.56	60.07	35.75	11.28	25.31	3.17	10.82	7.81
FAY	M	T1	574.52	56.96	35.39	11.05	25.17	3.06	10.95	7.89
FAY	M	T1	579.45	59.26	36.57	11.33	25.37	3.21	11.14	7.73
FAY	F	T1	529	54.57	36.65	12.49	24.91	3.95	9.68	6.76
FAY	F	T1	525	51.46	36.31	12.25	24.75	3.91	9.81	6.83
FAY	F	T1	517	53.76	37.52	12.51	24.96	4.05	9.99	6.68
SON	M	T2	619	57.07	39.33	12.33	28.29	3.17	12.71	8.63
SON	M	T2	593	61.04	38.83	12.84	28.52	3.29	12.67	8.67
SON	M	T2	607	57.35	39.31	12.43	28.49	3.22	12.76	8.79
SON	F	T2	535	55.26	36.27	11.87	25.57	3.54	10.74	7.55
SON	F	T2	521	59.23	35.76	12.37	25.76	3.65	10.68	7.62
SON	F	T2	527	55.54	36.23	11.96	25.72	3.59	10.82	7.73
FAY	M	T2	655.92	58.71	36.77	11.87	26.05	3.45	11.31	8.09
FAY	M	T2	629.85	62.65	36.26	12.36	26.23	3.63	11.27	8.16
FAY	M	T2	643.78	59.59	36.65	12.39	26.29	3.57	11.35	8.25
FAY	F	T2	579	53.21	37.72	13.06	25.65	4.29	10.16	7.04
FAY	F	T2	568	57.15	37.21	13.56	25.85	4.45	10.11	7.11
FAY	F	T2	562	54.09	37.65	13.21	25.83	4.38	10.23	7.23

Note: SON=*Sonali*, FAY=Fayoumi, M=Male and F=Female; T1 (control diet), T2 (T1+Vit-A), T3 (T1+EAAs) and T4 (T1+Vit-A+EAAs); LW= Live weight (g), DY= Dressing yield, TM= Total meat, BM= Breast meat, DKM= Dark meat, WM= Wing meat, THM= Thigh meat and DM= Drumstick meat.

Appendix 3 (Contd.) Meat features (%) of the experimental Fayoumi and *Sonali* chickens

Breeds	**Sex**	**Diet**	**LW (g)**	**DY**	**TM**	**BM**	**DKM**	**WM**	**THM**	**DM**
SON	M	T3	645	59.15	41.04	13.04	28.91	3.33	12.81	8.76
SON	M	T3	657	59.57	40.61	13.43	28.68	3.28	12.67	8.73
SON	M	T3	638	59.07	40.73	13.23	29.03	3.19	12.78	8.63
SON	F	T3	552	57.34	37.96	12.56	26.17	3.73	10.84	7.74
SON	F	T3	537	57.75	37.54	12.96	25.93	3.57	10.71	7.68
SON	F	T3	556	57.25	37.67	12.77	26.28	3.61	10.83	7.58
FAY	M	T3	684.72	61.85	38.42	12.67	26.63	3.69	11.41	8.31
FAY	M	T3	696.78	61.37	37.99	13.05	26.49	3.48	11.39	8.27
FAY	M	T3	677.83	60.96	38.18	12.85	26.78	3.59	11.29	8.24
FAY	F	T3	605	55.45	39.37	13.81	26.26	4.48	10.25	7.26
FAY	F	T3	616	55.83	38.94	14.23	26.05	4.32	10.17	7.17
FAY	F	T3	611	55.39	39.12	14.15	26.39	4.36	10.23	7.09
SON	M	T4	670	58.14	40.22	13.33	28.79	3.39	12.75	8.86
SON	M	T4	663	59.49	39.79	13.64	29.28	3.35	12.79	8.91
SON	M	T4	678	59.26	40.93	13.27	29.39	3.41	12.93	8.94
SON	F	T4	610	56.33	37.16	12.86	26.14	3.58	10.79	7.81
SON	F	T4	593	57.67	36.72	13.18	26.54	3.69	10.84	7.86
SON	F	T4	605	57.44	37.85	12.83	26.66	3.77	10.97	7.89
FAY	M	T4	724.52	60.97	37.62	12.96	26.73	3.55	11.42	8.36
FAY	M	T4	736.58	61.25	37.29	13.06	26.95	3.59	11.36	8.45
FAY	M	T4	717.63	61.85	38.35	13.17	26.79	3.71	11.53	8.41
FAY	F	T4	652	55.47	38.57	14.17	26.23	4.39	10.27	7.31
FAY	F	T4	643	55.73	38.15	14.32	26.63	4.44	10.21	7.39
FAY	F	T4	662	56.43	39.27	14.37	26.71	4.51	10.38	7.43

Note: SON=*Sonali*, FAY=Fayoumi, M=Male and F=Female; T1 (control diet), T2 (T1+Vit-A), T3 (T1+EAAs) and T4 (T1+Vit-A+EAAs); LW= Live weight (g), DY= Dressing yield, TM= Total meat, BM= Breast meat, DKM= Dark meat, WM= Wing meat, THM= Thigh meat and DM= Drumstick meat.

Appendix 4 Carcass features (%) of the experimental Fayoumi and *Sonali* chickens

Breeds	**Sex**	**Diet**	**LW (g)**	**SK**	**AFW**	**NK**	**HD**	**GW**
SON	M	T1	547	5.65	0.93	4.62	10.13	13.72
SON	M	T1	551	5.74	0.89	4.77	10.21	14.14
SON	M	T1	556	5.87	1.01	4.81	10.09	14
SON	F	T1	495	6.25	0.88	3.12	8.43	12.1
SON	F	T1	487	6.34	0.83	3.17	8.51	12.25
SON	F	T1	481	6.47	0.97	3.23	8.49	12.19
FAY	M	T1	570.56	5.67	0.94	3.94	10.87	13.72
FAY	M	T1	574.52	5.54	0.89	4.03	10.95	14.53
FAY	M	T1	579.45	5.71	1.05	4.11	10.99	14.48
FAY	F	T1	529	6.91	1.19	2.42	9.26	14.25
FAY	F	T1	525	6.79	1.14	2.47	9.35	14.4
FAY	F	T1	517	6.95	1.29	2.53	9.31	14.33
SON	M	T2	619	6.29	1.09	4.87	10.33	15.51
SON	M	T2	593	6.37	1.16	5.07	10.39	15.62
SON	M	T2	607	6.41	1.21	4.98	10.41	15.91
SON	F	T2	535	6.89	1.05	3.35	8.61	13.53
SON	F	T2	521	6.99	1.12	3.57	8.67	13.75
SON	F	T2	527	6.95	1.17	3.48	8.63	13.76
FAY	M	T2	655.92	6.26	1.11	4.16	11.17	15.89
FAY	M	T2	629.85	6.35	1.18	4.38	11.24	16.16
FAY	M	T2	643.78	6.39	1.23	4.31	11.21	16.02
FAY	F	T2	579	7.51	1.35	2.65	9.48	15.78
FAY	F	T2	568	7.59	1.43	2.87	9.55	16
FAY	F	T2	562	7.63	1.47	2.79	9.51	15.88

Note: SON=*Sonali*, FAY=Fayoumi, M=Male and F=Female; T1 (control diet), T2 (T1+Vit-A), T3 (T1+EAAs) and T4 (T1+Vit-A+EAAs); LW=live weight (g), SW=skin weight, AFW=abdominal fat weight, NW=neck weight, HW=head weight and GW=giblet weight.

Appendix 4 (Contd.) Carcass features (%) of the experimental Fayoumi and *Sonali* chickens

Breeds	**Sex**	**Diet**	**LW (g)**	**SK**	**AFW**	**NK**	**HD**	**GW**
SON	M	T3	645	6.35	1.07	5.07	10.42	15.93
SON	M	T3	657	6.39	1.13	5.11	10.46	16.1
SON	M	T3	638	6.25	1.17	5.19	10.51	16.12
SON	F	T3	552	6.86	1.02	3.55	8.69	14.02
SON	F	T3	537	6.92	1.08	3.61	8.76	13.99
SON	F	T3	556	6.84	1.11	3.59	8.79	14
FAY	M	T3	684.72	6.27	1.09	4.35	11.29	16.63
FAY	M	T3	696.78	6.35	1.15	4.43	11.35	16.42
FAY	M	T3	677.83	6.29	1.16	4.49	11.31	16.62
FAY	F	T3	605	7.51	1.33	2.81	9.57	16.37
FAY	F	T3	616	7.56	1.39	2.89	9.63	16.16
FAY	F	T3	611	7.49	1.41	2.95	9.61	16.28
SON	M	T4	670	7.05	1.17	5.29	10.55	16.57
SON	M	T4	663	6.87	1.15	5.18	10.47	16.14
SON	M	T4	678	7.12	1.11	5.23	10.53	16.43
SON	F	T4	610	6.95	1.09	3.69	8.83	14.44
SON	F	T4	593	7.19	1.12	3.64	8.71	13.92
SON	F	T4	605	7.24	1.07	3.63	8.78	14.3
FAY	M	T4	724.52	6.38	1.21	4.57	11.49	17
FAY	M	T4	736.58	6.51	1.16	4.51	11.37	16.37
FAY	M	T4	717.63	6.54	1.19	4.62	11.51	16.91
FAY	F	T4	652	7.63	1.44	2.99	9.75	16.69
FAY	F	T4	643	7.75	1.42	2.93	9.59	16.16
FAY	F	T4	662	7.81	1.38	3.02	9.66	16.48

Note: SON=*Sonali*, FAY=Fayoumi, M=Male and F=Female; T1 (control diet), T2 (T1+Vit-A), T3 (T1+EAAs) and T4 (T1+Vit-A+EAAs); LW=live weight (g), SW=skin weight, AFW=abdominal fat weight, NW=neck weight, HW=head weight and GW=giblet weight**.**

Appendix 5 Growth performance of the experimental Fayoumi, indigenous, RIR and *Sonali* chickens

Breeds	Diet	DW (g)	LW (20 wk)	LWG	FI (g/b/d)	FCR	FLW (48 wk)	SB (%)
FAY	T1	34.76	1125.45	1090.69	52.375	6.72	1237.995	93.75
FAY	T1	33.28	1105.72	1072.44	55.815	7.29	1216.292	81.25
FAY	T1	34.68	1165.25	1130.57	54.86	6.79	1281.775	87.5
IND	T1	21.85	665.45	643.6	42.39	9.22	731.995	81.25
IND	T1	22.68	725.35	702.67	40.425	8.05	797.885	87.5
IND	T1	23.65	748.68	725.03	41.71	8.05	823.548	81.25
RIR	T1	37.85	1350.56	1312.71	55.715	5.94	1485.616	87.5
RIR	T1	38.56	1328.65	1290.09	52.625	5.71	1461.515	87.5
RIR	T1	38.76	1295.34	1256.58	62.825	6.99	1424.874	81.25
SON	T1	34.55	1225.65	1191.1	53.725	6.31	1348.215	87.5
SON	T1	39.54	1287.25	1247.71	52.115	5.85	1415.975	81.25
SON	T1	33.56	1245.72	1212.16	61.135	7.06	1370.292	93.75
FAY	T2	36.67	1145.45	1108.78	51.125	6.45	1317.2675	87.5
FAY	T2	38.66	1205.72	1167.06	55.135	6.61	1386.578	87.5
FAY	T2	39.56	1172.24	1132.68	51.725	6.39	1348.076	93.75
IND	T2	23.56	772.62	749.06	46.34	8.66	888.513	81.25
IND	T2	23.87	810.44	786.57	43.325	7.71	932.006	87.5
IND	T2	24.76	790.72	765.96	44.67	8.16	909.328	87.5
RIR	T2	39.23	1365.55	1326.32	59.115	6.24	1570.3825	81.25
RIR	T2	38.65	1368.75	1330.1	54.71	5.76	1574.0625	93.75
RIR	T2	37.67	1325.45	1287.78	51.135	5.56	1524.2675	93.75
SON	T2	33.56	1245.56	1212	52.825	6.11	1432.394	87.5
SON	T2	35.75	1265.55	1229.8	51.125	5.82	1455.3825	93.75
SON	T2	32.54	1310.62	1278.08	59.115	6.47	1507.213	93.75

Note: FAY=Fayoumi, IND=Indigenous, RIR=Rhode Island Red and SON=*Sonali*; T1 (control diet), T2 (T1+Vit-A), T3 (T1+EAAs) and T4 (T1+Vit-A+EAAs); DW=Day-old chick wt (g), LW=Live wt at 20 weeks (g), LWG= Live wt gain (g), FI=Feed intake up to 20 weeks (g/b/d), FCR=Feed conversion ratio (FI/LWG), FLW=Final live wt at 48 weeks (g) and SB=Survivability (%).

Appendix 5 (Contd.) Growth performance of the experimental Fayoumi, indigenous, RIR and *Sonali* chickens

Breeds	Diet	DW (g)	LW (20 wk)	LWG	FI (g/b/d)	FCR	FLW (48 wk)	SB (%)
FAY	T3	31.67	1205.45	1173.78	49.935	5.95	1410.3765	100
FAY	T3	33.88	1195.72	1161.84	49.475	5.96	1398.9924	87.5
FAY	T3	34.56	1215.24	1180.68	53.24	6.31	1421.8308	87.5
IND	T3	24.65	835.76	811.11	45.335	7.82	977.8392	81.25
IND	T3	23.95	858.54	834.59	43.625	7.32	1004.4918	87.5
IND	T3	22.86	796.24	773.38	42.085	7.62	931.6008	87.5
RIR	T3	39.25	1355.68	1316.43	54.635	5.81	1586.1456	100
RIR	T3	38.67	1378.34	1339.67	53.155	5.55	1612.6578	87.5
RIR	T3	37.85	1425.36	1387.51	50.325	5.08	1667.6712	93.75
SON	T3	34.87	1285.63	1250.76	51.225	5.73	1504.1871	100
SON	T3	35.65	1275.25	1239.6	49.375	5.58	1492.0425	93.75
SON	T3	35.78	1305.58	1269.8	57.385	6.33	1527.5286	93.75
FAY	T4	37.95	1186.95	1149	49.115	5.98	1412.4705	100
FAY	T4	36.75	1230.72	1193.97	48.125	5.64	1464.5568	87.5
FAY	T4	38.25	1242.24	1203.99	51.145	5.95	1478.2656	100
IND	T4	25.65	865.75	840.1	42.38	7.06	1030.2425	93.75
IND	T4	23.87	845.43	821.56	43.115	7.35	1006.0617	87.5
IND	T4	24.45	895.73	871.28	40.635	6.53	1065.9187	87.5
RIR	T4	39.56	1395.65	1356.09	48.425	4.99	1660.8235	100
RIR	T4	38.65	1358.54	1319.89	51.375	5.44	1616.6626	87.5
RIR	T4	38.52	1430.25	1391.73	54.125	5.44	1701.9975	93.75
SON	T4	31.45	1280.24	1248.79	49.225	5.52	1523.4856	93.73
SON	T4	32.65	1320.35	1287.7	47.835	5.21	1571.2165	100
SON	T4	34.78	1295.62	1260.84	55.635	6.18	1541.7878	100

Note: FAY=Fayoumi, IND=Indigenous, RIR=Rhode Island Red and SON=*Sonali*; T1 (control diet), T2 (T1+Vit-A), T3 (T1+EAAs) and T4 (T1+Vit-A+EAAs); DW=Day-old chick wt (g), LW=Live wt at 20 weeks (g), LWG= Live wt gain (g), FI=Feed intake up to 20 weeks (g/b/d), FCR=Feed conversion ratio (FI/LWG), FLW=Final live wt at 48 weeks (g) and SB=Survivability (%).

Appendix 6 Egg production performance of the experimental Fayoumi, indigenous, RIR and *Sonali* chickens

Breeds	**Diet**	**EW (gm)**	**ASM (d)**	**APP (d)**	**EP (%)**	**EMP (g/b/d)**	**FI (g/b/d)**	**FCR (FI/EMP)**
FAY	T1	38.45	198	277	67.55	26.47	99.88	3.77
FAY	T1	33.77	193	282	67.86	26.45	103.32	3.91
FAY	T1	35.29	196	273	67.23	28.01	102.36	3.65
IND	T1	20.51	185	260	40.27	14.92	89.89	6.02
IND	T1	22.82	191	266	35.36	16.49	87.93	5.33
IND	T1	25.52	189	274	37.85	17.1	89.21	5.22
RIR	T1	48.23	202	288	59.23	32.87	103.22	3.14
RIR	T1	43.57	199	285	62.07	32.29	100.13	3.1
RIR	T1	46.26	197	284	63.27	31.42	110.33	3.51
SON	T1	40.71	198	276	69.55	29.6	101.23	3.42
SON	T1	42.86	195	272	72.32	31.21	99.62	3.19
SON	T1	39.78	193	278	69.21	30.12	108.64	3.61
FAY	T2	42.65	184	260	72.55	29.86	98.63	3.3
FAY	T2	45.27	189	266	72.86	31.51	102.64	3.26
FAY	T2	41.36	183	259	72.23	30.59	99.23	3.24
IND	T2	26.41	170	247	45.27	19.65	93.84	4.77
IND	T2	24.93	179	255	40.36	20.69	90.83	4.39
IND	T2	29.37	174	251	42.85	20.15	92.17	4.57
RIR	T2	52.27	193	269	64.23	35.89	106.62	2.97
RIR	T2	47.23	188	263	67.07	35.97	102.21	2.84
RIR	T2	49.38	191	267	68.27	34.79	98.64	2.83
SON	T2	43.65	185	261	74.55	32.6	100.33	3.08
SON	T2	44.57	182	257	77.32	33.15	98.63	2.97
SON	T2	47.34	188	264	74.21	34.38	106.62	3.1

Note: FAY=Fayoumi, IND=Indigenous, RIR=Rhode Island Red and SON=*Sonali*; T1 (control diet), T2 (T1+Vit-A), T3 (T1+EAAs) and T4 (T1+Vit-A+EAAs); EW=Egg wt (g), ASM=Age at sexual maturity (d), APP=Age at peak production (d), EP=Egg production (%), EMP=Egg mass production (g/b/d), FI=Feed intake 21 to 48 weeks (g/b/d) and FCR=Feed conversion ratio (FI/EMP).

Appendix 6 (Contd.) Egg production performance of the experimental Fayoumi, indigenous, RIR and *Sonali* chickens

Breeds	**Diet**	**EW (gm)**	**ASM (d)**	**APP (d)**	**EP (%)**	**EMP (g/b/d)**	**FI (g/b/d)**	**FCR (FI/EMP)**
FAY	T3	57.41	166	247	77.55	32.88	97.44	2.96
FAY	T3	58.23	169	251	77.86	32.6	96.98	2.97
FAY	T3	54.27	171	252	77.23	33.15	100.74	3.04
IND	T3	29.47	156	237	50.27	22.58	92.84	4.11
IND	T3	27.23	161	243	45.36	23.21	91.13	3.93
IND	T3	31.62	163	241	47.85	21.48	89.59	4.17
RIR	T3	55.67	175	258	69.23	37.06	102.14	2.76
RIR	T3	57.44	171	253	72.07	37.69	100.66	2.67
RIR	T3	59.27	177	256	73.27	39	97.83	2.51
SON	T3	51.23	169	248	79.55	35.11	98.73	2.81
SON	T3	49.43	173	251	82.32	34.82	96.88	2.78
SON	T3	52.64	176	255	79.21	35.66	104.89	2.94
FAY	T4	59.45	157	241	85.05	33.63	96.62	2.87
FAY	T4	60.23	161	245	83.36	34.87	95.63	2.74
FAY	T4	57.17	159	244	82.73	35.19	98.65	2.8
IND	T4	32.46	143	229	55.77	24.52	89.88	3.66
IND	T4	29.63	147	233	50.86	23.95	90.62	3.78
IND	T4	33.67	144	230	53.35	25.37	88.14	3.47
RIR	T4	61.28	163	249	74.73	39.54	95.93	2.43
RIR	T4	63.24	161	247	77.57	38.49	98.88	2.57
RIR	T4	65.23	158	242	78.77	40.52	101.63	2.51
SON	T4	53.27	155	240	85.05	36.27	96.73	2.67
SON	T4	56.37	158	244	87.82	37.4	95.34	2.55
SON	T4	57.29	161	247	84.71	36.7	103.14	2.81

Note: FAY=Fayoumi, IND=Indigenous, RIR=Rhode Island Red and SON=*Sonali*; T1 (control diet), T2 (T1+Vit-A), T3 (T1+EAAs) and T4 (T1+Vit-A+EAAs); EW=Egg wt (g), ASM=Age at sexual maturity (d), APP=Age at peak production (d), EP=Egg production (%), EMP=Egg mass production (g/b/d), FI=Feed intake 21 to 48 weeks (g/b/d) and FCR=Feed conversion ratio (FI/EMP).

Appendix 7 Egg quality traits of the experimental Fayoumi, indigenous, RIR and *Sonali* chickens

Breeds	Diet	EW (g)	ESI	AP (%)	YP (%)	SP (%)	SMP (%)	AI	YI	STH	YCS	HU
FAY	T1	41.83	76.68	52.95	35.30	9.20	0.31	0.036	0.367	0.31	7	58.92
FAY	T1	43.86	77.02	52.80	35.88	9.07	0.34	0.042	0.413	0.37	8	60.57
FAY	T1	44.23	74.75	52.61	35.90	9.08	0.32	0.046	0.408	0.34	8	64.76
FAY	T1	42.62	77.04	53.19	34.79	9.54	0.32	0.041	0.395	0.35	8	63.51
IND	T1	30.52	79.51	56.38	31.81	10.64	0.36	0.041	0.430	0.31	8	65.97
IND	T1	32.82	77.51	55.72	29.92	11.42	0.33	0.043	0.401	0.37	9	66.5
IND	T1	35.55	78.52	60.67	27.42	9.25	0.36	0.042	0.455	0.32	8	63.23
IND	T1	33.47	79.73	59.21	28.71	9.79	0.35	0.044	0.455	0.33	9	65.12
RIR	T1	43.77	73.96	56.31	31.91	9.50	0.41	0.045	0.457	0.35	8	58.41
RIR	T1	45.75	74.23	55.91	32.21	10.38	0.42	0.045	0.425	0.37	7	58.49
RIR	T1	46.43	75.49	55.71	32.01	9.92	0.45	0.048	0.445	0.34	9	59.73
RIR	T1	47.28	77.57	56.72	31.57	10.08	0.46	0.048	0.438	0.39	8	58.65
SON	T1	42.87	74.58	55.21	32.56	9.72	0.37	0.043	0.440	0.39	8	58.22
SON	T1	44.65	74.49	53.90	33.46	10.19	0.33	0.043	0.424	0.37	9	56.79
SON	T1	45.33	77.40	54.64	32.84	10.12	0.35	0.044	0.438	0.35	8	55.73
SON	T1	45.68	77.34	54.31	32.79	10.48	0.32	0.045	0.426	0.38	9	56.92
FAY	T2	44.25	75.52	53.24	34.84	10.50	0.33	0.046	0.391	0.33	9	64.55
FAY	T2	45.77	75.56	51.03	36.72	10.88	0.34	0.051	0.426	0.38	7	66.12
FAY	T2	48.13	74.75	52.91	35.27	10.07	0.35	0.055	0.395	0.37	8	69.13
FAY	T2	47.33	75.71	52.54	36.06	10.07	0.33	0.053	0.406	0.37	8	67.18
IND	T2	33.67	79.95	57.49	29.13	11.13	0.41	0.051	0.416	0.34	8	70.03
IND	T2	34.23	78.39	58.74	28.71	10.66	0.46	0.054	0.452	0.36	9	71.57
IND	T2	36.25	74.46	60.08	27.44	10.37	0.49	0.054	0.434	0.32	8	70
IND	T2	36.45	74.57	62.33	26.41	9.57	0.52	0.053	0.462	0.37	9	68.56

Note: FAY=Fayoumi, IND=Indigenous, RIR=Rhode Island Red and SON=*Sonali*; T1 (control diet), T2 (T1+Vit-A), T3 (T1+EAAs) and T4 (T1+Vit-A+EAAs); EW=Egg wt (g), ESI=Egg shape index, AP=Albumen percentage (%), YP=Yolk percentage (%), SP=Shell percentage (%), SMP=Shell membrane percentage (%), AI=Albumen index, YI=Yolk index, STH=Shell thickness, YCS=Yolk color score and HU=Haugh unit.

Appendix 7 (Contd.) Egg quality traits of the experimental Fayoumi, indigenous, RIR and *Sonali* chickens

Breeds	Diet	EW (g)	ESI	AP (%)	YP (%)	SP (%)	SMP (%)	AI	YI	STH	YCS	HU
RIR	T2	51.25	72.902	55.43	33.38	9.97	0.54	0.049	0.452	0.37	8	57.11
RIR	T2	48.87	72.491	54.45	34.19	10.06	0.55	0.050	0.461	0.35	8	59.46
RIR	T2	51.27	73.519	56.89	32.10	9.18	0.56	0.052	0.448	0.39	9	59.81
RIR	T2	49.66	74.131	57.65	32.03	9.04	0.58	0.052	0.448	0.38	8	59.76
SON	T2	47.96	75.317	56.02	32.86	9.11	0.45	0.045	0.448	0.38	8	55.65
SON	T2	47.67	74.954	55.52	33.37	9.88	0.44	0.046	0.437	0.39	9	57.03
SON	T2	48.23	73.534	55.09	34.25	9.59	0.47	0.047	0.434	0.37	8	56.9
SON	T2	48.76	73.936	55.25	34.00	9.68	0.45	0.048	0.466	0.39	9	56.8
FAY	T3	50.65	75.332	51.11	36.90	9.81	0.31	0.057	0.413	0.35	9	67.08
FAY	T3	46.47	74.810	51.99	36.23	10.37	0.36	0.059	0.435	0.39	9	70.45
FAY	T3	49.33	72.881	54.67	34.27	9.79	0.36	0.060	0.411	0.38	8	70.65
FAY	T3	49.83	75.334	53.82	34.85	9.45	0.36	0.064	0.401	0.41	8	71.52
IND	T3	36.78	76.833	60.84	26.78	10.25	0.73	0.058	0.423	0.35	8	72.32
IND	T3	36.13	74.666	59.95	27.34	10.37	0.71	0.058	0.461	0.36	9	71.93
IND	T3	37.27	75.711	61.38	26.58	10.08	0.75	0.058	0.466	0.37	9	71.73
IND	T3	37.55	73.921	61.03	26.17	9.66	0.71	0.061	0.473	0.33	9	71.99
RIR	T3	53.69	73.251	54.68	33.80	9.55	0.50	0.065	0.463	0.39	8	66.63
RIR	T3	54.61	73.575	54.51	34.15	9.11	0.53	0.059	0.470	0.37	9	62.44
RIR	T3	53.45	72.443	56.33	32.72	8.81	0.57	0.063	0.468	0.41	9	64.74
RIR	T3	55.16	73.344	58.39	32.28	8.17	0.54	0.061	0.455	0.40	8	62.98
SON	T3	52.86	74.509	55.75	33.63	9.21	0.52	0.065	0.456	0.41	9	66.47
SON	T3	51.87	73.565	56.62	32.98	9.15	0.52	0.064	0.476	0.42	9	66.77
SON	T3	49.33	72.774	53.86	35.53	9.38	0.50	0.064	0.442	0.38	8	68.64
SON	T3	51.76	73.767	55.52	33.88	9.19	0.54	0.066	0.450	0.40	9	67.92

Note: FAY=Fayoumi, IND=Indigenous, RIR=Rhode Island Red and SON=*Sonali*; T1 (control diet), T2 (T1+Vit-A), T3 (T1+EAAs) and T4 (T1+Vit-A+EAAs); EW=Egg wt (g), ESI=Egg shape index, AP=Albumen percentage (%), YP=Yolk percentage (%), SP=Shell percentage (%), SMP=Shell membrane percentage (%), AI=Albumen index, YI=Yolk index, STH=Shell thickness, YCS=Yolk color score and HU=Haugh unit.

Appendix 7 (Contd.) Egg quality traits of the experimental Fayoumi, indigenous, RIR and *Sonali* chickens

Breeds	Diet	EW (g)	ESI	AP (%)	YP (%)	SP (%)	SMP (%)	AI	YI	STH	YCS	HU
FAY	T4	50.95	74.387	51.40	36.76	9.79	0.33	0.060	0.447	0.36	9	68.58
FAY	T4	51.67	73.791	53.00	35.74	9.50	0.34	0.066	0.464	0.41	9	70.35
FAY	T4	51.53	72.574	52.33	36.46	9.37	0.34	0.060	0.422	0.39	8	68.39
FAY	T4	50.98	74.484	54.57	35.05	9.39	0.37	0.066	0.411	0.43	9	72.01
IND	T4	39.71	75.475	62.12	24.88	9.99	0.73	0.062	0.460	0.37	9	72.28
IND	T4	40.23	74.472	62.04	25.52	9.81	0.77	0.061	0.471	0.34	9	71.26
IND	T4	39.17	73.534	63.26	25.35	9.65	0.74	0.061	0.474	0.36	8	72.23
IND	T4	38.54	76.029	64.47	24.98	9.15	0.72	0.067	0.460	0.38	9	73.76
RIR	T4	56.23	72.061	55.43	34.23	9.26	0.51	0.065	0.473	0.41	9	65.23
RIR	T4	57.76	72.665	54.13	34.22	9.78	0.53	0.066	0.474	0.39	9	65.66
RIR	T4	56.46	72.927	55.18	34.23	9.58	0.56	0.067	0.478	0.42	9	64.92
RIR	T4	58.16	73.479	55.50	34.14	9.43	0.53	0.063	0.489	0.41	9	63.2
SON	T4	54.26	72.212	55.78	33.80	9.01	0.57	0.071	0.472	0.42	9	68.39
SON	T4	53.86	72.619	57.87	31.84	8.87	0.53	0.068	0.456	0.42	9	67.48
SON	T4	53.36	73.838	56.14	33.41	8.77	0.52	0.068	0.451	0.4	10	68.26
SON	T4	52.96	74.054	55.26	33.68	9.04	0.56	0.068	0.461	0.41	9	67.81

Note: FAY=Fayoumi, IND=Indigenous, RIR=Rhode Island Red and SON=*Sonali*; T1 (control diet), T2 (T1+Vit-A), T3 (T1+EAAs) and T4 (T1+Vit-A+EAAs); EW=Egg wt (g), ESI=Egg shape index, AP=Albumen percentage (%), YP=Yolk percentage (%), SP=Shell percentage (%), SMP=Shell membrane percentage (%), AI=Albumen index, YI=Yolk index, STH=Shell thickness, YCS=Yolk color score and HU=Haugh unit.