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PRODUCTIVE AND REPRODUCTIVE PERFORMANCES OF BOVANS BROWN AND KOEKOEK CHICKEN BREEDS UNDER VARIED SEASONS AND FEEDING REGIMES IN SOUTH WOLLO ZONE, ETHIOPIA

PhD DISSERTATION

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PRODUCTIVE AND REPRODUCTIVE PERFORMANCES OF BOVANS BROWN AND KOEKOEK CHICKEN BREEDS UNDER VARIED SEASONS AND FEEDING REGIMES IN SOUTH WOLLO ZONE, ETHIOPIA

A dissertation submitted to the College of Veterinary Medicine and Agriculture of Addis Ababa University in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Animal Production

By

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January, 2017

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As members of the Examining Board of the final PhD open defence, we certify that we have read and evaluated the Dissertation prepared by Gezahegn Tadesse titled: **Productive and Reproductive Performances of Bovans Brown and Koekoek Chicken Breeds under Varied Seasons and Feeding Regimens in South Wollo zone, Ethiopia**, and recommend that it be accepted as fulfilling the dissertation requirement for the degree of **Doctor of Philosophy in Animal Production**

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I hereby certify that I have read the revised version of this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

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ABSTRACT

PRODUCTIVE AND REPRODUCTIVE PERFORMANCES OF BOVANS BROWN AND KOEKOEK CHICKEN BREEDS UNDER VARIED SEASONS AND FEEDING REGIMES IN SOUTH WOLLO ZONE, ETHIOPIA

Gezahegn Tadesse Derseh

PhD Thesis

Addis Ababa University (2017)

This research consisted of 2 phases experiment. The experiments were conducted at Kalu district between October 2013 and January 2015 to evaluate the productive and reproductive performances of Bovans Brown (BB) and Koekoek (Kk) chicken breeds under 3 seasons (cold season-CS, hot season-HSe and main rainy season-MRS) and 2 feeding regimes-FR (Supplemented-SU and Non-supplemented-NS). Phase I was arranged as a 2x3 (2 breeds and 3 seasons) and Phase II as a 2x2x3 (2 breeds, 2 FR and 3 seasons) factorial arrangement in CRD, having 6 and 4 treatment combinations respectively with 3 replications for each treatment. During phase I, 50 chicks per replicate was reared up to 3-month age; and during phase II, 6 birds per replicate at 3-month age was distributed to 12 household farmers to be maintained up to 15-months age. For phase I: feed intake (FIg/b/d), average daily gain (ADG), feed conversion ratio (FCR). For phase II: body weight gain (BWG), egg production traits, the effect of breed and FR on GI and reproductive tracts measurements; were measured, fertility and hatchability were assessed, the farmer's perception on the chicken genotypes was also captured. In addition; mortality, rectal temperature (RT^{O}C), ambient temperature (AT) relative humidity (RH) and rain fall was taken for the two phases. Except the data on farmer's perception that was analysed by descriptive statistics; SAS, (2002) computer *package was used for all the rest dependent variables. The result of Phase I indicated that; BB was more pronounced in FIg/b/d and the Kk breed in ADG, FCR and mortality. Higher ADG and $RT^{O}C$, and better FCR was recorded during the HSe. BB had higher FIg/b/d in all the seasons. Higher ADG and mortality, better FCR in the MRS; and higher RT in the HSe observed on the Kk breed. The result of Phase II revealed that Kk breed, supplementation main effects and their interactions played a great role in improving BWG. Koekoek, supplemented, HSe birds and their two and three-way interactions were higher in RT. In TCE-Kk and in AEW-BB breeds main effect was more pronounced than the rest of the two and three-way interaction effects. Earlier AOEL was recorded in the main effect supplemented and the interaction effects of BB and Kk breeds due to supplementation. Among the reason of mortality/loss, mortality due to unidentified diseases was higher. The egg type BB was superior in ovary weight, follicle number, weight and length of major parts of the oviduct and important digestive organs. Supplementation stimulated the ovary weight, follicles number, and oviduct weight and length. There was significant ($p<0.05$) breed effect on hatchability. The farmer`s perception showed that most consumers prefer; brown shell color, small size and, local chicken eggs and local chicken meat. Docile and lack of permanent laying site behaviors were observed in BB, broodiness in Kk, and similar but higher than local chicken feed consumption in both. In conclusion, significant improvement in poultry production is possible through the replacement of existing less productive exotic breeds with a suitable stock that will thrive well under all existing natural hazards in intensive and in the rural free range condition, feed supplementation to scavenging birds following vaccination program against prevalent diseases. The physiological and anatomical changes in terms of digestive and female reproductive systems may be mediating the positive effects of selection of suitable breed and feed supplementation. To meet the increasing demand for commercial chicks in this country; favourable environment, adequate nutrition and a more productive breed of parent stock should be provided. Sensitization campaigns on nutritional quality of eggs and meat, on the behaviour and temperament of exotic chickens is necessary.*

STATEMENT OF AUTHOR

First, I declare that this dissertation is my *bonafide* work and that all sources of material used for this dissertation have been duly acknowledged. This dissertation has been submitted in partial fulfilment of the requirements for a PhD degree at Addis Ababa University, College of Veterinary Medicine and Agriculture and is deposited at the University/College library to be made available to borrowers under rules of the Library. I solemnly declare that this dissertation is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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BIOGRAPHICAL SKETCH

The author was born on July 23, 1961 in Debre Markos town, East Gojjam, Ethiopia; from his father Ato Tadesse Derseh and his mother W/o Debritu Wolde Tsadik. He attended his Elementary, Junior Secondary and High School at Debre Markos town between 1967 and 1979.

In September 1979, he joined the then Awassa College of Agriculture and he was graduated in the diploma program of animal sciences in 1981; and worked in ministry of agriculture for about seven years. Then, he joined the degree program in Animal Sciences at the former Alemaya University of Agriculture (AUA) as advanced standing student in 1988 and graduated in 1991.

The author was employed by Ministry of Agriculture (MOA) as animal husbandry expert at sheep Breeding and Multiplication Centre in 1991, and then he served at Poultry Breeding and Multiplication Centre as poultry husbandry expert until he joins the Graduate School of Alemaya University in Animal Production in September 2002.

After the completion of the graduate study, the author re-joined Kombolcha Agricultural Research Centre to assume responsibilities in management, research and extension and then transfer to Wollo University in 2008 for teaching, research and community service responsibilities.

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DEDICATION

To My Daughter Mitaye

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LIST OF ABBREVIATIONS

ACI	Agrifood Consulting International
AME/AMEn	Apparent Metabolizable Energy, nitrogen-corrected AME
AT, Ta	Ambient Temperature
CC	Climate change
CRD	Complete Randomized Design
CSA	Central Statistics Office of Ethiopia
ED	Early Dry
ESG	Egg Shell Gland
FAO	Food and Agriculture Organization
FC	Food Consumption
FE	Feed Efficiency
G´C	Interactions between naked neck genotypes and climates
G×E	Genotype by Environment interaction
GR	Growth Rate
HHL	Household Food waste and Leftover
HH/HHs	House Hold/House holds
HS	Heat Stress

LIST OF ABBREVIATIONS (*Continued*)

TSR	Tukey`s Studentized Range
IAEA	International Atomic Energy Agency
IFAD	International Fund for Agricultural Development
ILCA	International Livestock Centre for Africa
LD	Late Dry
LSL	Lohmann Selected Leghorn
ME	Metabolizable Energy
NaNa/Nana	Homozygous naked neck/heterozygous naked neck
Na/NN, nana	Naked Neck, normally feathered
ND	Newcastle Disease
RT, Tr	Rectal Temperature
SCFR/SFRB	Scavengable Feed Resource/Scavengable Feed Resource Base
SR	Shaver Redbro
TH	TETRA-H

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1. INTRODUCTION

Like other developing countries, poultry production is an important economic activity in Ethiopia. Beside its social and cultural benefits, it plays a significant role in poverty reduction. The total chicken population of Ethiopia is estimated to be 60.51 million (CSA, 2016), with native chicken of non-descriptive breeds representing 94.33%, 3.21% hybrid and 2.47% exotic breeds. From the total population of chicken in Ethiopia, 99% are raised under the traditional back yard system of management, while 1% is under intensive management system (Tadelle *et al.*, 2003). However, most of the research work is being carried out on intensive poultry production, using modern housing and sophisticated feeding systems, though a considerable part of poultry production is based on village chicken production system. Therefore, in view of the particular socio economic situation in the different regions, demand driven and participatory research is needed to find out the best development strategies. Ethiopia hasn't yet implemented a holistic intervention method to improve village chicken productions (Mammo, 2012). Different technical interventions have been introduced to rural areas in fragmented ways to improve the performance of village chicken. The most commonly used interventions are breed introduction, feed supplementation and control measures against diseases.

A study by Tadelle and Ogle (1996a) in the central highlands of Ethiopia demonstrated that the introduction of exotic breeds to three study villages at various times and in different forms (*viz*. through the introduction of cockerels, pullets or fertile eggs) has minimal impact in upgrading the genetic status of village stock. This is because parallel improvements in feeding, housing and health care were not implemented. But the poor meat and egg outputs of indigenous chicken have necessitated the introduction of exotic breeds. The exotic breeds have fast growth rates and better egg production potentials but are susceptible to a number of potential diseases that plague the industry today (Taiwo *et* *al.*, 2005).

Hence, Bovans Brown and Potchefstroom Koekoek chicken breeds were used for this study. The Bovans Brown is a brown feathered layer, which has the ability to meet the expectations of a variety of egg producers with different objectives. (http://www.backyardchickens.com/t/104396/). The Potchefstroom Koekoek is a South African registered dual purpose chicken breed. The breed has characteristic black and white speckled colour patterns, also described as barred (Van Marle-Köster and Nel, 2000; Nthimo, 2004).

According to Tadelle, (1996), improved management of these birds through, for example, supplementing indigenous birds with energy, protein and calcium can increase poultry productivity in extensive systems. In Nigeria, it is reported that supplementation at 30g/bird/day enhanced the growth rate of chicks while supplementation below 60g/day was insufficient to increase the growth rate of adult birds (Moreki, 2006). Likewise, Okitoi *et al.* (2009) reported nutrient (energy, protein and amino acids) intake from scavengeable resources was below the requirement of free-ranging local hens. Therefore, supplementation is inevitable to increase nutrient intake for optimum production.

Meanwhile, tropical and developing countries often rely on exotic germplasm for breeding purposes. They however have climatic conditions, production systems, and markets different from those where animals evaluated. Thus, the Genotype by Environment (G×E) interaction can cause a reduced efficiency of their genetic improvement programs. Genotype by environment interaction usually described as a situation in which different genotypes (breeds, lines, or strains) respond differently to different environments (Sheridan, 1990). The investigation of G×E interaction in order to thwart this fact was limited and concerned mainly large populations in the northern hemisphere and in a few tropical countries (Hammami *et al.*, 2009). With the rapid development of the poultry industry worldwide, especially in developing countries, importation of temperate-zone high-performance stocks to hot regions is on the rise. The use of unsuitable genotypes in hot regions results in large economic losses due to decreased growth, reduced protein gains, and higher mortality. To achieve further improvements in the world poultry industry, breeding programs need to identify genotypes that perform better in hot climates (Cahaner, 1990).

Generally, it is expensive to build and operate climatic controlled facilities to conduct seasonal stress factor studies. This problem can be prevented by conducting studies in natural environments. Moreover, to develop means and ways of improvement for suitable poultry farming system, the country realizes the need for a package of practices by incorporating some of the technical interventions. However, little has been done so far in this direction to identify combinations of the best technical interventions to the traditional poultry producers. Additionally, the two breeds mentioned earlier are widely distributed in most parts of the Amhara region probably without proper testing of their performance and adaptability. Therefore, there is a need to identify breeds that perform better in all climatic and management conditions of the country in general and the region in particular.

In view of forgoing facts, this study was designed to meet the following general and specific objectives, and with the hypothesis below: -

Hypothesis: season and feeding regime have effects on the productive and reproductive performance, and on GI and reproductive tracts of Bovans Brown and Koekoek chicken breeds.

General Objective

The general objective of this study is to test the performance of exotic chicken genotypes under different climatic and management conditions as a pre-requisite for wider adoption by end users.

Specific Objectives

1. To evaluate the responses of Bovans Brown and Koekoek chicken breeds to variabilities in seasonal parameters and feeding regimes,
2. To assess the effect of feeding regimes and season on productive and reproductive performances of Bovans Brown and Koekoek chickens,
3. To assess the effect of breed and feeding regimes on the anatomy and physiology of GI and reproductive tracts, and
4. To capture the farmer's perceptions about the technologies in relation to the genotypes of chickens.

2. LITERATURE REVIEW

2.1. The Effect of Season on the Performance of Poultry

Seasonal variation is one of the major non-genetic factors affecting poultry production most specially in tropical environment. Ayo *et al.* (2007) and Obidi *et al.* (2008) reported that season has been identified as one of the most important factor adversely affecting poultry production in the tropics, not only in those reared extensively, but also in those intensively-reared without artificial regulation of microclimatic conditions. On the other hand, the three major seasons; cold, hot and main rainy seasons; in Ethiopia are identified principally by change in ambient temperature, relative humidity and amount of rainfall. The principal meteorological element commonly implicated with the adverse effect of seasonal variation on performance of poultry is ambient temperature, most especially in tropical and sub-tropical regions of the world**.**

In chickens, Malau-Aduli *et al.* (2003) found significant effect of age, year and season on egg production and mortality. While breed, age, batch effects on productive and reproductive performance of poultry had been reported in literature, seasonal influence has not been given enough attention it deserves. Although many factors are involved, the combination of high temperature and relative humidity resulting in heat stress remains one of the major challenges to improved production efficiencies in warm regions (Yahav, 2000). Meanwhile, significant influence of season on egg production (Bawa *et al.,* 2001; Olawumi, 2011), fertility and hatchability (Olawumi, 2007) and mortality (Bawa *et al.*, 2001; Olawumi, 2007) had been documented in literature. Drastic decreases in food intake, growth and food efficiency have also been reported during summer months in countries with hot and temperate climates (Yalcin *et al.,* 1997b).

2.1.1. Effects of heat stress in poultry

For many years, researchers have been investigating the effect of high environmental temperature on the performance of different poultry species, including turkeys (McKee and Sams, 1997), young chickens and broilers (Cooper and Wash-burn, 1998), broiler breeders (McDaniel *et al.,* 1995), and laying hens (Muiruri and Harrison,1991; Whitehead *et al.,* 1998), and have found that high environmental temperatures have deleterious effects on productive performance. In laying hens, heat stress (HS) depresses body weight and egg production (Muiruri and Harrison, 1991; Whitehead *et al.,* 1998), egg weight (Balnave and Muheereza, 1997), and shell quality (Mahmoud *et al.,* 1996) and is generally accompanied by suppression of feed intake, which could be the cause of the decline in production. In addition, Larbier *et al.* (1993) found that chronic heat exposure significantly decreased protein digestion and Bonnet *et al.* (1997) reported that the feed digestibility of the different components of the diet (proteins, fats, starch) decreased with exposure of broiler chickens to high temperatures.

Many reports have shown that high ambient temperatures depress feed consumption (Suk and Washburn, 1995; Deeb and Cahaner, 2001; Xin *et al.,* 2002;) growth rate (Altan *et al.,* 2000; Temin *et al.,* 2000; Deeb and Cahaner, 2001) and feed conversion rate (Suk and Washburn, 1995) of broiler chickens. On the other hand, Muiruri and Harrison (1991) found that HS did not significantly affect egg weight or feed conversion. Koelkebeck *et al.* (1998) indicated that acute HS had no adverse effects on dietary amino acid digestibility in laying hens. The differences in the above results could be due to differences in HS treatments or the type of birds used. Regarding the decline in the reproductive performance of acutely heat-stressed hens, Mahmoud *et al.* (1996) suggested that alterations in acid-base balance, the status of Ca^{2+}, and diminished ability of duodenal cells to transport calcium could be critical factors in the detrimental effects of HS on egg production, egg-shell characteristics, and skeletal integrity often documented in laying hens.

In hot climates, periods of high temperatures have a negative effect on the health and performance of domestic animals. Poultry farming is no exception and the effect of stress caused by elevated temperatures can result in heavy economic losses from increased mortality and reduced productivity (St-Pierre *et al.*, 2003). For birds to perform at their optimum capacity they need, among other factors, to be in homeostasis with their environment through the maintenance of thermobalance. Thermobalance is the equilibrium between the heat produced and the heat given out by living organism, and this is at its maximal physiological level within the thermo-neutral range of any given specie. Birds, like mammals are homoeothermic, they produce heat to maintain a relatively constant body temperature and may permit certain variations within their temperature range without significant perturbation (St-Pierre *et al.*, 2003).

According to the IPCC, (2001) in the 20th century, there was an increase of 0.65°C in the average global temperature and 0.2 to 0.3% increase of precipitation in the tropical region. The changes in the biomass as result of the continuous global warming has a deleterious effect on domestic animals in general, and birds in particular. Thus, ambient temperature (AT) above 25 is stressful for birds, but more stressful is the fluctuations caused by this environmental thermal changes, especially when it is accompanied by high relative humidity (RH), as this unleash various patho-physiological response in birds (Sritharet *et al.,* 2002; Simon, 2003). Furthermore, it has been demonstrated that this response induces HS in chickens, and thus lead to disturbance in production (Estrada-Pareja, 2007).

At the same time, constant high temperature of 30-32^{O}C is more deleterious to broilers than cyclic or alternating temperatures of 30-32^{O}C by day and 25^{O}C by night. All studies indicate that high temperatures reduce the efficiency of utilizing feed energy for productive purposes. Broilers not only eat less at high temperature, but also gain less per unit of intake; especially at temperatures above 30^{O}C. Feed conversion in broilers is subject to marked fluctuations because of seasonal as well as ambient temperature changes (Joachim *et al*., 2011). The main effects of exposure of homoeothermic animals to heat are changes in the normal standard of rectal temperature (Tr). Rectal temperature can be considered the best isolated criterion to judge heat tolerance (Campos *et al.,* 2004) and it is an important efficiency indicator in the homeothermy maintenance facing the thermal environment. Rectal temperature can also be used to assess heat stress impacts (Spiers *et al.,* 2004).

Normally, the chicken's body temperature is 41.5^{O}C, but will fluctuate somewhat depending upon the temperature of its environment, while the established thermo-neutral zone for birds reared in the tropical regions ranges between 18-24 (Holik, 2009); and this narrow temperature ranges makes poultry flocks more vulnerable to climate change (Weaver, 2002). Maintaining a constant body temperature is not a problem when air temperature is at least 10-15 degrees less than body temperature. But air movement is critical. A bird can only give off heat to its environment if the temperature of that environment is cooler than the bird. If heat produced by the birds is not moved away from them and out of the poultry house quickly, it will be more difficult for them to avoid heat stress (Sottnik, 2002).

Besides, Post *et al.* (2003) reported that high environmental temperature leads to excretion of some minerals like Ca, Fe, Zn, and results in decreased bone strength. Impaired growth of cartilage and bone was one of the effects of heat stress mentioned by

Rosales, (1994) in a review on managing stress in broiler breeders. Heat stress causes depletion of vitamin C in animals. Vitamin C is required for conversion of 25-hydroxy vitamin D3 produced by the liver into the hormone calcitriol in the kidney. Calcitriol is essential in the regulation of calcium metabolism. Therefore, the depletion of vitamin C during HS results in obstruction of calcium metabolism. In addition to these effects on specific nutrients, gastrointestinal size was reported to decrease in heat-exposed chickens (Mitchell and Carlisle, 1992).

Furthermore, Kadim *et al.* (2008) reported, seasonal temperature differences had a significant ($P<0.05$) effect on broiler performance raised in open-sided house. The differences in ambient temperatures between the open-sided and closed house during the hot season were 7-8^{O}C. Birds reared in an open-sided house during the hot season had significantly ($P<0.05$) lower feed intake, body weight gain and feed conversion ratio than those reared during the cool season. Feed efficiency was also reduced which was probably due to decreased efficiency of nutrient utilization due to high energy requirements needed to dissipate extra heat load, reduced protein retention and/or enhanced lipid deposition (Bonnet *et al.,* 1997; Sands and Smith, 1999). Moreover, Mmereole *et al.* (2007) reported genotype, age, season as well as age x season interaction effects were significant ($P<0.05$) in influencing the mortality rates of the experimental chickens.

On the other hand, poultry production, holding more than one third of world meat market, has employed new technologies to enhance its competitiveness. The opening of new markets accentuated the search for productivity, involving both breeding program as well as the construction of high-tech poultry houses. Conditions of high ambient temperature are causing increasing concern in poultry due to the rapid development of the poultry industry in countries having hot climates and to the reduced performance of poultry during summer months in countries having temperate climates. Indeed, Geraert *et al.* (1996a) showed that about half of the growth reduction in hot environments was due to a direct effect of high temperature. This reduction of efficiency was partly explained by decreased metabolic utilization of nutrients, increased heat production, reduced protein retention, and enhanced lipid deposition (Aın Baziz *et al.,* 1996; Geraert *et al.,* 1996a). The reduction in feed efficiency might also be due primarily to lower feed digestibility, the first step of feed utilization.

Feed intake and physical activities have been recognized as main factors to increasing heat production in animal (Yamamato, 1992). As a result of high environmental temperature, energy consumption declines to reduce heat production (Yahav, 2000). The heat produced in the body gave rise to an increased body temperature, followed by responses in heat loss (Zhou *et al*, 1996b), i.e. the rise in body temperature precedes the change in heat loss. These reports indicate that factors such as feather cover, sex, age of bird, degree of acclimation, and bird species can all interact with relative humidity (RH) in defining the responses of poultry to high ambient temperatures. The ability of a nutritionist to provide a single set of nutrient specifications to satisfy all possible interacting factors is problematical to say the least.

The effect of high temperature on dietary ME appears rather controversial. Slightly increased or even unchanged ME in heat-exposed chickens have been reported (Geraert *et al.,*1992). However, Yamazaki and Zi-Yi (2008) found a decreased ME content of the diet when birds were exposed to high environmental temperature. Such discrepancies might be attributed to various factors, among these: feed intake, age, genotype, sex, and type of diet. For example, ME increased more in an experiment in which the feed reduction was about 10% than in the experiment, in which feed intake was reduced by 20%. Moreover, up to 4 week of age, high temperature did not affect nitrogen-corrected apparent metabilzable energy (AMEn) in broilers. Using raw materials, Zuprizal *et al.* (1993) reported a significant decrease of AMEn due to high temperature with rapeseed meal (either dehulled or not), whereas there was no decrease with soybean meal in hot environments. Dietary ME content was significantly increased in chickens with genetically lean genotypes than in chickens with more potential for fat deposition (Geraert *et al.*, 1992). Further, a tendency for increased ME observed in male chickens but not in females when birds were exposed to high temperature reported by Geraert *et al.* (1992).

Medeiros *et al.* (2001) showed that the average rectal temperature of broiler chickens is around 41.5°C, ranging from 40.6 to 43.0°C, and the upper safety limit to maintain their survival is equal to 45°C. Productivity and rectal temperature (Tr) are affected by environmental conditions. To get the most productivity in poultry production, it is essential that the thermal environment presents appropriate comfort levels, allowing broilers to express their maximum genetic potential. When thermal environment conditions inside a poultry house are out of the comfort limits, the environment becomes uncomfortable, requiring the animal body physiological adjustments to maintain homeothermy, be it to retain or dissipate heat. As the thermal environment becomes increasingly stressful, the animal body perceives the risk to life and ceases to prioritize production and reproduction, focusing only on their survival (Medeiros *et al.,* 2005).

2.1.2. Effects of cold stress in poultry

Cold is one of the main barriers limiting the development of the animal husbandry in cold regions (Li *et al.,* 2006). Research has proved that the central nervous system and its central locus were the dominant sections that played the integrated and regulative role in the cold stress reaction and carried out the regulation through the sympathetic-adrenal-medullary-axis, the hypothalamic-pituitary-adrenal-axis, and the hypothalamic-pituitary-thyroid-axis (Cheng *et al.,* 2004; Helmreich *et al.,* 2005). Study demonstrated that both acute and chronic cold stress may cause duodenum oxidative stress and change in inducible Nitric Oxide Synthase (iNOS), which is related to the intestinal damage process. However, the intestinal damage mechanism with respect to iNOS may be more important and requires further study (Zhang *et al.,* 2011).

Under the routine production conditions various types of stress are experienced by chicken such as heat/cold, transport, pre-slaughter holding, etc. Both high and low environmental temperatures stimulate the hypothalamo-hypophyseal-adrenocortical axis which may alter susceptibility of animals including the chicken to infectious diseases, resulting in production loss. Studies indicated exposure of poultry to comparable temperature stressors reduces humoral and cell-mediated immunity, leading to altered host-resistance to infectious pathogens (Li *et al.,* 2006).

Birds are naturally well adapted to cold due mainly to their highly efficient insulation provided by feathers. However, production efficiency of poultry goes down at low ambient temperatures. Low ambient temperatures cause an increase in feed intake, but also result in decreased egg production and feed efficiency in laying hens (Spinu and Degen, 1993). Such cold conditions also cause decreases in serum concentrations of some vitamins, minerals, and insulin, and increases in serum corticosterone in poultry as well as humans (Siegel, 1995). Animals stressed due to environmental temperature are found to have reduced ascorbic acid, α-tocopherol, and retinol concentrations in plasma and blood cells, whereas malondialdehyde levels were found high in plasma and tissues due to increased production of free radicals (Klasing, 1998). Moreover, ambient temperature impairs absorption of vitamins A, E and C, and increases the dietary requirement of these vitamins (Klasing, 1998).

2.2. Strategies to Alleviate Thermal Stress in Poultry

To date, several management techniques have been tested but only a few were found effective and economical in minimizing the undesirable effect of HS on poultry. These solutions include management strategies to make the birds more comfortable such as improving house insulation, providing adequate ventilation, installing roof sprinklers and evaporative cooling system and reducing bird density. Other techniques consist of feed withdrawal or fasting before onset of HS and feeding at cooler times of the day and providing cool drinking water (Ojano-Dirain and Waldroup, 2002).

Yahav (2000) also suggest that getting young birds accustomed to higher ambient temperature prior to HS exposure (acclimation) and exposing the birds at an early age to acute HS conditions (thermal conditioning), can improve the birds' resistance to HS. Kutlu and Forbes (1993) reported that to overcome or to alleviate the harmful effects of heat stress, heat tolerance in birds has to be increased. The physiological mechanisms underlying the acclimation induced heat tolerance in birds has yet to be elucidated in detail. Besides, one of the mitigation strategy to combat HS is biological mitigation, to identify alternate breeds/varieties of chicken which can perform under the global scenario of increased temperatures due to climate change (Rajkumar *et al.,* 2011). Strain differences in rectal temperature (RT) measurements also indicate the importance of choosing strains to be used in hot and warm climate conditions with attention to the thermoregulation ability of broilers (Altan *et al*., 2000). Results from the study by Aengwanich, (2007) provided fundamental knowledge for improving poultry production by identifying a heat tolerant genetic resource for poultry production in tropical regions.

Moreover, nutritional manipulations, such as the addition of fat and the reduction of excess protein are recommended (Joachim *et al*., 2011). Zhou *et al.* (1996b) showed that a bird's exposure to chronic or acute HS will affect physiological mechanisms and the necessary dietary or drinking water formulations needed to overcome the stress. Altan *et al*. (2000) have reported significantly reduced body temperatures in layers that were off feed between 10:00 and16:00 h during the summer season. Ozkan *et a.* (2003) from their experiment carried out in summer (July to August) in Turkey reported feeding strategy significantly affected body weight at week 6 (BW6) and daily weight gain during week 6 (DWG5-6). Strain effect-was significant on DWG4-5 and DWG5-6. Total food consumption (FC0-6), food conversion ratio (FCR0-6), mortality, and carcase characteristics were not affected by short-term fasting in the experimental conditions. It can be recommended that broiler producers may practise 6h of fasting during the hot period of the day without any adverse effect on slaughter weight and FCR when the birds are close to the average slaughter weight and a heat wave is expected.

At temperatures, above or below thermo-neutral zone, corticosteroid secretion increases in response to stress. Ascorbic acid supplement reduced the synthesis of corticosteroid hormones in birds under stressed conditions. By decreasing synthesis and secretion of corticosteroids, vitamin C alleviates the negative side effects of stress. Although poultry can synthesize vitamin C it becomes inadequate under stressful conditions such as low or high environmental temperature, high humidity, and high egg production rate and parasite infestation. So, extra supplementations of vitamin C is needed to meet up additional requirements (Ali *et al.,* 2010).

2.3. Family Chicken Production

Poultry production in tropical countries is based on traditional scavenging system and chickens are the most important poultry species (Tadelle *et al.*, 2003). There is no generally accepted definition of rural poultry production, and various production systems have been described by a number of authors, including Alemu (1995) and Tadelle and Ogle (1996a). The production systems are characterized as including small flocks, with nil or minimal inputs, low outputs and periodic devastation of the flocks by disease. Birds are owned by individual households and are maintained under a scavenging system, with little or no inputs for housing, feeding or health care. Typically, the flocks are small in number with each flock containing birds from each age group, with an average of 7-10 mature birds per household, consisting of 2-4 adult hens, a male bird and a number of growers of various ages. Gunaratne *et al.* (1992) and Tadelle and Ogle (1996a) also described village poultry flocks in Asia as including 10-20 birds of different ages per household.

Guèye (2005) has defined two forms of the traditional backyard system: Firstly, unimproved backyard system: Use of low-input, low producing native birds, brooding, scavenging, no regular water or feed supply, little or poor night shelter, no vaccination and medication. Secondly, improved backyard system: use of genetically improved birds, scavenging, regular water, supplementary feeding, improved shelter, care of chicks in the early age, vaccination against prevalent diseases and de-worming. To identify the right type of birds it is essential to evaluate and understand the local production systems, their limitations and opportunities, the circumstances under which such traditional systems came to existence and how they can be gradually improved.

Attempts are being made to raise the productivity of family chickens in developing countries, by improving housing, nutrition and health programmes. Improvements in performance resulting from improved management (nutrition, housing and disease control) and marketing strategies have been reported in some countries such as Indonesia (Moreki, 2006).

2.4. Exotic Breed Introduction and Associated Constraints

Local chickens remain predominant in African villages despite the introduction of exotic and crossbred types, because farmers have not been able to afford the high input requirements of introduced breeds (Safalaoh, 1997). Although the introduction of high yielding chicken breeds in Africa dates back to the 1920`s, village chicken populations comprise from five to 50 local types (FAO, 1998). A study by Tadelle and Ogle (1996a) in the central highlands of Ethiopia demonstrated that the introduction of exotic breeds to three study villages at various times and in different forms (*viz*. through the introduction of cockerels, pullets or fertile eggs) has minimal impact in upgrading the genetic status of village stock. Because parallel improvement in feeding, housing and health care were not implemented. The poor meat and egg outputs of indigenous chicken have necessitated the introduction of exotic breeds. The exotic breeds have fast growth rates and better egg production potentials but are susceptible to a number of potential diseases that plague the industry today (Onwurah and Nodu, 2006).

Further, poultry production is being severely hampered by lack of suitable stocks. The main problem of the indigenous chicken is that they are poor producers of egg and meat. In addition, the adaptability of the exotic breeds under the tropical climate is also a great problem for their susceptibility to heat and diseases than the local chickens. The environmental conditions under which poultry are kept and imbalanced diets do not permit to express the full genetic potentials of exotic breeds. Therefore, a suitable stock is necessary that will thrive well under all existing natural hazards in the rural free range condition (Barua *et al.,* 1998).

On the other hand, the breeds included under this study were the Bovans Brown and Potchefstroom Koekoek. Many years of genetic research have produced the Bovans Brown, a docile, robust, colour-sexable brown egg layer that delivers large numbers of good quality eggs, is strong and shows a good appetite. These highly favourable genetic characteristics can only be fully realised when the bird is provided with proper management, which includes but is not limited to, good quality feed, good housing and proper management practice. The Bovans Brown is a brown feathered layer, which has the ability to meet the expectations of a variety of egg producers with different objectives. She is the bird of choice for today's egg farmers who expect high egg numbers and a forgiving bird, all essential ingredients to keep their business profitable. The standard performances of the breed: laying period 18 to 80 weeks, average egg weight 63.8g, peak production 95%, feed conversion 2.21 Kg/Kg, and egg number per hen housed is 350. (http://www.backyardchickens.com/t/104396/.

The Potchefstroom Koekoek is a South African registered chicken breed developed in the 1950’s at the Potchefstroom Agricultural College. It is considered as a composite breed of White leghorn, Black Australorp and Barred Plymouth Rock (Fourie and Grobbelaar, 2003). Grobbelaar *et al.* (2010) reported the meat of Koekoek chicken as being popular and mostly preferred by local communities over that of commercial broiler breeders. The carcass is attractive with deep yellow coloured skin. The breed has characteristic black and white speckled colour patterns, also described as barred, which is present in about nine poultry breeds hence why the chicks are sexable soon after hatching (Van Marle-

Köster and Nel, 2000; Nthimo, 2004). Joubert (1996) pointed out that Koekoek chicken is considered as a heavy breed with an average mature weight of 3-4kg and 2.5-3.5kg for cocks and hens respectively. Koekoek chickens are known to have a large body size and higher egg production compared to indigenous breeds (Joubert, 1996; Van Marle-Köster and Casey, 2001). Van Marle-Köster and Casey (2001) further reported the total egg production of 204 eggs in a 51-weeks laying period. The birds attain their first oviposition at 130 days with an average egg weight of 55.7g (Nthimo, 2004).

2.5. The Sources of Feeds and Feeding Family Chickens

According to Moreki (2006) family chickens usually have to find food for themselves. The opportunity to scavenge is way of allowing the chickens to correct any nutritional deficiency in the feeds offered as supplements. The free-range system makes it difficult to measure feed consumption, body weight and egg production. Although feeding is mainly limited to insects and kitchen wastes, bran (mainly sorghum) and whole grains are sometimes used as well. Bran is widely fed, especially to chicks, and is obtained from milling plants found in villages or is generated from homes.

Besides, scavenging chickens start roaming the fields in the morning to search for feeds such as earthworms, beetles, spiders and scorpion, grasshoppers, centipedes, lizards, grass and legume seeds, berries, green leaves etc. and return to the farmer’s house in the late afternoon. In addition to scavenging, birds are fed maize chaff, cowpea testa, melon fruits, kitchen waste etc. Birds are fed at different times of the day depending on feed and labour availability. They are fed once, twice or three times a day and are fed mainly in the morning before they roam the village outskirts in search of feed and late afternoon to encourage them to return home. Once a day feeding is common during periods of feed shortage, especially in summer. At times, they are not fed at all leaving them to depend entirely on scavenging. The common feeding method is by broadcasting grain on the bare ground. Generally, rural farmers only occasionally supplement feeds in small amounts when they can afford it. There is evidence that if feeding of family poultry is improved, they will be more productive. Improved feeding is particularly important if indigenous breeds are upgraded using exotic and more productive breeds. Feeding may be improved either by allowing the birds to scavenge and be fed a daily ration or they may be enclosed and fed complete diets (Moreki, 2006).

Sonaiya *et al.* (2002a) indicated that without the confinement of the homestead, the scavengeable feed resource base (SFRB) can be defined as all the materials that are always or seasonally available in the environment and which the scavenging birds can use as feed. The amount and availability per bird of this scavengeable feed resource (SCFR) were significantly dependent on season, grain availability in the household, time of grain sowing and harvest, and the biomass of the village flock. The SCFR is deficient in protein during the dry season and energy during the rainy season. Generally, the supply of feed from scavengeable sources will be low from mid-dry season to mid-rain season, when there will be low insects and metazoan numbers, less green plant cover, low or no harvesting activities and so on. The reverse will be the case for between mid-rains to mid-dry seasons (Sonaiya, 1995).

Supplementary feeding is required when the SCFR is critically deficient or unbalanced in nutrients as determined from chemical analyses of crop contents of scavenging hens and their egg production. SCFR is deficient in protein and energy (and probably calcium for laying birds) as supplementation of scavenging birds with energy, protein and calcium sources bring about a considerable increase in egg production (Tadelle *et al.,* 2002; Sonaiya *et al.,* 2002b). In Nigeria, it is reported that supplementation at 30g/bird/day enhanced the growth rate of chicks while supplementation below 60g/day was insufficient to increase the growth rate of adult birds (Moreki, 2006). Nutrient (energy, protein and amino acids) intake from scavengeable resources was below the requirement of free-ranging local hens. Supplementation is inevitable to increase nutrient intake for optimum production. Offering two complementary foods is an effective method of feeding scavenging chickens allowing birds to select to meet requirements (Okitoi *et al.*, 2009).

2.6. Fertility and Hatchability

It is believed that fertility rate of breeder hens is a very important measure of their reproductive performance. Fertility refers to the percentage of incubated eggs that are fertile while hatchability is the percentage of fertile eggs that hatch. According to (Cyril Hrnčár *et al.*, 2015) mean fertility was 59.81%, 57.36% and 58.82% for Brahma, Cochin and Orpington respectively. There was no significant difference ($P>0.05$) in fertility among the different chicken breeds. Mean hatchability from fertilized eggs was 80.08%, 82.54% and 89.86% for Brahma, Cochin and Orpington respectively. Comparisons between heavy breeds revealed significant differences ($P<0.05$) in hatchability among the breeds. Significant effect of genotypes on hatchability was also observed by Jayarajan (1992). They found that hatchability of total eggs set as 91.28, 86.08, 79.57 and 84.95% for Barred Plymouth Rock, White Leghorn, Rhode Island Red and White Rock, respectively.

Studies have shown that fertility can highly vary even within the same breed mainly due to poor management and improper proportion of males or poor ability of males in the flock to produce viable sperms (Murad *et al.*, 2001; Islam *et al.*, 2002; Zelleke *et al.*, 2005 and Jayarajan, 1992). Variations in hatchability on the other hand can be accounted for by various factors. Several researchers have reported that hatchability decreases with increasing egg storage period as percentage early and late embryonic mortality increases (Elibol and Brake, 2008 and Hrnčár and Bujko, 2012).

2.7. Consumers preference for chicken meat and egg and behaviour of chickens

There are two types of meat and egg chickens on the local market: exotic and local. Consumer preference for any of these birds varies from one individual to another. In terms of adaptive traits and consumption the indigenous chickens were considered favourable. Nigussie *et al.* (2010) reported that the main reason for preference of local chicken meat and egg was its perceived good taste. Most of the respondents have the opinion that the eggs (90%) and meat (92%) obtained from modern breeds have poorer taste. According to (Senbeta *et al.*, 2015) almost half of respondents preferred to buy eggs of local chickens as they were considered to be tasty and the yellow coloured yolk was commonly favoured. Respondents explained that eggs from local chickens tastes better because they are scavenging natural rather than formulated feed (chemical feed). Others preferred to buy eggs of exotic chickens as they were considered to be large in size to maximize utility and better visual attractiveness of the shell colour and few respondents cannot choose for the breeds of eggs understood for their similar nutrition.

Similarly, Fisseha (2009) reported in his study that most consumers preferred to buy local eggs from producers as they were considered to be tasty and attractive dark coloured yolk. Consumer preference observed for eggs from local, improved and both local and improved chicken were 77.8%, 17.8% and 4.4% respondents in Ada'a and 87.8%, 7.8% and 4.4%, in Lume districts, respectively, as reported by (Desalew, 2012).

Shell colour is another factor that influences consumer choice. Shell colour is not an indication of internal egg quality and says nothing about the nutritive value or the quality of the egg (Flock *et al.,* 2007). However, (Senbeta *et al.,* 2015) reported that there is usually a consumer preference to either white or brown, which needs to be given a due consideration in marketing eggs. In this regard, more than half prefer brown-shelled eggs, incorrectly believing them to be more nutritious and a better taste than white eggs and also, they expected as brown eggs comes from local hens with attractive yellow yolk colours. On the other hand, some respondents were found to prefer white shelled eggs as they appear cleaner and fresher, while other consumers do not pay attention to the colour of the shell considered as the same function and quality. However, there is no evidence that white and brown eggs have different nutritional value (Goddard *et al.,* 2007).

Additionally, Odabasi *et al.* (2007) reported that consumers in United Kingdom, Italy, Portugal, Ireland, Southeast Asia, Australia, and New Zealand prefer brown eggs over white eggs. On the other hand, white eggs are most in demand among Americans (Jacob *et al.,* 2000; Johnston *et al.,* 2011), and Japanese consumers (Hashimoto *et al.,* 2011). The preference for brown shelled eggs in New England (Jacob *et al.,* 2000), United Kingdom, Australia and New Zealand (Odabasi *et al.,* 2007) indicates a cultural dimension to egg shell colour preference considering the common geo-cultural origin of populations in these regions.

One of the essential characteristic for scavenging chicken that have been suggested by two workers (Rao, 2002; Singh, 2003) is morphology and temperament of the bird. In backyard areas where there is always danger of predators like wild cats, too many stray dogs etc. a lighter bird with long shank and strong wings has a greater chance of escaping from predators by fast running and flying till they reach a safer place. If possible the birds should have an aggressive behaviour, which may act as deterrent to some extent. Most of the respondents claimed that the modern breed is poor in disease and stress tolerance (86%) and in the ability to escape predators prevalent in their village conditions (96%) (Nigussie *et al.*, 2010). On the other hand, the local chickens have the capability of self-defence from predators due to its alertness, light body weight, longer shank length, camouflagic characters and aggressiveness.

Nesting and laying are also important forms of behaviour in laying hens. Pre-laying behaviour is initiated by hormonal changes that accompany ovulation and hens seek out potential nest sites each time they lay an egg. Although hens typically prefer to lay eggs in nests, it is not unusual for some eggs to be laid on the floor of the hen house or on the ground. Nest site preference, however, depends on environmental cues, including the nest site surroundings and substrates. Hens prefer to lay in enclosed or secluded nest sites (Appleby and Smith, 1991), and work harder for access to enclosed nest sites than for open nest sites (Cooper and Appleby, 1994a). Hens also prefer nest sites with mouldable or peckable nest-building substrates (Reed and Nicol, 1992). Hens may, therefore, floor lay, not because they are less motivated to seek out and use a nest site, but because man made nest boxes are poorly designed and unattractive.

Further, a major step towards the success of chickens as a domesticated species was the separation between maternal care and reproduction. Artificial incubation replaced the natural maternal behaviour of incubation and, thus, in certain breeds, it became possible to breed chickens with persistent egg production and no incubation behaviour; a typical example is the White Leghorn strain. Conversely, some strains, such as the Silkie breed, are prized for their maternal behaviour and their willingness to incubate eggs. This is often colloquially known as broodiness (Basheer *et al.*, 2015). Hence, (Grobbelaar, 2008) confirmed the broody behaviour of Kk chicken who reported that this breed is very popular among rural farmers in South Africa and neighboring countries for egg and meat production as well as their ability to hatch their own offspring.

Broody behaviour consists termination of egg production, the incubation of eggs, and care of the young. The onset of incubation occurs coincident with complete regression of the ovary and accessory reproductive tissues such as the oviduct and comb. In present-day commercial egg-producing hens, broodiness is virtually non-existent, but is still present in the Bantam hen and broiler-breeder and is common in turkeys. Broody behaviour is often accompanied by the development of an incubation (or brood) patch, and the increased vascularity, oedema, and thickening of the epidermis occurs under the regulation of estrogen and prolactin. Induction of incubation behaviour in turkey hens can be initiated by administration of prolactin, and active immunization against prolactin reduced the incidence or delayed the onset of broodiness in Bantam hens (March *et al.*, 1994).

In incubating gallinaceous birds, persistent nesting activity stimulates release of prolactin; the increased prolactin, in turn, maintains incubation behaviour (El Halawani *et al.*, 1991). According to Muhammad *et al.* (2014) anterior pituitary gland secrets a polypeptide hormone prolactin which have diverse range of biological functions and activities in vertebrates. The induction of broodiness and incubation behaviour is one of the most important function of prolactin in chickens (Talbot and Sharp, 1994). It has been observed that prolactin secretions may cause the regression of ovary, the regression of ovary may lead to reduction in egg production (Shimada *et al.*, 1991). Removal or reduction of broodiness might have possibility to be due to the inhibition of prolactin expression, reducing its secretions or blocking of the receptors binding sites (Rozenboim *et al.*, 1996).

Regarding feed consumption of different genotypes, higher feed intake was reported by McCrea *et al.* (2014) in which broilers was consistently greater than that of the Delawares. According to Akhtar *et al.* (2007) feed consumption per bird per week in Fayoumi was significantly ($P<0.05$) higher compared to that of Lyallpur Silver Black (LSB) and RIR. The lowest feed consumption per bird per week was recorded in RIR birds. Jaroni *et al.* (1999) also reported that strain showed a significant ($P<0.05$) effect on feed intake rather than that of rearing diet. Normally, feed consumption is considered a heritable characteristic, however, a probable explanation for more feed consumption in Fayoumi birds might be their activeness, where a large portion of feed might have been consumed in their physical activities. Further (Barua *et al.,* 1992) reported that average feed consumption up to 25 weeks of age for White Leghorn*Naked Neck (WL*NN), RIR*NN, WL and RIR respectively were 8041.95g, 7864.71g, 7530.52g and 7054.93g.

3. MATERIALS AND METHODS

3.1. Experimental Site

The Amhara National Regional State (ANRS) is one of the nine states of the Federal Democratic Republic of Ethiopia. The ANRS is divided in to different administrative zones, one of which is South Wollo. Kalu is one of the *Woreda* of South Wollo administrative zone, and shares borders with Worebabo and Tehuledere *Woreda* in the North, with Dessie zuria *Woreda* in the West, with Oromia administrative zone in the South and in the East. The *Woreda* is situated in the North-eastern zone of Amhara region (Figure 1).

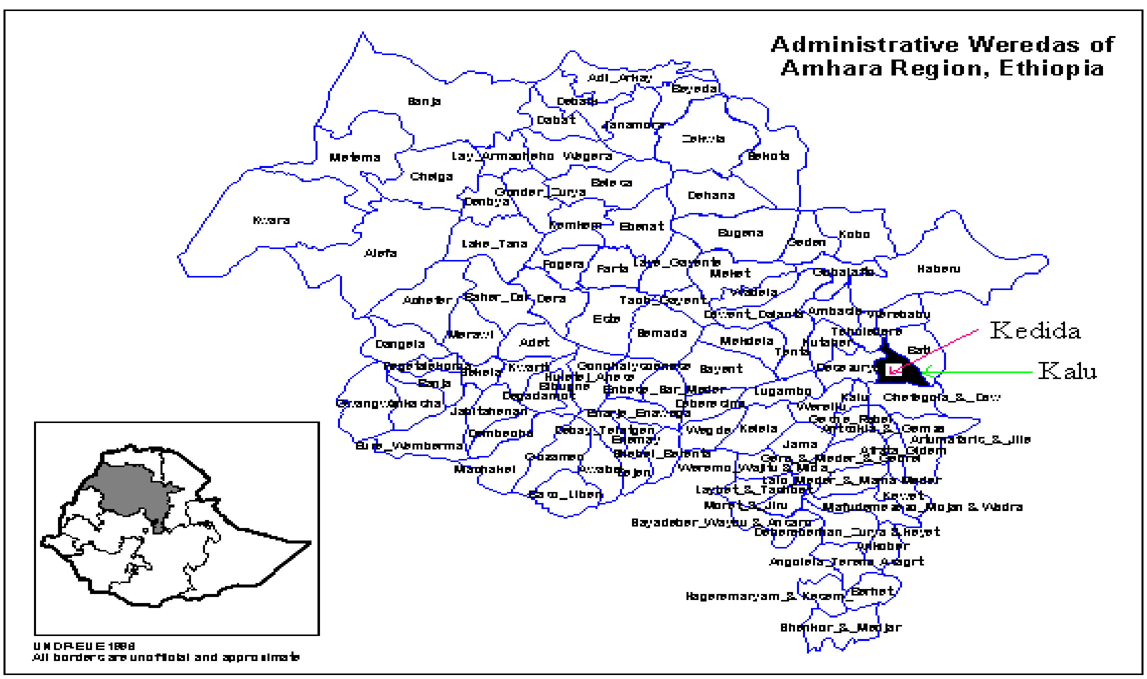

Figure 1. Location of Kalu Woreda, Kombolcha town and Kedida kebele of Amhara Region.

The research was conducted in Kalu *Woreda*, phase I in Kombolcha town and phase II in Kedida village. The sites are located 375 km Northeast of Addis Ababa and 25 km from the main town of South Wollo, Dessie. The geographical location of the experimental site is between 11˚05`00″ N latitude and 39˚43`00″ E longitude with an altitude ranges from 1810 to 1839 meters above sea level and with average temperatures ranging between 12.5 to 18.15ºC; and average humidity 53% having the range of 50 and 57% relative humidity (RH) and average annual rain fall (RF) ranges from 750 to 900mm (Archives of Kalu district of Agriculture). During the experimental period; AT, RH and RF of Kombolcha town were collected from Kombolcha meteorology station. Accordingly, the average minimum and maximum ambient temperature (AT), for the cold season (CS), hot season (HSe) and main rainy season (MRS) were 10.1/25.6, 14.5/29, 13.9/27.3^{O}C; average RH 56.5, 49, 60.5% and total RF 33.8, 52 and 199.8 mm respectively. Based on the recent classification of agro-ecological zones by the MOA (2000) the experimental site is located in mid high land and sub-moist Π.

3.2. Experimental Design

The experiment of phase I was arranged in 2x3 factorial experiment in Completely Randomized Design (CRD). There were two factors, the 1st factor with two levels and the 2nd with three levels as given below, with 6 treatments replicated three times.

Factor A- Breed; levels: a_0-BB Factor B Season; levels: b_0-CS

a_1-Kk b_1-HSe

b_2-MRS

One hundred fifty chicks from each breed were assigned to CS, HSe and MRS (Table 1).

Table 1. Breeds of day-old chicks and distribution of birds among the seasons in Phase I

Seasons	Breeds	
	Bovans Brown (BB)	Koekoek (Kk)
Cold Season (CS)-October 21/2013-January 19/2014	150	150
Hot Season (HSe)-March 25-June 22/2014	150	150
Main Rainy Season (MRS)-July 24 -October 21/2014	150	150

Therefore, the arrangements of the six treatments of phase I are:

T1= BB-CS, T2= Kk-CS, T3=BB-HSe, T4= Kk-HSe, T5=BB-MRS, T6=Kk-MRS

However, based on the three meteorological variables i.e. ambient temperature, relative humidity and rain fall, seasons in most parts of the country might be classified in to three; CS, HSe and MRS which covered the months between October to January, February to May and June to September respectively. Of course, some variations are observed in some years.

Group formation for two-way (Br*Se) interaction of phase one are presented below:

Group 1-6; BB*CS, BB*HSe, BB*MRS, Kk*CS, Kk*HSe, Kk*MRS; respectively.

Phase II was arranged in 2x2x3 factorial experiment in CRD as illustrated in Table 2, and with factors and levels as given below.

Factor C; Breed, levels: c_0-BB

c_1-KK

Factor D; Feeding regime (FR), levels: d_0-Supplemented with scavenging (SU)

d_1-Non-supplemented or Scavenging only (NS)

Factor E; Seasons, levels: e_0-HSe, e_1-MRS, e_2-CS

Hot season, MRS, and CS of the experimental period covered the age between 181-270 days (lasted from April 19-July 17/2014), 271-360 days (July 18-October 15/2014), and 361-450 days (October 16/2014-January 13/2015), respectively. But the growing period was the age between the distribution of the birds at 91 to 180-day age which lasted from January 20-April 18/2014. This time considered as an adaptation period of the birds.

Table 2. Treatment combinations for phase II

Factors and levels		Treatments 1	2	3	4
Breed (Br)	Bovans Brown (BB)	+	+		
	Koekoek (Kk)			+	+
Feeding Regime (FR)	Supplemented (SU)	+		+	
	Non-Supplemented (NS)		+		+
Season (Se)	Hot Season (HSe)	+	+	+	+
	Main Rainy Season (MRS)	+	+	+	+
	Cold Season (CS)	+	+	+	+

As presented on Table 2 above, the arrangements of the treatments of phase II are:

T1=BB-S-HSe/MRS/CS; T2=BB-NS-HSe/MRS/CS; T3=Kk-S-HSe/MRS/CS; T4= Kk-NS-HSe/MRS/CS

Thus, the effects of the three seasons were evaluated on one batch of chickens.

Table 3. Group formation for two and three-way interaction effects of phase II

A. In two interaction effects

a) For Br*FR interaction	b) For Br*Se interaction	c) For FR*Se interaction
Group 1. BB*S	Group 1. BB*CS	Group 1. S*CS
Group 2. BB*NS	Group 2. BB*HSe	Group 2. S*HSe
Group 3. Kk*S	Group 3. BB*MRS	Group 3. S*MRS
Group 4. Kk*NS	Group 4. Kk*CS	Group 4. NS*CS
	Group 5. Kk*HSe	Group 5. NS*HSe
	Group 6. Kk*MRS	Group 6. NS*MRS

B. In three interaction effects for Br*FR*Se

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
BB*S*CS	BB*S*HSe	BB*S*MRS	BB*NS*CS	BB*NS*HSe	BB*NS*MRS
Group 7	Group 8	Group 9	Group 10	Group 11	Group 12
Kk*S*CS	Kk*S*HSe	Kk*S*MRS	Kk*NS*CS	Kk*NS*HSe	Kk*NS*MRS

Table 4. Layout of the experiment of phase II.

Treatment	Household	No of birds distributed/replicate distributed to farmers	Birds/treatment
1	3	6	18
2	3	6	18
3	3	6	18
4	3	6	18
Total-4	12	24	72

3.3. Farmers Selection

A total of 12 farmers to 4 treatments was randomly selected for phase two study, and each treatment was distributed to 3 households (HHs). The selected farmers were those who showed interest and had the experience of poultry rearing. They were of similar socioeconomic characteristics. For the sake of avoiding mixing up of the treatments all the four treatments were conducted separately. One-day training about the management of experimental birds was given. Besides, Amharic written leaflets on routine poultry husbandry were distributed and verified through time to time visits.

3.4. Management of Experimental Animals

The two breeds used for this experiment were BB and Kk. Koekoek breed was purchased from Kombolcha Poultry Multiplication Centre (KPMC), and BB from KPMC and from private poultry farms in Dessie and Mekele towns. The standard vaccination program was followed in all the treatments and birds were vaccinated once for Marek's disease on day 1, twice for Infectious Bursal disease on day 21 and 28, three times for Newcastle disease (on day 7-HB1 on day 18 and 42 LaSota), once for fowl pox on day 56. Birds were vaccinated against Marek`s disease at the farm before their distribution in Mekele and Dessie private poultry farms but KPMC did not vaccinate chicks against Marek`s disease. The rest of the vaccines were purchased from National Veterinary Institute (NVI) and application of the vaccine was as per the NVI prescription. Moreover, medications were given on regular basis to boost the immunity level of the birds. Foot bath containing formalin was also placed at the entrance of the house.

For phase I, a total of 900 unsexed day-old chicks (DOC) were reared till 90-days age on deep litter floor house. For the three seasons one-month brooding period was adopted and to adjust the recommended brooding temperature, one bulb was removed from each pen containing three 100 watt incandescent bulbs, every week. Hence exposure of the birds to the natural seasonal environmental variables started at the end of one month and continued till the end of 90 days' age. To study the effect of season on chick performance the same experiment was carried out in three different seasons. From Phase I-CS birds, 5 pullets and 1 cockerel at the age of 3 months were distributed to each of the 12 households making a total of 60 pullets and 12 cockerels for the whole experiment; during the second phase. Of the 60 pullets 30 were BB and 30 Kk; and from 12 cockerels 6 were BB and 6 Kk.

During the experimental period of Phase I, on average 3679g/b commercial feed was offered and their nutritional specification is shown in Table 5.

Table 5. Nutrient composition of commercial feed used for starters, growers and pullets/cockerels during Phase I.

Diet	Starter	Grower	Pullet/Cockerel
Age (weeks)	0-4	4-10	10-13
Nutrients			
Crude Protein (%)	20	18	16
Crude Fibre (%)	4.0	4.5	5.0
ME (kcal/kg)	2975	2875	2750
Crude fat (%)	4.0	3.7	3.5
Crude ash %	7.3	7.0	6.5
Methionine (%)	0.54	0.45	0.35
Lysine (%)	1.20	1.00	0.78
Available Phosphorus (%)	0.50	0.48	0.45
Sodium (%)	0.16	0.15	0.15
Added vitamins per Kg of feed			
Vitamin A, IU	13000	10000	10000
Vitamin D_3, IU	3000	2000	2500
Vitamin E, mg	25	25	25

For phase II, commercial feed with nutritional specification illustrated in Table 6; was supplemented to treatments 1 and 3, with 45g during 3-5 and 60g during 5-15 months of age per bird per day which was offered twice daily. The rest two-2 and 4 treatments left to scavenge only (NS). For all age groups vitamins, minerals and amino acid supplements were incorporated in the drinking water according to the manufacturer's recommendation and water was provided *ad libitum*. The feed was purchased from KPMC, as well as Desse and Mekele private poultry farms. The nutrient contents of the feed used mentioned above were calculated from each ingredient used for the formulation of the diet.

Table 6. Nutrient composition of commercial feed used for pullet/cockerel and layers during the experimental period of phase II.

Diet	Pullet/Cockerel	Layers
Age (months)	3-5	5-15
Nutrients		
Crude Protein (%)	16	16.5
Crude Fiber (%)	5	5.3
Metabolizable energy (kcal/kg)	2750	2800
Crude Fat (%)	3.5	7
Crude Ash (%)	6.5	12.5
Methionine (%)	0.35	0.39
Lysine (%)	0.78	0.8
Available Phosphorus (%)	0.45	0.35
Sodium (%)	0.15	0.19
Calcium (%)	2.2	4.2
Added Vitamins per kg of feed		
Vitamin A, IU	10000	12000
Vitamin D3, IU	2500	2500
Vitamin E, mg	25	20

3.5. Data Collection

The data were collected in two phases, the first phase on station and the second phase on-farm. From the first phase, feed intake-FI (g/b/d), RT(^{O}C) and mortality were recorded while average daily gain (ADG) and feed conversion ratio (FCR) were calculated. The feed offered to the breeds determined FI (g/b/d). Average daily gain is the amount of weight gained per day for the bird gained over a given period of time. Accordingly, ADG was obtained by dividing body weight gain with 88-day since the initial weight was taken at day 3 age of the birds, and the body weight gain was determined as the difference between the final and the initial weights taken during the experimental period on a sensitive scale. Feed conversion ratio was determined as the proportion of the weight of feed eaten by a bird per day to their ADG. Rectal temperature was taken from five sample birds of each replication using digital thermometer. The mortality was determined by recording birds that died during the experimental period.

The second phase includes RT, age at onset of egg laying (AOEL), total collected eggs (TCE) and mortality and reason of mortality or loss. Body weight gain, average egg weight (AEW) and egg mass (EM) were also calculated. These parameters were collected from all 12 households throughout the experimental period, excluding BWG and AOEL. Body weight gain was determined as the difference between the final (the weight obtained at the age 450th day or end of the experimental period) and the initial weights taken during the commencement of the experimental period (91st day age). Data on all egg production traits were collected between April 20/2014 and January 13/2015 for about 9 months. Average egg weight and EM were determined at sexual maturity, at 40 weeks of age and at the end of the experiment. The age at first egg within each of the treatment was determined AOEL. Rectal temperature was taken from one bird/replication once every three months. Data for egg production, mortality and supplement offered was collected daily on group basis from each of the HH. Attributes of mortality or loss were also recorded by taking the reason of mortality or loss, as the birds died or lost.

At the end of the experimental period of Phase II, 12 randomly selected hens were slaughtered (3 hens/treatment) for the purpose of measuring the effect of breed and feeding regimes on GI and reproductive tracts. The reproductive and GI tract measurements includes: relative length, relative empty weight and absolute weight with contents of esophagus, crop, proventriculus, gizzard, duodenal loop, small intestine (jejunum and ileum), caecum and large intestine; absolute and relative weight of ovary, with and without yellow follicles and number of normal and atretic yellow follicles (generally >6mm in size) and white ovarian follicles (>2-6 mm size) as well as their respective square-root transformed values, were taken prior to oviposition. Moreover, absolute and relative weight and length of infundibulum, magnum, isthmus, uterus and vagina, separately, excluding developing egg if present were also recorded.

Fertility and hatchability were assessed in 23 eggs from Kk and 18 eggs from BB, and the eggs from each breed were incubated three times under six broody hens. Eggs that were not stored for more than 3 days were collected on a single day, from those households who have eggs at the onset of incubation. They were set at the same time during the hot season, which lasted from April to May/2014. At the end of each incubation, all non-hatched eggs were broken and their fertility checked. Fertility and hatchability of fertile and total eggs set was compared. The formula for fertility and hatchability is as follows: -

Fertility (%)= number of fertile eggs/ number of eggs set X100

Hatchability on total eggs set (%)=number of chicks hatched/number eggs set X 100

Hatchability on fertile eggs (%)=number of chicks hatched/ number of fertile eggs X 100

Besides, farmers' perceptions about the chicken genotypes was captured using focus group discussions involving those households where Phase II of the experiment were conducted. Some of the points of discussion were; egg quality characteristics (visual-for example egg shell colour and size), marketability and taste of the eggs and meat, behavioural characteristics of the birds for management purposes i.e. their ability to escape from predators and thieves, nesting and brooding behaviour, as well as comparison of feed consumption of the birds.

3.6. Data Analysis

All the data were subjected to the General Linear Model (GLM) procedure of Statistical Analysis System (SAS) Copyright (c) 2002 by SAS Institute Inc., Cary, NC, USA. Least squares mean (LSM) were employed for mean comparisons and Tukey's Studentized Range (TSR) Test was used to separate the means. Arc Sine data transformation method (Gomez and Gomez, 1976) was used for percent mortality. Similarly, for ovarian follicles (in terms of number), square-root data transformation method was used to analyse the data. Square root data transformation is appropriate for data consisting of small whole numbers. If most of the values in the data set are small (eg less than 10, especially with zeros present, $(X+0.5)^{1/2}$ should be used instead of $X^{1/2}$, where X is the original data. An arc sine transformation is appropriate for data on proportions, data obtained from a count, and data expressed as decimal fractions or percentages. The mechanics of data transformation are greatly facilitated by using a table of the arc sine transformation.

Moreover, the mean comparisons were treated in two ways. The first one employed in phase I and II or in the major parameters which directly meet to the objectives of the experiment were compared all the treatment combinations. The mean comparisons in the reproductive and digestive tract measurements, that evaluates the experiment indirectly or which supports the results of phase II, compared the means of the main effects only. Mean comparisons employed for fertility and hatchability compared the eggs collected from the two breeds.

Coefficient of variation, root MSE, and mean; and also, F and P values have been given in appendices tables.

The processes employed the following models:

Phase I; $Yij=\mu+a_i+b_j+(ab)_{ij}+e_{ij}$

Where:

Y_{ij} =The observation taken at the i^{th} breed and j^{th} season.

μ =The overall mean of the population.

a_i =The effect due to the i^{th} breed.

b_j =The effect due to the j^{th} season.

$(ab)_{ij}$ =The effect due to the interaction between the i^{th} breed and the j^{th} season.

e_{ij} =Random error associated with the observation Y_{ij}

Phase II; $Y_{ijk} = \mu + c_i + d_j + (cd)_{ij} + e_k + (ce)_{ik} + (de)_{jk} + (cde)_{ijk} + e_{ijk}$

Where:

Y_{ijk} = The observation taken at the i^{th} breed, j^{th} feeding regime, and k^{th} season

μ = The overall mean of the population for Y_{ijk}

c_i = The effect due to the i^{th} breed

d_j = The effect due to the j^{th} feeding regime

e_k = The effect due to the k^{th} season

$(cd)_{ij}$ = The effect due to interaction between the i^{th} breed and the j^{th} feeding regime

$(ce)_{ik}$ = The effect due to the interaction between the i^{th} breed and the k^{th} season

$(de)_{jk}$ = The effect due to the interaction between the j^{th} feeding regime and k^{th} season

$(cde)_{ijk}$ = The effect due to the interaction between i^{th} breed, j^{th} feeding regime and k^{th} season

e_{ijk} = Random error associated with the observation Y_{ijk}

Furthermore, appropriate descriptive statistics was employed to evaluate the farmer's perception on the chicken genotypes.

4. RESULTS

This section describes the results of Phases I and II; which included FI, ADG, FCR, RT and mortality for Phase I; BWG, RT, egg production traits, mortality, reproductive and gastro intestinal tract measurements, fertility and hatchability, and perception of farmers for Phase II.

4.1. Phase I

The detail results of Phase I; the performances, RT and mortality are presented in the ANOVA (Appendix Table 1), and least squares mean (LSM) of the main effects in Table 7, and the interaction effects in Table 8.

4.1.1. Feed intake (FIg/b/d)

Significantly ($p>0.05$) higher feed intake (FIg/b/d) was observed in BB compared to the Koekoek breed (Table 7). However, there was no significant ($p>0.05$) difference between seasons in FIg/b/d. The effect of breed by season interaction (Table 8) on the other hand, indicated that BB was significantly superior in FIg/b/d across the seasons and Koekoek breed during the HSe. Significantly ($p<0.5$) lower FIg/b/d was recorded in the Koekoek breed during the MRS.

Table 7. Least squares mean (LSM) and standard error (SE) values of the main effects of breed and season for various performance traits of Phase I (n=18).

Dep. Var.	Br				Se					
	BB		Koekoek		CS		HSe		MRS	
	LSM	SE	LSM	SE	LSM	SE	LSM	SE	LSM	SE
FIg/b/d	42.27^{a}	0.45	39.49^{b}	0.98	41.17^{a}	0.52	41.73^{a}	0.20	39.73^{a}	1.79
ADGg	6.93^{b}	0.29	8.24^{a}	0.65	6.06^{b}	0.24	8.09^{a}	0.65	8.61^{a}	0.50
FCR	6.17^{a}	0.21	5.25^{b}	0.56	7.06^{a}	0.18	5.31^{b}	0.39	5.75^{b}	0.47
RT^{O}C	41.86^{a}	0.17	41.94^{a}	0.23	41.22^{c}	0.06	42.58^{a}	0.11	41.90^{b}	0.06
Mortality (%)	2.89^{b}	0.59	9.78^{a}	2.12	6.00^{a}	1.55	4.00^{a}	0.52	9.00^{a}	3.68

abc: - means with different superscript in a row are significantly different from each other within the main effect. LSM-Least squares mean, Dep. Var.-Dependent Variables, Br-Breed, Se-Season, BB-Bovans Brown, CS-cold season, HSe-hot season, MRS-main rainy season, FIg/b/d- feed intake in gram, ADG-average daily gain, FCR-feed conversion ratio, RT^{O}C- rectal temperature in ^{O}C.

4.1.2. Average daily gain (ADG)

Average daily gain (ADG) in the main effects Breed and Season are shown in Table 7. In this study from main effect breed, Koekoek was significantly ($p<0.5$) superior in ADG to their BB counterparts. From season main effect, ADG was significantly ($p<0.5$) higher in the MRS followed by HSe and significantly ($p<0.5$) lower during the CS. Breed by season interaction (Table 8) showed that Koekoek breed during the MRS followed by Koekoek breed during the HSe and then the BB during the HSe had significantly ($p<0.5$) higher ADG. Both breeds showed significantly ($p<0.5$) poor ADG performance during the cold season.

Table 8. Least squares mean and standard error values for interaction effects of breed with season for various performance traits of Phase I (n=18).

				Dep. Var.				
				FIg/b/d	ADGg	FCR	RT^{O}C	Mortality %
Br*Se	BB	CS	LSM	41.77^{a}	6.16^{c}	6.78a^{b}	41.22^{d}	3.33^{b}
			SE	0.53	0.08	0.03	0.14	1.33
		HSe	LSM	41.97^{a}	6.96^{bc}	6.05^{ab}	42.36^{b}	3.33^{b}
			SE	0.33	0.29	0.21	0.07	0.67
		MRS	LSM	43.07^{a}	7.67^{abc}	5.68^{bc}	41.99^{c}	2.00^{b}
			SE	1.24	0.56	0.40	0.04	1.16
	Kk	CS	LSM	40.57^{ab}	5.95^{c}	7.34^{a}	41.21^{d}	8.67^{ab}
			SE	0.84	0.52	0.29	0.02	1.76
		HSe	LSM	41.50^{a}	9.21^{ab}	4.58^{dc}	42.81^{a}	4.67^{b}
			SE	0.17	0.88	0.40	0.06	0.67
		MRS	LSM	36.40^{b}	9.55^{a}	3.82^{d}	41.80^{c}	16.00^{a}
			SE	1.82	0.20	0.25	0.07	4.16

abcd: - means with different superscript in a row are significantly different from each other within the two interaction effects

4.1.3. Feed conversion ratio (FCR)

In the present study, the main effect breed showed that Koekoek had significantly better feed conversion ratio (FCR) over BB breed. The main effect season revealed that HSe and MRS birds showed significantly ($p<0.5$) better FCR and significantly ($p<0.5$) poorer

FCR was recorded during the CS (Table 7). From the interaction between breed and season, significantly ($p<0.5$) better FCR was noted in the Koekoek breed during the MRS and significantly ($p<0.5$) poorer FCR was recorded in the Koekoek breed during the CS.

4.1.4. Rectal temperature (RT^{O}C)

There was no significant difference for rectal temperature (RT) among breeds (Table 7), but from season main effect significantly ($p<0.5$) higher RT was recorded during the HSe (42.58^{O}C), followed by MRS and the lower RT was recorded during the CS (41.22^{O}C). Again, from the interaction between breed and season Koekoek breed during the HSe showed significantly ($p<0.5$) higher RT (42.81^{O}C), followed by the interaction between BB and hot season and significantly ($p<0.5$) lower RT^{O}C was recorded in both breeds during the cold season (BB-41.22^{O}C and Koekoek-41.21^{O}C).

4.1.5. Mortality

This study showed that significantly ($p<0.5$) higher mortality was observed in the Koekoek breed (9.78%) and BB had less mortality (2.89%) (Table 7). Even though season did not affect mortality, it was affected by the interaction effect of breed by season with the highest mortality value recorded during the MRS in the Koekoek breed (16%) followed by during the CS in this same breed (8.67%) (Table 8).

4.2. Phase II

The detail results of Phase II; BWG, $RT^{O}C$, different egg production traits and mortality are presented in the ANOVA (Appendix Table 4); and least squares means of the main effects in Table 9, and the interaction effects is available in Tables 10-14.

4.2.1. Body weight gain (BWGg)

In the present study from breed main effect, the Koekoek breed were significantly ($p<0.5$) higher in body weight gain (1159g) than their BB counterparts (856g). From feeding regimes main effect, supplemented birds (1101g) had higher BWG compared to the non-supplemented groups (870g) (Table 9). Among the interaction between breed and feeding regimes, the Koekoek breed due to supplementation obtained significantly ($p<0.5$) higher BWG (1273g) (Table 10). However, there was no significant ($p>0.05$) difference between the rest of the two-way interaction effects of breed and feeding regimes. The lower BWG from this two-way interaction was the interaction between BB-non-supplemented birds. Though insignificant supplemented BB showed higher BWG (930g) than the non-supplemented BB (783g).

Table 9. Least squares mean and standard error values of the main effects of breed, feeding regime and season for various performance traits of Phase II (n=36)

Dep. Var.		Breed		FR		Season		
		BB	Koekoek	S	NS	HSe	MRS	CS
BWG (g)	LSM	856^{b}	1115^{a}	1101^{a}	870^{b}	0^{b}	0^{b}	986^{a}
	SE	37.83	88.37	83.05	60.54	-	-	-
RT^{O}C	LSM	42.08^{b}	42.26^{a}	42.28^{a}	42.06^{b}	42.54^{a}	42.26^{b}	41.71^{c}
	SE	0.08	0.10	0.09	0.09	0.07	0.05	0.05
TCE (Number)	LSM	87^{b}	119^{a}	111^{a}	95^{a}	92^{a}	108^{a}	108^{a}
	SE	6.89	6.18	6.45	8.26	9.06	10.34	8.04
AEW (g)	LSM	53.3^{a}	42.4^{b}	47.6^{a}	48.1^{a}	47.40^{a}	47.16^{a}	49^{a}
	SE	0.53	0.80	6.42	1.45	1.86	1.54	2.05
EM (g)	LSM	4694^{a}	5167^{a}	5377^{a}	4484^{a}	5006^{a}	4233^{a}	5552^{a}
	SE	394	281	297	359	391	375	429
AOEL (days)	LSM	194^{a}	188^{a}	185^{b}	197^{a}	176^{a}	0^{b}	0^{b}
	SE	4.21	2.81	2.13	2.95	2.06	-	-
Mortality (%)	LSM	15.73^{a}	10.19^{a}	12.04^{a}	13.89^{a}	15.27^{a}	15.28^{a}	8.34^{a}
	SE	3.43	1.97	2.26	3.37	3.81	2.51	3.82

abc: - means with different superscript in a row are significantly different from each other within the main effect. SU-supplemented, NS-non-supplemented, BWG-body weight gain, RT^{O}C -rectal temperature in ^{O}C, TCE-total collected eggs, AEW-average egg weight, EM-egg mass, AOEL-age at onset of egg laying.

4.2.2. Rectal temperature ($RT^{O}C$)

Significantly ($p<0.5$) higher rectal temperature (RT) was recorded in the Koekoek breed (42.26^{O}C) compared to the BB chicken (42.08^{O}C) (Table 9). On the other hand, supplemented birds showed significantly ($p<0.5$) higher RT (42.28^{O}C) than the non-supplemented groups (42.06^{O}C). Season had a significant effect ($p<0.5$) on RT where a higher value was recorded in the HSe (42.54^{O}C) birds followed by in the MRS, the lowest RT was recorded during the cold season (41.71^{O}C).

The interaction between breed and feeding regimes (Table 10) showed a significant ($p<0.5$) effect on RT where supplemented Koekoek chicken exhibited the highest (42.51^{O}C). The lowest RT was recorded in non-supplemented BB chicken (41.97^{O}C). The higher values of the Koekoek chicken breed both on supplementation and on scavenging only feeding regimes could be due to the effect of higher BW in this breed than the effect of supplementation. However, effect of supplementation was more pronounced in the BB. The difference in RT between supplemented and non-supplemented BB was 0.21^{O}C and on the reverse the difference in the non-supplemented and supplemented Koekoek chicken breed was 0.13^{O}C. The reason for the unexpected higher RT of the non-supplemented compared the supplemented Koekoek chicken breed was due to mere chance.

The interaction between breed and season (Table 11) indicated that significantly ($p<0.5$) higher RT in the Koekoek breed during the HSe (42.73^{O}C) and significantly ($p<0.5$) lower RT recorded in both BB and Koekoek chickens during the CS (41.69^{O}C and 41.73^{O}C). The higher rectal temperature of the Koekoek breed is clearly observed here in this two-way interaction too. Feeding regimes with season interaction (Table 12) revealed that birds supplemented during the HSe noted significantly (p<0.5) higher RT (42.63^{O}C) and significantly (p<0.5) lower RT recorded in non-supplemented birds during the CS (41.57^{O}C). The higher RT values in the interaction between supplemented and hot season birds could be due to the effects of more feed intake in the supplemented birds and due to the higher ambient temperature during the hot season. The overall two-way interaction showed higher values between the interaction of breed and season (42.73^{O}C) in the Koekoek*hot season birds which indicated that larger sized breeds with higher feed intake from both supplementation and scavenging had more body heat production than the rest of the two-way interactions.

The three-way interaction between breed, feeding regimes and season (Table 13 and 14) in this study revealed higher rectal temperature (42.83 ^{O}C) in the Koekoek*supplemented*hot season birds and this value pointed out higher feed intake and ambient temperature had more effect on larger breeds compared to the lighter ones. As indicated above, the Koekoek chicken with supplementation recorded significantly (p<0.5) higher RT during the HSe (42.83^{O}C) and significantly (p<0.5) lower RT recorded in BB chicken without supplementation during the cold season (41.55^{O}C). In general; it is clearly observed that higher RT is recorded in the Koekoek breed and its two and three-way interactions, as well as HSe birds and their interactions.

4.2.3. Egg production traits

Egg production is a composite of at least the following four traits: age at onset of egg laying-AOEL, total collected eggs-TCE, average egg weight-AEW and egg mass-EM.

Table 10. Least squares mean and standard error values of the two-way interactions effect of breed with feeding regime for various performance traits of Phase II (n=36).

Dep. Var.				BWG	RT	TCE	AEW	EM	AOEL	Mort (%)
Br*FR	BB	S	LSM	930[b]	42.18[b]	99[ab]	52.89[a]	5372[a]	185[b]	14.82[a]
			SE	18.27	0.09	8.14	0.77	469	1.67	3.34
		NS	LSM	783[b]	41.97[c]	74[b]	53.71[a]	4016[a]	202[a]	16.66[a]
			SE	38	0.11	9.73	0.75	569	3.71	6.21
	Kk	S	LSM	1273[a]	42.38[b]	122[a]	42.28[b]	5382[a]	184[b]	9.26[a]
			SE	68.46	0.14	8.86	1.46	392	4.37	2.93
		NS	LSM	957[b]	42.51[a]	116[a]	42.51[b]	4953[a]	192[ab]	11.11[a]
			SE	96.70	0.15	9.04	0.77	412	1.73	2.78

abc: - means with different superscript in a row are significantly different from each other within the two interaction effects

4.2.3.1. Age at onset of egg laying (AOEL)

Though Koekoek breed reach earlier, there was no significant (p>0.05) difference between breeds in the age at onset egg laying (AOEL). However, in the feeding regimes main effect (Table 9), significantly (p<0.5) earlier AOEL was noted in supplemented (185 days) compared to the non-supplemented (197 days) birds. Among the two-way interaction effects of breed and feeding regimes (Table 10), both breeds showed significantly (p<0.5) earlier AOEL due to supplementation.

Table 11. Least squares mean and standard error values of the two-way interactions effect of breed with season for various performance traits of Phase II (n=36).

Dep. Var.				BWG	RT	TCE	AEW	EM	AOEL	Mort (%)
Br*Se	BB	CS	LSM	-----	41.69[d]	101[ab]	54.45[a]	5744[a]	----	8.34[a]
			SE	-----	0.07	13.20	1.32	767	----	3.73
		HSe	LSM	-----	42.36[b]	85[ab]	53.38[a]	4529[a]	----	19.43[a]
			SE	-----	0.04	9.4	0.56	491	----	6.68
		MRS	LSM	-----	42.19[bc]	73[b]	52.07[a]	3808[a]	----	19.45[a]
			SE	-----	0.05	11.95	0.49	606	----	6.69
	Kk	CS	LSM	-----	41.73[d]	116[ab]	43.55[b]	5361[a]	----	8.34[a]
			SE	-----	0.06	9.48	12.81	9.19	----	3.73
		HSe	LSM	-----	42.73[a]	132[a]	41.40[b]	5483[a]	----	11.11[a]
			SE	-----	0.06	12.81	0.78	583	----	3.51
		MRS	LSM	-----	42.33[bc]	110[ab]	42.25[b]	4659[a]	----	11.11[a]
			SE	-----	0.06	9.19	0.71	423		3.51

abcd: - means with different superscript in a row are significantly different from each other within the two interaction effects

4.*2.3.2. Total collected eggs (TCE)*

As observed in this study from the main effect of breed, Koekoek breed showed significantly ($p<0.5$) higher total collected eggs (119) compared to the BB (87). There was insignificant ($p>0.05$) difference between feeding regimes and season main effects on TCE. From the interaction between breed and feeding regimes both supplemented and non-supplemented Koekoek chicken yielded significantly ($p<0.5$) higher TCE (122 and 116), and lower TCE was noted in non-supplemented BB chicken (74) (Table 10). Significantly ($p<0.5$) higher TCE was recorded in the Koekoek chicken during the HSe and lower TCE was observed in the BB chicken during the MRS from the interaction between breed with season (Table 11). There was no significant ($p>0.05$) interaction between feeding regimes and season. From the three-way interaction effects, significantly ($p<0.5$) higher TCE was recorded in supplemented Koekoek chicken during the hot season (145), and significantly ($p<0.5$) lower TCE observed in non-supplemented BB chicken during the main rainy season (56) (Table 13 and 14).

Table 12. Least squares mean and standard error values for the two-way interactions effect of feeding regime with season on various performance traits of Phase II (n=36).

Dep. Var.				BWG	RT	TCE	AEW	EM	AOEL	Mort (%)
FR*Se	S	CS	LSM	-----	41.85[d]	113[a]	47.72[a]	5934[a]	----	11.11[a]
			SE	-----	0.03	5.90	3.45	459	-----	3.51
		HSe	LSM	-----	42.63[a]	117[a]	47.55[a]	5411[a]	-----	11.11[a]
			SE	-----	0.10	15.22	2.77	527	-----	5.55
		MRS	LSM	-----	42.37[b]	102[a]	47.50[a]	4786[a]	-----	13.89[a]
			SE	-----	0.05	11.55	1.96	523	-----	2.78
	NS	CS	LSM	-----	41.57[e]	104[a]	50.28[a]	5170[a]	-----	5.56[a]
			SE	-----	0.03	15.51	2.45	734	-----	3.51
		HSe	LSM	-----	42.45[b]	100[a]	47.23[a]	4601[a]	-----	19.44[a]
			SE	-----	0.08	14.51	2.76	573	-----	5.12
		MRS	LSM	-----	42.15[c]	82[a]	46.82[a]	3681[a]	-----	16.67[a]
			SE	-----	0.04	13.74	2.55	470	-----	7.45

abcde: - means with different superscript in a row are significantly different from each other within the two interaction effects

4.2.3.3. Average egg weight (AEWg)

The present study showed that BB yielded significantly ($p<0.5$) higher average egg weight (53.3g) compared to the Koekoek chicken (42.4g). However, there was no significant ($p>0.05$) difference in the main effects feeding regimes and season. From the interaction between breed and feeding regimes, significantly ($p<0.5$) higher AEW was recorded in both supplemented and non-supplemented BB breed (52.89g and 53.71g) and the reverse was true in the Koekoek chicken. Similar pattern was observed in the interaction of breed and season, BB showed significantly ($p<0.5$) higher AEW in all the seasons unlike the Koekoek that showed significantly ($p<0.5$) lower AEW in all the seasons. However, no significant ($p<0.5$) difference was observed in the interaction effects of feeding regimes and season. The three-way interactions also showed that BB with or without supplementation in all the seasons had significantly ($p<0.5$) higher AEW. In general, BB breed main effect, two and three-way interaction with BB chicken yielded higher AEW.

4.2.3.4. Egg mass (EM)

There was insignificant ($p<0.5$) difference in EM in all of the breed, feeding regimes and season main effects and the two-way interaction effects of breed and feeding regimes, breed and season, and feeding regimes and season as well as three-way interaction effects of breed, feeding regimes and season. Finally, Kk and BB chickens attain AOEL at 188±2.81 and 194±4.21 days and produced 119±6.18 and 87±6.89 eggs with an AEW of ±42.4±0.8 and 53.3±0.53g, respectively.

Table 13. Least squares mean and standard error values of the three-way interaction of breed with feeding regime with season for various performance traits of Phase II (n=36).

Dep. Var.					$RT^{O}C$	TCE	AEW	EM	Mort (%)
Br*FR*Se	BB	S	CS	LSM	41.83^{fg}	119^{ab}	53.47^{ab}	6752^{a}	11.11^{a}
				SE	0.06	6.69	2.07	231	5.56
			HSe	LSM	42.43^{bc}	88^{ab}	53.50^{ab}	4705^{a}	16.67^{a}
				SE	0.05	9.07	1.19	478	9.61
			MRS	LSM	42.29^{cd}	90^{ab}	51.70^{abc}	4658^{a}	16.67^{a}
				SE	0.04	19.06	0.57	963	0.0
		NS	CS	LSM	41.55^{h}	83^{ab}	55.43^{a}	4736^{a}	5.56^{a}
				SE	0.05	22.28	1.86	1369	5.56
			HSe	LSM	42.29^{cd}	82^{ab}	53.27^{ab}	4353^{a}	22.20^{a}
				SE	0.04	18.72	0.35	972	11.10
			MRS	LSM	42.09^{de}	56^{b}	52.43^{ab}	2957^{a}	22.22^{a}
				SE	0.04	7.89	0.87	4.32	14.70

Table 14. Least squares mean and standard error values of the three-way interaction of breed with feeding regime with season for various performance traits of Phase II (n=36) (Cont).

Dep. Var.					RT^{O}C	TCE	AEW	EM	Mort (%)
			CS	LSM	41.87^{ef}	107^{ab}	41.97^{d}	5117^{a}	11.11^{a}
				SE	0.04	9.54	4.70	577	5.56
			HSe	LSM	42.83^{a}	145^{a}	41.60^{d}	6116^{a}	5.56^{a}
		S		SE	0.05	15.96	1.20	814	5.56
			MRS	LSM	42.44^{bc}	113^{ab}	43.30^{cd}	4913^{a}	11.11^{a}
				SE	0.06	13.12	1.07	660	5.56
Br*FR*Se	Kk		CS	LSM	41.60^{gh}	124^{ab}	45.13^{bcd}	5604^{a}	5.56^{a}
				SE	0.04	16.92	0.24	0.96	5.56
			HSe	LSM	42.62^{ab}	118^{ab}	41.20^{d}	4849^{a}	16.67^{a}
		NS		SE	0.04	19.47	1.25	798	0.0
			MRS	LSM	42.21^{cd}	107^{ab}	41.20^{d}	4405^{a}	11.11^{a}
				SE	0.04	15.52	0.53	628	5.56

abcdefgh: - means with different superscript in a row are significantly different from each other within the two interaction effects. Kk-Koekoek.

4.2.4. Mortality and reasons of mortality or loss

The detail results of mortality and reasons of mortality or loss of phase II are presented in the ANOVA (Appendix Table 8); and least squares means of the main effects is in Table 15 and interaction effects in (Appendix Tables 9-12).

In this study, there was no significant ($p>0.05$) difference between breeds, feeding regimes and season main effects and their interaction on mortality. There was also a non-significant difference between breeds, feeding regimes, season main effects and their interactions in any of the causes of mortality, except significant ($p<0.5$) difference noted in the mortality due to unidentified diseases (UD). The higher values due to UD were 8.51% in the BB breed (Table 15) among the main effects; 11.48% in the supplemented BB chickens, among the interaction between breed with feeding regimes and 13.89% in BB chickens during the MRS, from breed with season interaction effects (Appendix Table 9).

Table 15. Least squares mean and standard error values of the main effects of breed, feeding regime and season for the Reason of Mortality or loss of Phase II (n=36).

Dep. Var.		Breed		FR		Season		
		BB	Kk	S	NS	HSe	MRS	CS
Mort. (%)	LSM	15.74[a]	10.19[a]	12.04[a]	13.89[a]	15.27[a]	8.34[a]	15.28[a]
	SE	3.43	1.97	2.26	3.37	3.81	2.51	3.82
WM	LSM	3.70[a]	3.70[a]	2.78[a]	4.63[a]	5.56[a]	5.56[a]	0.00[a]
	SE	1.68	1.68	1.51	1.81	2.37	2.37	0.0
WB	LSM	0.93[a]	0.00[a]	0.00[a]	0.93[a]	1.39[a]	0.00[a]	0.00[a]
	SE	0.93	0.0	0.0	0.93	1.39	0.0	0.0
UD	LSM	8.51[b]	0.93[a]	5.74[a]	3.70[a]	5.83[a]	6.94[a]	1.39[a]
	SE	2.47	0.93	1.98	2.15	2.50	3.22	1.39
L	LSM	0.93[a]	0.00[a]	0.00[a]	0.93[a]	0.00[a]	1.39[a]	0.00[a]
	SE	0.92	0.0	0.0	0.93	0.0	1.39	0.0
BS	LSM	0.00[a]	0.93[a]	0.93[a]	0.00[a]	1.39[a]	0.00[a]	0.00[a]
	SE	0.0	0.93	0.93	0.0	1.39	0.0	0.0
Theft	LSM	0.00[a]	2.78[a]	0.93[a]	1.85[a]	1.39[a]	1.39[a]	1.39[a]
	SE	0.0	1.51	0.93	1.27	1.39	1.39	1.39

ab: - means with different superscript in a row are significantly different from each other within the main effect. Wild Mammals (WM), Wild Birds (WB), Unidentified Diseases (UD), Beaten by Someone (BS)

4.2.5. Effects of breed and FR on the reproductive tract measurements

The detail results on the effects of breed and feeding regimes on the absolute weight of ovary with and without yellow and/or atretic follicles and status on the number of normal, atretic yellow and white ovarian follicles are presented in ANOVA (Appendix Table 14) and least squares means Table 16 and 17.

4.2.5.1. The weight of ovary and number of ovarian follicles

Weight of ovary including yellow and atretic follicles (WOYAF), weight of ovary excluding yellow follicles (WOEYF), weight of ovary excluding yellow and white follicles (WOEYWF) were significantly ($p<0.5$) more in BB as compared to Koekoek but there was no significant difference in the weight of ovary excluding yellow, white and yellow atretic follicles (WOEYWAF). This shows that the more weight of ovary in BB breed as compared to Koekoek was mainly due to yellow and white ovarian follicles. Besides, the number of yellow follicles (NYF) was also far more in BB (6.3) as compared to Koekoek (3.8). The number of white ovarian follicle (NWOF) is also significantly more in BB (8.67) as compared to Koekoek (4.83). But, no significant difference was noted in atretic yellow follicles number (NAYF) between these breeds.

Table 16. Least squares mean and standard error values for main effects of breed and feeding regime on the weight of ovary of Phase II (n=16).

Measurements of Ovary	Breed				Feeding Regime			
	BB		Kk		S		NS	
	LSM	SE	LSM	SE	LSM	SE	LSM	SE
WOYAF (g)	55.73[a]	1.21	45.83[b]	1.52	52.07[a]	1.66	47.50[b]	2.28
WOYAFp	5.74[a]	1.35	3.72[b]	0.22	5.12[a]	0.54	4.33[a]	0.47
WOEYF(g)	42.00[a]	0.58	38.00[b]	0.86	40.50[a]	0.76	39.50[a]	1.41
WOEYFp	4.47[a]	0.21	3.10[b]	0.15	3.99[a]	0.37	3.58[a]	0.32
WOEYWF (g)	5.00[a]	0.58	2.87[b]	0.31	4.50[a]	0.67	3.37[a]	0.56
WOEYWFp	0.54[a]	0.08	0.24[b]	0.03	0.46[a]	0.10	0.32[a]	0.08
WOEYWAF (g)	2.67[a]	0.82	1.62[a]	0.37	2.55[a]	0.62	1.73[a]	0.68
WOEYWAFp	0.30[a]	0.09	0.13[a]	0.03	0.26[a]	0.08	0.16[a]	0.08

ab: - means with different superscript in a row are significantly different from each other within the main effect. WOYAF-weight of ovary with yellow and atretic follicles, WOYAFp-relative weight of ovary with yellow and atretic follicles, WOEYF-weight of ovary excluding yellow follicles, QOEYFp-relative weight of ovary excluding yellow follicles, WOEYWF-weight of ovary excluding yellow and atretic follicles, WOEYWFp-relative weight of ovary excluding yellow and atretic follicles, WOEYWAF-weight of ovary excluding yellow, white and atretic follicles, WOEYWAFp-relative weight of ovary excluding yellow, white and atretic follicles.

Feed supplement improved the weight of ovary (WOYAF) on account of yellow follicle as their removal had no significant difference in WOYAF (Table 16). Further, significantly ($p<0.5$) more number of white ovarian follicles (NWOF) and atretic yellow follicles (NAYF) were recorded on supplementation as compared to non-supplemented group (Table 17).

Table 17. Least squares mean and standard error values for main effects of breed and feeding regime on the number of ovarian follicles of Phase II (n=16).

Number of Ovarian Follicles	Breed				Feeding Regime			
	BB		Kk		S		NS	
	LSM	SE	LSM	SE	LSM	SE	LSM	SE
NYF	6.33[a]	0.76	3.83[b]	0.70	6.00[a]	0.86	4.17[a]	0.79
SRT	2.59[a]	0.14	2.00[b]	0.22	2.52[a]	0.16	2.07[a]	0.24
NWOF	8.67[a]	1.17	4.83[b]	0.54	8.17[a]	1.33	5.33[b]	0.76
SRT1	2.98[a]	0.18	2.30[b]	0.12	2.88[a]	0.21	2.39[b]	0.16
NAYF	2.17[a]	0.48	1.50[a]	0.22	2.33[a]	0.42	1.33[b]	0.21
SRT2	1.47[a]	0.19	1.21[a]	0.09	1.54[a]	0.16	1.14[b]	0.09
BW	950[b]	43.0	1233[a]	36.0	1050[a]	76.0	1133[a]	68.0

ab: - means with different superscript in a row are significantly different from each other within the main effect. NYF-number of yellow follicles, NWOF-number of white ovarian follicles, NAYF-number of atretic yellow follicles, SRT-Square root transformed.

4.2.5.2. Absolute and relative weight and length of different parts of oviduct

The detail results of the ANOVA on the main effects of breed and supplementation on the absolute and relative weight and length of the different parts of oviduct are presented in Appendix Table 19. The main effect of breed and supplementation on the absolute and relative weight and length of the different parts of oviduct are given in least squares means Table 18 and 19.

The overall percent basis weight of oviduct was significantly ($p<0.5$) more in BB than Koekoek birds. Besides, magnum, uterus and vagina weight not only in absolute term but also on percent body weight basis was also significantly ($p<0.5$) more in BB as compared to Koekoek birds. On absolute and percent body weight basis, the length of the magnum, isthmus and total length of the oviduct was significantly ($p<0.5$) more in BB compared to Koekoek breed.

Table 18. Least squares mean and SE values for main effects of Br and FR on absolute weight (g) and length (cm) of the different parts of oviduct of Phase II (n=16).

Parts of Oviduct	Breed				Feeding Regime			
	BB		Kk		S		NS	
	LSM	SE	LSM	SE	LSM	SE	LSM	SE
Infundibulum (Wt)	1.38^{a}	0.33	1.02^{a}	0.29	1.15^{a}	0.34	1.25^{a}	0.30
Magnum (Wt)	24.33^{a}	1.38	12.57^{b}	1.98	19.25^{a}	1.74	17.65^{a}	4.05
Isthmus (Wt)	4.73^{a}	0.44	4.20^{a}	0.54	5.25^{a}	0.29	3.68^{b}	0.43
Uterus (Wt)	12.63^{a}	1.14	7.97^{b}	2.26	11.58^{a}	1.45	9.02^{b}	1.25
Vagina (Wt)	5.05^{a}	0.92	3.23^{b}	0.79	4.98^{a}	0.82	3.30^{a}	0.57
Total Wt	49.45^{a}	1.62	30.03^{a}	8.41	43.23^{a}	3.78	36.25^{a}	5.74
Infundibulum (L)	8.92^{a}	0.87	8.50^{a}	1.61	9.58^{a}	0.88	7.83^{a}	0.36
Magnum (L)	32.50^{a}	2.05	24.92^{b}	5.85	31.42^{a}	1.99	26.00^{a}	2.96
Isthmus (L)	11.08^{a}	0.58	8.38^{b}	0.43	10.47^{a}	0.841	9.00^{b}	0.58
Uterus (L)	7.20^{a}	0.79	7.47^{a}	0.25	8.03^{a}	1.38	6.63^{a}	0.42
Vagina (L)	7.48^{a}	0.28	6.17^{a}	0.88	7.45^{a}	0.67	6.20^{a}	0.65
Total (L)	67.18^{a}	3.83	55.43^{b}	3.45	66.95^{a}	3.67	55.67^{b}	3.77

ab: - means with different superscript in a row are significantly different from each other within the main effect. L-length, Wt-Weight

Supplementation stimulated significantly ($p<0.5$) the isthmus and uterus weight on absolute and percent BW basis; and only the percent BW basis of vagina and the overall percent BW basis of oviduct. The length on absolute and percent BW basis of isthmus and the overall oviduct weight was also stimulated significantly ($p<0.5$) due to supplementation (Table 18 and 19).

Table 19. Least squares mean and standard error values for main effects of breed and feeding regime on relative weight (g) and length (cm) of the different parts of oviduct of Phase II (n=16).

Parts of the Oviduct	Breed				Feeding Regime			
	BB		Kk		S		NS	
	LSM	SE	LSM	SE	LSM	SE	LSM	SE
Infundibulum (Wtp)	0.14[a]	0.03	0.08[a]	0.02	0.11[a]	0.03	0.12[a]	0.03
Magnum (Wtp)	2.58[a]	0.15	1.02[b]	0.16	1.95[a]	0.31	1.66[a]	0.44
Isthmus (Wtp)	0.51[a]	0.06	0.34[b]	0.05	0.52[a]	0.05	0.34[b]	0.05
Uterus (Wtp)	1.35[a]	0.14	0.65[b]	0.08	1.17[a]	0.20	0.83[b]	0.15
Vagina (Wtp)	0.49[a]	0.13	0.27[b]	0.03	0.52[a]	0.12	0.24[b]	0.02
Total (Wtp)	5.27[a]	0.31	2.45[b]	0.29	4.34[a]	0.65	3.38[b]	0.68
Infundibulum (Lp)	0.97[a]	0.14	0.69[a]	0.06	0.96[a]	0.14	0.71[a]	0.05
Magnum (Lp)	3.47[a]	0.33	2.04[b]	0.23	3.13[a]	0.42	2.38[a]	0.36
Isthmus (Lp)	1.19[a]	0.11	0.68[b]	0.04	1.05[a]	0.16	0.82[b]	0.09
Uterus (Lp)	0.78[a]	0.12	0.61[a]	0.02	0.80[a]	0.11	0.59[a]	0.02
Vagina (Lp)	0.81[a]	0.06	0.50[b]	0.07	0.74[a]	0.10	0.56[a]	0.07
Total (Lp)	7.20[a]	0.70	4.52[b]	0.33	6.68[a]	0.87	5.05[b]	0.54

ab: - means with different superscript in a row are significantly different from each other within the main effect. Wtp-relative weight, Lp-relative length.

4.2.6. Effects of breed and FR on Gastro-Intestinal Tract measurements

The detail results of relative empty weight and length, and absolute weight with contents of gastro-intestinal tract are presented in the ANOVA (Appendix Tables 20 and 23) and least squares means in Tables 20-22.

4.2.6.1. Relative length and empty weight of the different parts of GIT

In view of least square means in Table 20 the effect of breed on percent empty weight basis of oesophagus, crop, proventriculus, gizzard, duodenum, jejunum, ileum, ceca and large intestine; BB birds yielded significantly ($p<0.5$) more weight as compared to Koekoek; but no statistical difference was noted in crop. On relative length, the organs oesophagus, gizzard, jejunum, ileum and large intestine were significantly longer ($p<0.5$) in BB than Koekoek birds (Table 21).

Table 20. Least squares mean and standard error values for main effects of breed and feeding regime on the relative empty weight (EW) of GIT of Phase II (n=16).

Parts of GIT	Breed				Feeding Regime			
	BB		Kk		S		NS	
	LSM	SE	LSM	SE	LSM	SE	LSM	SE
Oesophagus (g)	0.63[a]	0.04	0.44[b]	0.03	0.58[a]	0.05	0.49[a]	0.05
Crop (g)	0.59[a]	0.04	0.51[a]	0.07	0.57[a]	0.08	0.52[a]	0.04
Proventriculus (g)	0.77[a]	0.05	0.46[b]	0.02	0.67[a]	0.09	0.55[b]	0.06
Gizzard (g)	4.83[a]	0.51	3.24[b]	0.22	4.28[a]	0.58	3.79[a]	0.45
Duodenum (g)	1.55[a]	0.14	0.71[b]	0.07	1.21[a]	0.27	1.05[a]	0.14
Jejunum (g)	1.70[a]	0.13	1.18[b]	0.07	1.51[a]	0.21	1.38[a]	0.07
Ileum (g)	1.49[a]	0.15	0.81[b]	0.05	1.28[a]	0.22	1.02[a]	0.13
Ceca (g)	1.02[a]	0.12	0.43[b]	0.03	0.84[a]	0.19	0.61[b]	0.09
Large Intestine (g)	0.77[a]	0.13	0.46[b]	0.04	0.70[a]	0.14	0.53[a]	0.07
BW	950[b]	43	1233[a]	36	1050[a]	76	1133[a]	68

ab: - means with different superscript in a row are significantly different from each other within the main effect. EW-empty weight.

In the present result; no significant difference was detected due to supplementation except empty weight of proventriculus, and ceca and length of oesophagus, crop and gizzard.

Table 21. Least squares mean and standard error values for main effects of breed and feeding regime on the relative length (cm) of GIT of Phase II (n=16).

Parts of GIT	Breed				Feeding Regime			
	BB		Kk		S		NS	
	LSM	SE	LSM	SE	LSM	SE	LSM	SE
Oesophagus (cm)	1.27[a]	0.13	0.94[b]	0.11	1.29[a]	0.16	0.92[b]	0.09
Crop (cm)	0.55[a]	0.08	0.42[a]	0.03	0.56[a]	0.07	0.40[b]	0.03
Proventriculus (cm)	1.16[a]	0.67	0.30[a]	0.01	0.45[a]	0.06	1.01[a]	0.70
Gizzard (cm)	0.56[a]	0.05	0.39[b]	0.03	0.53[a]	0.06	0.41[b]	0.04
Duodenum (cm)	1.87[a]	0.29	1.12[a]	0.16	1.52[a]	0.25	1.47[a]	0.32
Jejunum (cm)	6.67[a]	0.48	3.96[b]	0.26	5.75[a]	0.75	4.88[a]	0.63
Ileum (cm)	6.10[a]	0.44	3.67[b]	0.24	5.18[a]	0.66	4.59[a]	0.61
Ceca (cm)	1.89[a]	0.40	1.25[a]	0.14	1.93[a]	0.82	1.21[a]	0.23
Large Intestine (cm)	0.98[a]	0.08	0.67[b]	0.08	0.89[a]	0.10	0.75[a]	0.11
BWg	950[b]	42	1233[a]	36	1050[a]	76	1133[a]	68

ab: - means with different superscript in a row are significantly different from each other within the main effect. L-Length.

4.2.6.2. Absolute weight with contents of the different parts of GIT

As shown in least squares means Table 22, BB had significantly ($p<0.5$) heavier absolute weight with contents than Koekoek birds in proventriculus, duodenum, ileum and ceca GIT parts. No significant difference was noted in all the organs of GIT with contents due to feeding regimes.

Table 22. Least squares mean and standard error values for main effects of breed and feeding regime on the absolute weight with contents of GIT of Phase II (n=16).

Parts of GIT	Breed				Feeding Regime			
	BB		Kk		S		NS	
	LSM	SE	LSM	SE	LSM	SE	LSM	SE
Oesophagus (g)	6.40[a]	0.52	5.37[a]	0.32	6.18[a]	0.59	5.58[a]	0.31
Crop (g)	35.25[a]	4.45	36.72[a]	1.95	35.28[a]	4.49	36.68[a]	1.87
Proventriculus (g)	8.47[a]	0.90	5.90[b]	0.23	7.87[a]	1.02	6.50[a]	0.55
Gizzard (g)	70.80[a]	5.10	62.68[a]	6.22	70.75[a]	4.52	62.73[a]	6.67
Duodenum (g)	19.33[a]	0.81	10.95[b]	1.02	15.35[a]	2.45	14.93[a]	1.64
Jejunum (g)	25.87[a]	3.20	19.08[a]	0.27	22.75[a]	2.74	22.20[a]	2.71
Ileum (g)	27.08[a]	1.48	20.72[b]	1.64	24.08[a]	2.78	23.72[a]	1.09
Caeca (g)	14.60[a]	0.86	8.05[b]	0.45	12.37[a]	1.70	10.28[a]	1.38
Large Intestine (g)	7.25[a]	0.90	6.27[a]	0.40	7.33[a]	0.85	6.18[a]	0.46
Total weight (g)	221.62[a]	8.10	179.70[a]	6.59	206.57[a]	9.20	194.75[a]	13.64
BWg	950[b]	105	1233[a]	36	1050[a]	76	1133[a]	68

ab: - means with different superscript in a row are significantly different from each other within the main effect.

4.2.7. Fertility and Hatchability

The detail results of fertility and hatchability are presented in the ANOVA (Appendix Tables 26) and least squares means in Table 23.

Table 23. Least squares mean values for the effects of Breed on fertility and hatchability of Phase II (n=6).

Dep. Var.	Breed			
	Koekoek		BB	
	LSM	SE	LSM	SE
Number of eggs set	7.67[a]	0.88	6.00[a]	1.53
Number of fertile eggs	4.33[a]	0.33	3.33[a]	0.88
Number of infertile eggs	3.33a	1.20	2.67[a]	0.67
Number of dead in shells	0.00[b]	0.0	1.33[a]	0.33
Number of chicks hatched	4.33[a]	0.33	2.00[b]	0.58
Fertility (%)	59.23[a]	12.14	55.20[a]	2.89
Hatchability on fertile eggs (%)	100.00[a]	0.0	58.90[b]	4.85
Hatchability on set eggs (%)	59.23[a]	12.14	32.77[a]	4.34

ab: - means with different superscript in a row are significantly different from each other within the main effect.

As shown in Table 23, there was significant ($p<0.5$) difference between breeds in the number of dead in shells and number of chicks hatched. Average hatchability on fertile eggs also varied significantly at $p<0.5$ (100% in Koekoek and 58.90% in BB). But there was no significant ($p>0.05$) difference between breeds in the number of eggs set, number of fertile eggs, number of infertile eggs, fertility % and hatchability on eggs set.

4.2.8. Perception of farmers on chicken genotypes

Focus group discussion on the perception of farmers on chicken genotypes revealed that most consumers prefer brown egg shell color (83.3%; n=10), because they expected as brown eggs are coming from local hens with attractive yellow yolk colours. They believe the local chickens meat and egg is good and best marketed compared to the exotic (58.3%; n=7). Small size eggs are preferred because these eggs are believed to be from local chickens (66.7%; n=8). Regarding behavior of the exotic breeds; BB is a bird with quite temperament as a result unable to escape from predators and thieves (83.3%; n= 10), has no permanent laying site (91.7%; n=11) compared to Koekoek, the Koekoek is one of the exotic breed known with a broody behavior (91.7%; n=11). Further there is no difference in feed consumption between the two breeds (50%; n=6) but higher than the local chickens.

5. DISCUSSION

Under this section, the effects of season and feeding regimes on BB and Koekoek chicken breeds will be discuss in two phases. Phase I considers FI, ADG, FCR, RT and mortality; and Phase II addressed BWG, RT, egg production traits, mortality and reason of mortality or loss, reproductive tract and gastro intestinal tract measurements, fertility and hatchability and perception of farmers.

5.1. Phase I

5.1.1. Feed intake (FIg/b/d)

The results of the present study agreed with those of Rondelli *et al.* (2003) and Taha *et al.* (2011) who found significant differences in FI among strains of chickens. Jaroni *et al.* (1999) reported a similar finding where strain had a marked effect on feed consumption, with Hisex having higher feed consumption than DeKalb hens. Conversely, the lower FIg/b/d of the Koekoek breed in the present study could be due to its higher mortality rate during the MRS, though better FIg/b/d recorded in this breed during the HSe followed by the CS. Additionally, the morbidity in some of the survived Koekoek birds also reduced their feed intake. This study further showed significant ($p<0.5$) difference in the effect of breed by season interaction effects in FIg/b/d, Bovans Brown performed better in all the seasons than Koekoek breeds of chicken. Similarly, Yakubu *et al.* (2007) noted that genotype × season interaction had significant effect on FI.

5.1.2. Average daily gain (ADGg)

In this study, the Koekoek chicken breed was superior in ADG to their BB counterparts. Earlier investigators including Ajayi and Ejiofor (2009), Youssao *et al.* (2009), Enaiat *et al.* (2010), Taha *et al.* (2011) and Youssao *et al.* (2012) reported similar results using different strains and breeds. Likewise, Anita *et al.* (2012) reported that the broilers of Shaver Redbro line were heavier and reached higher slaughter yield in both sexes than TETRA H. However, Ali (2006) revealed to a non-significant difference between three broiler hybrids (Lohman, Ross and Hubbard) in their body weights. Other authors such as Thutwa *et al.* (2012) and Hristakieva *et al.* (2014) also reported insignificant strain differences in body weight gain. The difference of growth between the present result and the above reports could be due to the breed types (layers vs broilers and exotics vs local chickens).

Regarding the effect of season on ADG, the current result is in harmony with previous result reported by Yakubu *et al.* (2007) who indicated that body weight was higher in the wet season compared with the hot-dry season. In contrast to the result of the present study, (Lu *et al.*, 2007) reported no difference between chickens exposed to different levels of temperatures in terms of BWG. Regarding the interaction effects, similar to the present study the result of Jesuyon and Salako, (2013) indicated that significant ($p<0.5$) interaction existed between genotype and season in mean cock weight. According to the same authors, Bovan nera (BN) cocks exhibited higher body weight in late dry season, while Isa-Brown (IB) cock showed higher weight in early dry season. This result negated the preliminary analyses of Adebambo *et al*. (2006) in which they reported that the effect of interaction of breed with season was not significant in the same environment.

5.1.3. Feed conversion ratio (FCR)

Results on FCR in the present study were significantly different in the two breeds as Koekoek was significantly better in FCR than BB. The observed breed effects in affecting feed conversion ratio were in agreement with the reports of several authors (Yakubu *et al.,* 2010; Taha *et al.,* 2011; Anita *et al.,* 2012 and Udeh *et al.,* 2015). Other authors like Choo *et al.* (2014) also obtained similar reports that gain: feed of 3 breeds of Korean local chicken was superior to that of reported data of local breeds such as Benin (Youssao *et al.,* 2012), Nigerian (Momoh *et al.,* 2010) and Tunisian local chickens (Moujahed and Haddad, 2013); though Momoh *et al.* (2010) reported that local chicken presented generally low efficiency of feed utilization. However, other authors such as Thutwa *et al.* (2012) and Hristakieva *et al.* (2014) reported insignificant strain differences in feed conversion ratio. In addition, genotype had no influence on feed conversion ratio reported by Kow *et al.* (2015) was inconsistent to the present study.

On the other hand, feed efficiency varied depending on season of rearing the birds. This is consistent with the report of Oguntunji *et al.* (2008). In contrast to the results of the present study, (Garcês *et al.,* 2001) and (Uzum and Oral Topluh, 2013) reported no significant season effect on the feed efficiency of birds. Regarding the interaction effects, unlike the results of the present study, Rack *et al.* (2009) reported that no significant interaction between season and genotype. However, (Yalcin *et al.,* 1997b) presented similar reports that the interactions between genotype and climate affected feed efficiency.

5.1.4. Rectal temperature (RT ^{O}C)

The three seasons included under this study were clearly differed in ambient temperature (AT) and relative humidity (RH). The average minimum and maximum AT of the CS, HSe and MRS recorded during the experimental period was 10.1/25.6, 14.5/29, 13.9/27.3^{O}C and average RH was 56.5, 49, 60.5%; respectively. In the present study, the RT was significantly higher, intermediate and lower during the HSe, MRS and CS; respectively. The fact that performance (FI, ADG and FCR) was not affected by the 29 ^{O}C moderate AT and 49% RH observed during the HSe may relate to better thermoregulation capability of the two breeds unlike the heavier broiler chickens. Likewise, Joachim *et al.* (2011) reported that high temperature accompanied by high humidity is more detrimental to layer performance than high temperature with low humidity. At the same time, constant high temperature of 30-32°C is more deleterious to birds than cyclic or alternating temperatures of 30-32°C by day and 25°C by night. The result also corroborates what Medeiros, (2001), reported in that the average RT of broiler chickens is around 41.5°C, ranging from 40.6 to 43.0°C, and the upper safety limit to maintain their survival is equal to 45°C.

Regarding breed effect, the current study found a non-significant RT difference between the two breeds because both are not heavy breeds like those of broilers. Deeb and Cahaner, (2002) for instance revealed that the intensive genetic selection for fast growth rate means that modern species of broiler chickens are very susceptible to heat stress. In addition, proper ventilation employed during the present study could play an important role in thermoregulation of the two breeds at moderate AT (29 ^{O}C) that observed during the HSe. Accordingly, Yahav *et al.* (2008) reported that efficient ventilation affects thermoregulation and, thereby, the performance of domestic fowl. According to Lin *et al.* (2005) the effect of humidity on non-evaporative heat loss was depended on air temperature, as non-evaporative heat loss was supressed by high humidity (>60% RH) at high temperature but enhanced at the mild temperature.

Yet the interaction effects in Koekoek breed during the HSe showed significantly ($p<0.05$) higher RT, followed by BB breeds during the HSe and significantly ($P<0.5$) lower RT was recorded in both breeds during the CS. The difference between the higher HSe and the lower cold season RT was 1.6^{O}C for Koekoek (42.81-41.21 ^{O}C) and 1.14^{O}C for BB (42.36-41.22^{O}C). From the observed RT of the present study Koekoek breed seems to be more sensitive to seasonal variation than the BB. Body temperature of the normally fed broilers (BT1) increased by AT, i.e., it was higher in summer than in fall reported by Yalcin *et al.* (1997a) is consistent with the present study. In general, information on the interaction effect of breed with season, on chickens RT and performance is scarce.

5.1.5. Mortality

The result of the current study is in consistence with the reports of Yakubu *et al.* (2007), Olawumi *et al.* (2008) and Reta *et al.* (2012) who indicated significant effect of breed on mortality rate. Unlike the present study where there is breed variation in their survival rate, Del Castilho *et al.* (2013) reported that the liveability values did not suffer significant effect of genotype. Similarly, Benyi *et al.* (2015) reported no effect of genotype on the performance and mortality rates of birds during the starter and grower period. This disagreement could be due to the genotype differences between the experimental animals studied where these reports emerged from studies on broiler types against layer types in the current study. Indeed, the Koekoek chicks, especially those reared during the MRS were of poor quality as were obtained from the poultry farm where they hatched, to which the observed higher mortality rates recorded for the breed of chicks. In addition, cannibalism (toe picking) behaviour observed in the Koekoek breed could be the other cause of losses of chicks for the breed. This behaviour was not manifested in the BB breed that reared with similar rearing environments.

Moreover, the present study is in harmony with that of Spiers *et al.* (2004) who found significant ($p<0.01$) strain by season interaction effects on mortality. However, disagrees with the result obtained by Mmereole *et al.* (2007) who reported genotype x season interaction effects were not significant ($p<0.5$) in influencing the mortality. Environmental difference could be the reason for such variation between the present study and the above report.

5.2. Phase II

5.2.1. Body weight gain (BWG)

The higher BWG of the Koekoek chicken breed in this study was in agreement with Joubert (1996) who pointed out that Koekoek considered as a heavy chicken breed with an average mature weight of 3-4 kg and 2.5-3.5 kg for cocks and hens, respectively. The egg-type BB breed guide, on other hand, showed 1.9kg average body weight at 64-week age. The present result supported these independent reports showing higher weight of Koekoek as compared to the BB chicken breed at 64 weeks of age. This result is also in harmony with that of Joubert, (1996) and Van Marle-Köster and Casey, (2001) who reported that Koekoek is a dual-purpose chicken breed known to have a large body size compared to indigenous breeds.

Moreover, results from random sampling of mature birds from villages done in a previous study in Tanzania indicated *Kuchi* ecotype to be superior to other ecotypes in terms of body weight and converse was true for *Medium* ecotype (Msoffe *et al.,* 2001; Msoffe, 2003). Besides, the dual-purpose RIR breed is significantly heavier than the egg layer white leghorns (Tadelle *et al.,* 2003). Banerjee (1995) also indicated that the standard body weight of adult RIR hens is 3.0 kg and 3.8 kg for cocks; whereas the local male birds weigh only 1.5 kg and females still weigh 30% less, corroborating the results of the present.

In the scavenging system, supplementation rarely practiced but studies have shown that improvement in productivity may occur if it properly done (Smith, 1990). For instance, better weight gains on feed supplementation, reported by Ramalah (1996), Hong (1999), and Sonaiya *et al.* (2002b). Consequently, the superiority of supplemented birds (1101g) over the scavenging only birds (870g) in terms of BWG demonstrated in the present finding is in agreement with the results of the previous study of Mwalusanya *et al.* (2002) and Rashid *et al.* (2004). These authors reported that the low body weight and growth rate for birds on the scavenging feeding regimes in all periods was a reflection of the low nutrient availability from scavenging. According to Mutayoba *et al.* (2012), feed supplementation to free range local chickens improved performance in terms of growth rate and body weight. The result of Solomon (2003) also noted that White Leghorn chickens are suitable for scavenging conditions in terms of growth performance, and that they are more responsive to supplementation than Local chickens.

As in this study, the Koekoek chicken breed on supplementation yielded better result (316g) as compared to the non-supplemented Koekoek chicken breed; and BB supplemented groups gained 147g, compared with the non-supplemented BB chicken breed. Therefore, it could be easily observed that Koekoek breed on supplementation gain better body weight compared to BB supplemented groups. This could be due ability of the Koekoek breed to use the scavenageable feed resources more efficiently compared the BB. Of course, the difference in mere BWG could also be due to breed effect than due to supplementation. According to Mutayoba *et al.* (2011), the increase in body weight with feed supplementation observed in their study followed a common phenomenon that increased plane of nutrition leads to better performance.

5.2.2. Rectal temperature ($RT^{O}C$)

The larger size in the Koekoek chicken breed, better digestion and metabolic processes of the supplemented birds and the higher ambient temperature of the hot season might be associated with the higher rectal temperature values recorded in the above main effects and their interactions. In general breeds intended for the production of eggs (for instance the BB) have a small body size where as those used as dual purpose (like the Koekoek) have a larger body size. Accordingly, nutrient requirement and metabolic heat production may vary with body size of birds; larger body size birds require greater quantities of nutrients than do small body size birds and heat generated from larger birds is higher than smaller size birds. The current body of literature generally indicates that, breed and strain within breed variations in terms of RT as indicator of adaptation to a given ecology. For example, the White Leghorn has been shown to have a greater tolerance to high temperature than heavier breeds such as RIR, Barred Plymouth Rock, White Plymouth Rock and Australorps too (Gowe and Fairfull, 2008).

In the present study, the supplemented birds had relatively higher FI both from scavenging and from supplementation than the non-supplemented birds. Therefore, the higher RT of supplemented birds could be from the metabolic heat generated by the oxidation of additional feed from supplementation. Likewise, Yamamato (1992) reported that feed intake and physical activities had recognized as the main factors to increasing heat production in animals.

Regarding season effect, results of the current study revealed that the higher ambient temperature during the hot season may increase the heat load and could be the reason to increase the rectal temperature in the experimental birds compared to other two seasons. Ethiopia in general and the study area in particular characterized by three seasons: CS, HSe and MRS. Each season has its positive or negative effects on livestock production. For example, the HSe in the study area is thermally stressful to poultry. While the negative impacts (or increase in the RT) of environmental stress on poultry was minimum during the MRS. In connection to this, Campos *et al.* (2004) has documented that the main effect of exposure of homoeothermic animals to heat are changes in the normal standard of rectal temperature. Further; it has been indicated that season has been identified as one of the most important factor adversely affecting poultry production in the tropics, not only in those reared extensively, but also in those intensively reared without artificial regulation of microclimatic conditions (Mahmoud *et al.,* 1996), (Ayo *et al.,* 2007) and (Obidi *et al.,* 2008). The principal meteorological element commonly implicated with the adverse effect of seasonal variation on performance of poultry is ambient temperature, most especially in tropical and sub-tropical regions of the world. Finally, no related finding was obtained from the available literature which deals with the two and three-way interaction effects.

5.2.3. Egg production traits

5.2.3.1. Age at onset of egg laying (AOEL)

Timing of the onset of lay may be determined by a number of interrelated factors, such as age and body weight as threshold factors (Dunnington *et al.*, 1983), body fat (Brody *et al.*, 1984) and lean tissue. Sexual maturity can be delayed by either the qualitative and quantitative restriction of nutrient intake. Flock size, stocking rate and rearing system had no significant effect on age at point-of-lay whereas, strain of the chicken and hygienic conditions on farm had a significant effect. Layers kept in cages attained peak-of-lay at lower age compared with those kept on the floor. Hisex layers had earlier age at point-of-lay and peak-of-lay than Babcock. The delay in age at point-of-lay under poor hygienic conditions is attributable to higher mortality and stressful conditions that the laying hens were exposed to (Zelenka *et al.*, 1986).

Accordingly, the insignificant difference of AOEL between breeds found in this study has supported by many research workers on other breeds; such as Solomon, (2004), Nthimo, (2004) and Grobbelaar *et al.* (2010). Further, this result is in harmony with previous results reported by Barua *et al.* (1998) who indicated that Fayomi attained sexual maturity at an earlier age followed by Fyomi*RIR and RIR. It has been also well documented by Gunaratne *et al.* (1993) and Gezahegn, (2005) that village chickens are characterized by late maturity; and the majority of the birds (above 50%) starting laying late at 7-8 months of age by Lulseged, (1998).

But, the report of Farooq *et al.* (2002) on commercial laying hens showed earlier average

age at-first-of lay to be 126±1.02 days and according to Petek, (1999) commercial egg type layers started laying eggs at the age of 20-21 weeks and produced 277 eggs till 72[nd] week of their production cycle. The present result showed more delayed sexual maturity i.e. overall AOEL of the two breeds was 191±2.58 days. This could be due to the variation of breed and management system followed. The sexual maturity (production of first egg) found by Grobbelaar *et al.* (2010), who stated that the sexual maturity for the Potchefstroom Koekoek was 138.5 days is in contradiction with the 188 days AOEL of the Koekoek chicken breed observed in the present study. The difference in sexual maturity of the Koekoek chicken breed obtained during this investigation and the results obtained by the above authors could be due to various factors such as the rearing process.

Regarding the main effect of feed supplementation, a significant ($p<0.5$) improvement of 17days AOEL was noted between the interaction effects of BB*supplemented and BB*non-supplemented birds; but no significant difference was observed between supplemented and non-supplemented Koekoek chicken breed. This result is in agreement with that conducted by Yakubu *et al.* (2007) who found age at sexual maturity of birds fed extra feed to scavenging had significantly better performance than those without extra feed group ($p<0.5$). Similarly, Solomon, (2004) reported that in a trial conducted in Ethiopia; the comparative egg production performance of local Ethiopian hens and White Leghorn hens under rural household conditions, a combination of rural household conditions plus 50 g of commercial supplementary feed and intensive conditions, the mean days to sexual maturity for the White Leghorn were 165, 158 and 149 days, respectively and for the local were 169, 158 and 149 days, respectively.

5.2.3.2. Total collected eggs (TCE)

Genetic and non-genetic factors affect the productivity of laying birds. According to Farooq *et al.* (2002), egg production is a dependent variable and influenced by several factors like strain of chicken, feeding, mortality and age at point-of-lay; and there exists negative association of egg production with mortality and age at point-of-lay. On breed effect, unlike the present study Duduyemi *et al.* (2005) found no significant effect of breed on egg production while Yakubu *et al.* (2007) reported significant effect of breed on egg production. In addition, this result is in consistence with that of Mwalusanya *et al.* (2002) who indicated the existence of significant differences between ecotypes with respect to egg number ($p < 0.05$). There is also a variation even in the same Koekoek breed between this study, which recorded 119 TCE in about 9-months egg production period, and 195.9 eggs per year reported by Grobbelaar *et al.* (2010). Indeed, the mean TCE of this study (103 eggs in 9 months) is lower than from Chittagong Government Veterinary college Pahatali (140.7) Khan *et al.* (2006), water shed area of North Ethiopia (144 ±6.97) Abraham and Yayneshet, (2010) and then Adami Tulu research centre (159.9±10.7) Tesfa *et al.* (2013); due to different feeding, climate and production period.

Breed variation in egg production as revealed in this study could be attributed to differences in environmental factors. Because, numerically higher mortality (15.74%) was recorded in the temperate region BB chicken; though the birds were of the same age, reared under the same family production system and subjected to the same management practices except the variation in breed and feeding regimes. Besides, the rearing process could be one of the reasons for the variation in egg number with in the same Koekoek chicken breed. Higher number of hen housed eggs produced (119 eggs) by Koekoek breed was due to low mortality of the breed as hen housed egg production is directly related with mortality.

In the present finding; Koekoek and BB both supplemented improved total collected eggs by 6 and 25 eggs respectively, which was similar with results reported elsewhere Guèye, (2005) where egg production was improved by feed supplementation. Besides, the following authors presented similar reports. The mean egg number for free range local chickens supplemented with homemade feed and commercial was 31.9 and 31.8, respectively; whereas it was 20.4 for the un-supplemented free range chickens (Mutayoba *et al.*, 2012). Total egg production/hen/year of local hens, under existing farmers' management condition was calculated and estimated to be 51.6 eggs and the average number of eggs laid by supplemented local hens per six months laying period were 50.78 and 51.79 eggs for the first and second years, respectively (Fisseha *et al.*, 2014).

Further, the interaction between breed with season showed higher total collected eggs (132) in the Koekoek*hot season birds followed by 116 during the cold season and 110 during the main rainy season in the same breed. The reason for such variation could be the higher mortality in the BB, in which the maximum total collected eggs they produced was 101 during the cold season. This two-way interaction showed breed effect is more pronounced in total collected eggs than season effect. Besides, the origin of the breeds could also be attributed for the variation in total collected eggs, the temperate BB breed showed better egg production performance during the cold season and the tropical Koekoek breed during the hot season. So, it should be concluded that both breeds under study performed differently in different seasons and hence there was genotype*season interaction. The interaction between feeding regimes with season showed higher total collected eggs of 117, 113, and 102 in the hot season, cold season and main rainy season, respectively; on those supplemented birds. This interaction indicates total collected eggs are more affected by supplementation than season.

Concerning 3-way interaction effects, 145 total collected eggs in Kk*S*HSe birds could be due to the higher mortality in the BB which might reduce the total collected eggs to 119 eggs. The two breeds recorded higher total collected eggs both due to supplementation but in different seasons, the BB in the cold season and the Koekoek in the hot season. As mention earlier, the origin of the breeds could be the reason for such variation. Two and three-way interactions effects, except the interaction between breed and feeding regimes, on total collected is very scanty to compare the present study with others.

5.2.3.3. Average egg weight (AEW)

This study clearly observed breed effect is more pronounced in average egg weight than the rest of the factors i.e. BB was superior in breed main effect and in all the interaction effects. Higher egg weight in an egg type BB and low egg weight in the dual-purpose Koekoek chicken was due to genetic reason. Compared to the previous study, the value obtained in the Koekoek breed (42.4g) for AEW is very close to that of 42g given by Mwalusanya *et al.* (2002) for medium ecotype of Tanzania. 42.5 g given by Ramalah, (1996) for local chickens of Malaysia using semi-intensive system; around 40 g given by Alemu (1995), Islam *et al.* (2002), Pedersen (2002), and Fayeye *et al.* (2005), for local chickens of Ethiopia, Bangladesh, Zimbabwe and Nigeria respectively.

The above 42.4 g AEW value obtained in the Koekoek chicken breed is lower than 55.7g average egg weight of Potchefstroom Koekoek reported by Nthimo, (2004). 53.3g observed in the present study on the BB breeds; 48.9 g reported by Nhleko *et al.* (2003) in South Africa indigenous chickens; 46.0g reported by Ramalah, (1996) in Malaysia local chickens using intensive system, and 52.73±0.29g reported by Yakubu *et al.* (2007) for BB breed. Higher than 36.8g reported by Adetayo and Babafunso, (2001) in Nigeria indigenous chickens kept in cages, 36.27g reported by Ershad, (2005) in Bangladesh native hen in the field level, 38g average egg weight of local chickens of Ethiopia reported by (Haftu, 2016). The value (53.3g) for average egg weight of the BB breed obtained in this study is very close to that of 52.73±0.29g given by Yakubu *et al.* (2007); but lower than 63.5g obtained from the guideline published by the company and 63.9g reported by Anderson, (2009); for the same BB breed.

Besides, Mwalusanya *et al.* (2002) reported that significant differences ($P<0.01$) were observed among the three strains and control populations with respect to egg weight. Similar differences were reported by earlier authors in White Leghorns (Devi and Reddy, 2005; Chatterjee *et al.*, 2006; Giriraj *et al.*, 2008 and Singh *et al.*, 2009). Further, Mwalusanya *et al.* (2002) showed that egg weight ranged from 50.01 ± 0.48 to 53.89 ± 0.43 g, which is in agreement with the published reports of Devi and Reddy (2005), Chatterjee *et al.* (2007) and Singh *et al.* (2009).

5.2.3.4. Egg mass

The insignificant difference between breeds, feeding regimes, season and their two and three way interactions on the egg mass measured could be due to the fact that the lower total collected eggs (87) of the BB chicken breed was compensated by their higher average egg weight (53.3g) and the higher number of total collected eggs (119) of the Koekoek breed was compensated by their lower average egg weight (42.4g). Though not significant, mortality was higher in the BB and this could be one of the reasons for the lower total collected eggs and egg mass in this breed.

Published literature on egg mass of village chickens is very scanty and difficult to compare with this obtained in the present study. However, this result is in agreement with Hanan and Gehan (2013), who found overall egg mass of Lohman brown hens, was more, but not significantly more than that of the Lohmann selected leghorn (LSL). Disagrees with the result obtained by Bonekamp *et al.* (2010), who reported daily egg mass production increased significantly (P<0.5) with increasing balanced protein. With the findings of Grobas *et al.* (2001), who compared production performance of IB hens with Dekalb Delta, a White Leghorn egg layer strain, and found that egg mass from IB was more than that from Dekalb Delta.

The 4931g egg mass reported in this work is much lower than 11790±544.50g reported by Agu *et al.* (2012) for the heavy ecotype of Nigerian local chicken. Lower than 7.2 kg/hen reported by Solomon, (2004) for the mean annual egg mass of the leghorn hens; close to that of 5600g reported by Nwosu, (1990) for the light ecotype chicken in south east Nigeria and higher than 1.8kg/hen reported by Solomon, (2004) for the mean annual egg mass of the local hens. The difference between the results in the egg mass obtained during this study and the results obtained by the above authors could be due to the factors such as egg production period and breed type.

5.2.4. Mortality and reasons of mortality or loss

The present finding is in harmony with previous results reported by Olawumi and Dudusola, (2011) in which there was an insignificant (p>0.05) effect of breed on mortality rate and with Lwelamira *et al.* (2008) in which mortality differences between ecotypes in both management systems were not significant (p > 0.05). There was no any mortality of hens during the trial period in all study districts reported by Fisseha *et al.*

(2014) is in contradiction with the present study. The same author showed that, this might be related with the presence of vaccination against Newcastle disease and supplementary feeding. The variation between the two reports could be other causes of mortality other than those diseases prevented by vaccines in the present study.

Additionally, there are several studies in the literature that compared the mortality rate of different breeds/strains. For example, Yakubu *et al*. (2007) and Olawumi *et al*. (2008) had revealed the significant effect of breed on mortality rate; and Ershad, (2005) reported that the native layer mortality percentage was much higher in case of unskilled farmers. The various environmental (such as management, climate, etc) and genetic factors could be the reason for the variation between the insignificant difference of mortality in the present study and the significant difference reported by the above authors.

On the other hand, the causes of mortality or loss in the present study were unidentified diseases (UD), wild mammals (WM), wild birds (WB), loss (L), beaten by some body (BS) and theft. But significant difference was noted due to UD. Consequently, this result indicated that the significantly ($p<0.5$) higher mortality was due to different kinds of diseases despite the treatment/prevention measures taken. Of course, the rest of the birds were died or lost due the above-mentioned reasons. For instance, wild mammal and wild bird predators account for far more mortality than is usually recognized. Besides, the real causes and the type of diseases that led to chicken deaths were not identified and were beyond the scope of this study.

Variable causes of chicken losses were reported by different authors, but the results of this study are in harmony with that of Kusina *et al.* (2001), Msami (2002), Lwelamira *et al.* (2008), Kugonza *et al.* (2008), Habtamu *et al.* (2014) and Emmanuel *et al.* (2015) who showed that major constraints to extensive chicken production is disease and predators. However, the present finding disagrees with the result obtained by Czech, *et al.* (2003) Melkamu and Wube (2013) and Selam and Kelay (2013) who reported that predation is a more important cause of mortality than disease. The rearing environment might be the reason for such variation.

The insignificantly higher mortality due to UD (6.94%) during the MRS of the present study contradicted with the result obtained by Msami, (2002) who indicated most farmers reported that flock mortalities were higher during the dry season than the wet season. Habtamu *et al.* (2014) revealed that the highest chicken death rate was observed during the beginning of rainy season and 99 percent of the chicken owners reported occurrences of chicken diseases. Kusina *et al.* (2001) reported that the occurrence of disease and predator problems was seasonal, the former being highest during the hot season. Reasons given for high mortality during the hot season were improper housing and the heat. Yakubu *et al.* (2007) observed that incidence of mortality was significantly higher in the hot-dry season. The deleterious effect of thermal stress could be responsible for the high mortality rate recorded in the hot-dry season. Kugonza *et al.* (2008) indicated that majority of the farmers reported that diseases mainly strike during the dry season, showing the positive relationship between Newcastle prevalence and low humidity.

But the present study is in harmony with the findings of Mmereole and Omeje (2005) in that mortality rates of the wet season were higher than that of the dry season. Related studies indicate severity of Newcastle disease during the rainy season in Kenya Anonymous, (1990) and Ethiopia Sonaiya, (1999), while in West and Central Africa; major outbreaks are seen during the dry season (Mukiibi-Muka, 1992; Guèye, 1998).

It is impossible to compare the above mentioned two-way interaction effects between breed with feeding regimes and between breed with season on UD to other findings in the literature because most of the literature only gives main effects of either breed or feed supplementation or season.

5.2.5. Effects of breed and FR on the reproductive tract measurements

As shown in the present study, the difference in reproductive activity during the laying period was due to breed variation of the chicken. The egg type BB was superior in ovary weight and follicle number (the source of yolk) than the dual-purpose Koekoek breed, which also reflected previously in their laying performance. The same trend also noted in the oviduct. Major parts of the oviduct; weight of magnum, uterus and overall oviduct as well as length of isthmus and overall oviduct; which has secretary role in the deposition of albumen, shell membrane and egg shell was superior in BB than Koekoek breed. This shows the thickness of the wall of oviduct associated with secretary activity was much more in BB than Koekoek; and this was one of the probable reasons for bigger size of egg in former case as the magnum contributes all the thick albumen (55.8% of the egg weight) and uterus produces egg shell (12.3% of the egg weight) (Lakhotia, 2002). Besides yolk size is also much more in BB as discussed earlier. This foregoing discussion in view of results obtained from the present study provides the scientific evidences for the cause of smaller size of egg in Koekoek birds.

Differences in the reproductive potential of BB and Koekoek breeds are related to differences in the recruitment of follicles to the pre-ovulatory follicle. From this finding it is concluded that the entry of number of white follicles in to growing phase was higher in BB breed. Thus, at least in part, it can be safely said that BB is superior in laying intensity and egg size on account of this fact. However, the higher mortality of the BB reduced the TCE noted in the above results.

Regarding effect of feeding regimes, supplementation has profound effect on egg productivity of birds which was reflected on the total weight of ovary (WOYAF) and number of white ovarian follicles that would undergo to the growing phase. But the superiority of NAYF in supplemented birds could be due to mere chance. Supplementation may also improve the egg size by promoting the development of isthmus and uterus part of the oviduct as well as the development of overall oviduct.

The reasons of the variation in egg production performance of different breeds or the difference with in breeds might be associated with the effect of atresia; mostly caused by feed deficiency; though there are also other responsible factors as reported by Moudgal, (2000); atresia may act as a supporting control mechanism adjusting clutch size to nutrient reserves. Atresia mostly observed in small white follicles, but also in yellow follicles as reported by the following authors. The follicles which make up the hierarchy of domestic birds almost always ovulate. Atresia or apoptosis (programmed cell death) of the large hierarchical follicles can occur under certain circumstances, such as during the transition to broody behaviour or at the end of the breeding season. In general, however, it appears that most follicular atresia occurs in a population of small growing follicles which have not yet been selected in to the hierarchy. It is logical that atresia is a rare occurrence in the large follicles since yolk formation and deposition is energetically demanding (William, 2015). Small follicles are either recruited into the follicular hierarchy or, more commonly, they undergo atresia, eventually being reabsorbed into the ovary. In laying hens, once a follicle is recruited into the hierarchy, it is committed to ovulate within 5-7 days, as atresia within this group of follicles is rare under normal physiological conditions. Atresia is the common fate for small follicles, whereas it is a rare event for large pre-ovulatory follicles under normal physiological conditions (Armstrong, 1994).

5.2.6. Effects of breed and FR on Gastro-Intestinal Tract measurements

It is indicated from this observation that the bigger empty weight of important organs (oesophagus, crop, proventriculus, gizzard, duodenum, jejunum, ileum, ceca and large intestine) as well as the length of important organs (oesophagus, gizzard, jejunum, ileum and large intestine) in BB may be responsible for superior production traits, which may be on account of better digestion and absorption oriented process. Of course, at early age diet supplementation influences the growth of GIT (Nitsan *et al*., 1991; Nir *et al.*, 1993; Iji, 1999). But under the present study, supplementation was initiated at later stage. Therefore, supplementation may not be able to stimulate the development of GIT.

The higher egg productivity of the BB could be the reason for bigger weight with contents of GIT. Supplementation may not be able to stimulate the development of GIT as observed also in the weight with contents of the GIT.

In general, the comparison on individual parts of GIT on mature birds could not be gathered from published literature; weather the difference is anatomical or functional it requires further histological studies in order to assess the production of enzymes. Hopefully, this experiment will provoke further and detail anatomical and physiological study and this supposed study is required to reach to the actual role of each parts of GIT in digestion. Of course, some of the following papers have some relevant report on this subject.

According to Iji (1999), fibrous diets have long been known to increase the full weight of the GIT and a few studies have revealed similar effects on the empty weights of the digestive organs, suggesting the occurrence of changes at the tissue level (Smits *et al.*, 1997). Siri *et al*. (1992) reported that the inclusion of pectin in the diets of White Leghorn chickens resulted in increases in the relative weights (weight on percent basis of body weight) of the internal organs, including the crop, small intestine, ceca and rectum. The length of the oesophagus and those of the small intestine, ceca and rectum were also increased. Jorgensen *et al*. (1996) observed increases in the lengths and weights of the small intestine and ceca in broiler chickens that had been fed on diets supplemented with pea fibre, wheat bran or oat bran. Some of the gross changes in the GIT could be eliminated by increased digestion of the non-starch polysaccharides. For example, the addition of a 13-glucanase to a barley-based diet was shown by Viveros *et al*. (1994) to improve weight gain and to reduce the relative lengths of the small intestinal regions and the ceca.

5.2.7. Fertility and Hatchability

Results of the current study related to fertility are consistent with reports of Olawumi and Salako (2011) and Ali *et al.,* (1993) who reported that breed has no effect on fertility. Unlike the present study where there was insignificant (P>0.05) difference between breeds in fertility, higher fertility has been recorded by Islam *et al.* (2002) for light (White Leghorn) when compared with heavy breeds (Barred Plymouth Rock, Rhode Island Red, White Rock and New Hampshire).

These studies and several others have shown that fertility can be highly variable even within the same breed mainly due to poor management and improper proportion of males or poor ability of males in the flock to produce viable sperms (Jayarajan, 1992, Murad *et al.*, 2001; Islam *et al.*, 2002 and Zelleke *et al.*, 2005). The results of the present study allude that the 1:5 cock to hen proportion. Similarly, King'ori (2011) reported that the optimum cock: hen ratio to ensure production of fertilized eggs should be maintained for the class of poultry under consideration. This ratio ranges from 1 cock for 5-10 hens, depending on the system (intensive or extensive) of production and size (light or heavy) of the breed. In general; improved management, favourable environment and balanced breeder nutrition would also promote good fertility rate.

Comparisons between the two breeds on the other hand, revealed significant differences ($p<0.5$) in hatchability. The current results of the BB are lower compared with other researchers who reported high hatchability levels of 95.5% in scavenging chicken Murad *et al.* (2001) and 96.11% in commercial layer chicken (Islam *et al.*, 2002 and Zelleke *et al.*, 2005). The finding of this study did not agree with that of Ali *et al*. (1993) who found no significant effect of breed on hatchability in RIR, Fayoumi and Fayoumi x RIR fowls. However, Jayarajan (1992) and Islam *et al.* (2002) found significant variation in hatchability among genotypes. Further, no significant ($p>0.05$) difference in dead in shell were found attributable to genotype (Islam *et al.* 2002) is inconsistent to the present study.

The lower hatchability was observed in BB, and the chicks hatched were also of poor quality in terms of vigor, which might be attributed to the poor hatchability of BB eggs. Variations in hatchability can be accounted for by various factors. Several researchers have reported that hatchability decreases with increasing egg storage period as percentage early and late embryonic mortality increases (Elibol and Brake, 2008 and Hrnčár and Bujko, 2012). Besides, providing good feeding management and good mothering ability of the brooding hen to incubate the egg had effects in reducing embryonic mortality.

Finally, both genetic and non-genetic factors are important in the productivity of parent stock. It was hereby suggested that to meet the increasing demand for commercial chicks in this country, favorable environment, adequate nutrition and a more productive breed of parent stock should be provided.

5.2.8. Farmers perception on chicken genotypes

There are two types of meat and egg chickens on the local market: exotic and local. Consumer preference for any of these birds varies from one individual to another. In terms of adaptive traits and consumption the indigenous chickens were considered favourable. Thus, the main reason for preference of local chicken meat and egg observed in this study was its perceived good taste. Likewise, Nigussie *et al.* (2010) reported that most of the respondents have the opinion that the eggs and meat obtained from modern breeds have poorer taste. Kyarisiima *et al.* (2011) also revealed that consumers perceived local chicken to be the tastiest and safest of all other chicken meats on the market.

According to Senbeta *et al.* (2015) almost half of respondents preferred to buy eggs of local chickens as they were considered to be tasty and the yellow coloured yolk was commonly favoured. Respondents explained that eggs from local chickens tastes better because they are scavenging natural rather than formulated feed (chemical feed). Others preferred to buy eggs of exotic chickens as they were considered to be large in size to maximize utility and better visual attractiveness of the shell colour and few respondents cannot choose for the breeds of eggs understood for their similar nutrition. Similarly, Fisseha, (2009) reported in his study that most consumers preferred to buy local eggs from producers as they were considered to be tasty and attractive dark coloured yolk. Consumer preference observed for eggs from local, improved and both local and improved chicken were 77.8%, 17.8% and 4.4% respondents in Ada'a and 87.8%, 7.8% and 4.4%, in Lume districts, respectively, as reported by (Desalew, 2012).

Brown egg shell colour preference of consumers observed in the focus group discussion agreed with the findings of Jibir *et al.* (2012) and Uwagboe *et al*. (2009). Of course, shell colour is not an indication of internal egg quality and indicates nothing about the nutritive value or the quality of the egg (Flock *et al.,* 2007); further Goddard *et al.* (2007) reported that there is no evidence that white and brown eggs have different nutritional value. However, Senbeta *et al.* (2015) reported that there is usually a consumer preference to either white or brown, which needs to be given a due consideration in marketing eggs. In this regard, more than half prefer brown-shelled eggs, incorrectly believing they are more nutritious and taste better than white eggs and also, they expected as brown eggs are coming from local hens with attractive yellow yolk colours. On the other hand, some respondents were found to prefer white shelled eggs as they appear cleaner and fresher, while other consumers do not pay attention to the colour of the shell as the egg colour does not have impact on the function and quality of the eggs.

Besides; Odabasi *et al.* (2007) reported that consumers in United Kingdom, Italy, Portugal, Ireland, Southeast Asia, Australia, and New Zealand prefer brown eggs over white eggs. On the other hand, white eggs are most in demand among Americans Jacob *et al.* (2000) and Johnston *et al.* (2011), and Japanese consumers (Hashimoto *et al.,* 2011). The preference for brown shelled eggs in New England (Jacob *et al.,* 2000), United Kingdom, Australia and New Zealand; Odabasi *et al.* (2007) indicates a cultural dimension to egg shell colour preference considering the common geo-cultural origin of populations in these regions.

On the other hand, unlike the present study, Jibir *et al.* (2012) reported that large egg size was the characteristics most preferred to be expected as it is natural for consumers to want to maximize utility. Jacob *et al.* (2000) indicated that the greatest consumer demand in America is for Large and Extra Large eggs. Hashimoto *et al.* (2011) showed a similar trend in a survey of 273 households in 23 districts of Japan.

Meanwhile, one of the essential characteristics for scavenging chicken is morphology and temperament of the bird (Rao, 2002 and Singh, 2003). The local chickens have the capability of self-defence from predators due to its alertness, light body weight, longer shank length, camouflagic characters and aggressiveness. The BB is a bird with quite temperament and is poor in this regard but the Koekoek chicken is better. Most of the respondents claimed that the modern breed is poor in disease and stress tolerance and in the ability to escape predators prevalent in their village conditions Nigussie *et al.* (2010) is consistent to the present findings.

On the other hand, poor nesting behaviour during egg production, observed in the BB chicken of the present study is unfavourable for both extensive and intensive management. Nesting and laying are important forms of behaviour in laying hens. Hens prefer to lay in enclosed or secluded nest sites (Appleby and Smith, 1991), and work harder for access to enclosed nest sites than for open nest sites (Cooper and Appleby, 1994a). Hens also prefer nest sites with mouldable or peckable nest-building substrates (Reed and Nicol, 1992). Hens may, therefore, floor lay, not because they are less motivated to seek out and use a nest site, but because man made nest boxes are poorly designed and unattractive.

The broody trait of the Koekoek chicken breed and the ability to incubate may be preferred in most extensive management system where there is no artificial incubator. The broody behaviour of Koekoek chicken breed is also confirmed by Grobbelaar, (2008) who reported that this breed is very popular among rural farmers in South Africa and neighboring countries for egg and meat production as well as their ability to hatch their own offspring.

Finally, the farmers involved in the present study perceived that higher feed consumption was noted in both exotics compared to local chickens with no difference between the two exotic chickens. The intake of feed for the exotics and local chickens is in concordance with the BW and production performance. Similar breed variation in feed intake was reported by McCrea *et al.* (2014) in which feed intake for the broilers was consistently greater than that of the Delawares. In general, sensitization campaigns on nutritional quality of eggs and meat, on the behaviour (nesting, broody, and feed consumption) as well as on the temperament of exotic chickens is necessary.

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

To evaluate the productive and reproductive performances of Bovans Brown (BB) and Koekoek (Koekoek) chicken breeds, under 3 seasons (CS, HSe and MRS) and 2 feeding regimes (Supplemented-SU and Non-supplemented-NS), and to capture the perception of farmers on chicken genotypes; a study was conducted at Kalu district of South Wollo Zone of the Amhara National Regional State between October 2013 and January 2015. Phase I, was arranged as a 2x3 factorial experiment in CRD having 6 treatment combinations and 3 replications for each treatment with 50 chicks per replicate, that was conducted at 3 different seasons. In each season, 300 day-old chicks (DOC) reared until 3-months age on a commercial diet. For Phase II experiment 3-month old five pullets and one cockerel per replicate assigned to a 2x2x3 factorial arrangement as a completely randomized design with four treatments of three replicates for each treatment, distributed to 12 household farmers and maintained until 15-months age. Except the data on farmer's perception, that was analysed by descriptive statistics, SAS (2002) computer package used for all collected data.

The result of Phase I indicated that the effect of breed on FIg/b/d was significant ($p<0.5$) and more pronounced in BB, the effect on ADG, FCR and mortality was also significant ($p<0.5$) but more pronounced in the Koekoek breed. Among the seasons ADG and RT was significantly ($p<0.5$) higher, and FCR was significantly ($p<0.5$) better during the HSe. There was a significant ($p<0.5$) breed by season interaction for FIg/b/d, ADG, FCR, RT and mortality. In all the seasons BB breed had higher FIg/b/d and in the MRS the Koekoek breed had higher ADG and mortality and better FCR. Further, Koekoek breed had higher RT in the HSe.

In general, Koekoek breed originated from the tropical region of Africa better adapted when reared to three months of age, which expressed in terms of ADG and FCR. However, the higher mortality during the MRS affected the survival rate of this breed which was associated with the poor quality of the chicks and this low survival rate in turn influenced their feed consumption. The higher ADG in the dual-purpose breeds like the Koekoek is expected one unlike the BB that is an egg type and lighter breed. In the present study, the two breeds perform better during the MRS and HSe compared to CS that is CS seems stressful to both breeds.

The result in Phase II revealed the main effects Koekoek breed and feed supplementation had played a great role in improving BWG. The significant difference recorded in two-way interaction effects showed that feed supplementation had played significantly ($p<0.5$) greater role in BWG of the Koekoek breed. However, this study did not include main season or interaction with season effect of BWG, because BWG was determined as the difference between the final and the initial weights taken during the commencement of the experimental period. Koekoek breed, supplemented, HSe birds from the main effects and Koekoek*S, Koekoek*HSe, S*HSe and Koekoek*S*HSe from the interaction groups were significantly ($p<0.5$) higher in RT. Significantly ($p<0.5$) higher TCE observed in Koekoek and AEW in BB breed. There were no significant differences in EM among all main and interaction effects. Though insignificant Koekoek chicken attained 6 days earlier in the AOEL, and significantly ($p<0.5$) earlier AOEL was recorded in the main effect supplemented and the interaction effects of both breeds due to supplementation. In TCE-Koekoek and in AEW-BB breeds main effect more pronounced than the rest of the two and three-way interaction effects. No significant ($p<0.5$) difference was observed between the main and interaction effects in the mortality of the birds, but numerically higher mortality was recorded in BB, NS and in both HSe and MRS birds. The causes of mortality or loss were unidentified diseases (UD), wild mammals, wild birds, loss, beaten by some body and theft. However, significant difference noted due to UD.

Concerning anatomical and physiological responses of the two breeds, the difference in reproductive activity during the laying period were due to breed variation of the chicken. The egg type BB was superior in ovary weight and follicle number (the source of yolk) than the dual-purpose Koekoek breed, which also reflected in their laying performance. The same trend also noted in the oviduct. Major parts of the oviduct; weight of magnum, uterus and overall oviduct as well as length of isthmus and overall oviduct; which has secretary role in the deposition of albumen, shell membrane and egg shell was superior in BB than Koekoek breed. Regarding effect of feeding regimes, supplementation has profound effect on egg productivity of birds, which reflected in the total ovary weight (WOYAF) and number of white ovarian follicles that would undergo to the growing phase. However, the superiority of NAYF in supplemented birds could be due to mere chance. Supplementation may also improve the egg size by promoting the development of isthmus and uterus part of the oviduct as well as the development of overall oviduct.

It is indicated from this observation that the bigger weight of important organs (oesophagus, crop, proventriculus, gizzard, duodenum, jejunum, ileum, ceca and large intestine) as well as the length of important organs (oesophagus, gizzard, jejunum, ileum and large intestine) in BB may be responsible for superior production traits may be on account of better digestion and absorption oriented process. The higher egg productivity of the BB could be the reason for bigger weight with contents of GIT. Supplementation may not be able to stimulate the development of GIT as observed also in the weight with contents of the GIT.

There was significant ($p<0.5$) breed effect on hatchability but the reverse was the case for fertility rate. Perception of farmers on chicken genotypes revealed that most consumers prefer brown egg shell color, believe the local chicken meat and egg is good and best marketed compared to the exotic, small size eggs are preferred because these eggs are believed to be from local chickens. Regarding behavior of the exotic breeds; BB is a bird with quite temperament and unable to escape from predators and thieves, has no permanent laying site compared to Koekoek, the Koekoek is one of the exotic breed known with a broody behavior. Further there is no difference in feed consumption between the two breeds but higher than the local chickens.

Finally, the result of phase II showed that Koekoek chicken is well adapted to semi-arid conditions in Ethiopia and their production performance was better than the BB chicken indicating that it is a good choice for egg producers who can regularly supply supplementary feed. Besides, farmers may opt for the Koekoek breed because of their lower mortality, plumage colour, and overall conformation. Higher mortality due to unidentified diseases could be one of the reasons for the poor production performance of the temperate BB chicken. The larger size in the Koekoek breed, better digestion and metabolic processes of the supplemented birds and the higher AT of the HSe might be associated with the higher RT values recorded in the earlier sections main effects and their interactions. Bovans brown is a bird with quite temperament. This behaviour is desirable characteristics for intensive management although unfavourable for extensive management. Nesting and laying are important forms of behaviour in laying hens. However, poor nesting behaviour of the BB chicken during egg production is harmful for both extensive and intensive management. The broody trait of the Koekoek chickens and the ability to incubate may be preferred in extensive management system where there is no artificial incubator.

It is concluded that significant improvement in poultry production is possible through the replacement of less productive exotic breeds with a suitable stock that will thrive well under all existing natural hazards in intensive and in the rural free range condition, feed supplementation to scavenging birds following vaccination program against prevalent diseases. The physiological and anatomical changes in terms of digestive and female reproductive systems may be mediating the positive effects of selection of suitable breed and feed supplementation. Both genetic and non-genetic factors are important in the productivity of parent stock. It was hereby suggested that to meet the increasing demand for commercial chicks in this country, favourable environment, adequate nutrition and a more productive breed of parent stock should be provided. Sensitization campaigns on nutritional quality of eggs and meat, on the behaviour (nesting, broody, and feed consumption) as well as on the temperament of exotic chickens is necessary.

6.2. Recommendations

- Feed supplementation to scavenging birds is highly recommended. Further, research needed to substitute the alternative (cheaper, easily available and non-competitive to human) feed resources.
- There is a need to make further investigations on the response of the two breeds to the rearing environments as reflected by RT under controlled environmental conditions for extended periods.
- Further research is still needed using three identical batch of chickens for each season separately that will be maintained till the 72^{nd} weeks age and repeated for a minimum of three years to determine breed, season and year effect.
- More research is required to control the follicular atresia and manipulation of digestive tract to improve the rural poultry production efficiency.

- Weather the difference in the comparison of individual parts of GIT is anatomical or functional requires further histological studies in order to assess the production of enzymes and to reach the actual role of each parts of GIT in digestion.

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8. APPENDICES

Appendix A. Table

Appendix Table 1. Summary of the ANOVA of the effect of breed, season and the interaction effects of breed with season for various performance traits of Phase I.

Dependent Variables	Mean Square/Source			
	Br	Se	Br*Se	Error
FIg/b/d	34.72*	6.38	17.22*	2.99
ADGg	7.71*	10.92*	2.62	0.74
FCR	3.81*	8.73*	2.53*	0.26
RT^{O}C	0.03	2.80*	0.17*	0.02
Mortality (%)	213.56*	38.00	62.89*	12.22

*Significantly different at $p<0.05$; Br-Breed, Se-Season, Br*Se- Breed by Season interaction.

Appendix Table 2. Values of coefficient of variation (CV), root mean square error (RSME), and mean for various performance traits of Phase I.

Dependent Variable	CV	RMSE	Mean
FIg/b/d	4.23	1.73	40.88
ADGg	11.35	0.86	7.58
FCR	8.89	0.51	5.71
RT^{O}C	0.31	0.13	41.90
Mortality %	55.20	3.50	6.33

Appendix Table 3. F and P values for various performance traits (F-value and Pr>F) of Phase I.

Dependent Variable	Br		Se		Br*Se	
	F-V	P	F-V	P	F-V	P
FIg/b/d	11.62	0.0052	2.13	0.1611	5.76	0.0176
ADGg	10.40	0.0073	14.73	0.0006	3.54	0.0620
FCR	14.80	0.0023	33.92	<.0001	9.84	0.0030
RT^{O}C	1.68	0.2197	162.70	<.0001	9.70	0.0031
Mortality %	17.47	0.0013	3.11	0.0817	5.15	0.0243

Appendix Table 4. Summary of the ANOVA of the main, two and three-way interaction effects for various performance traits of Phase II.

Dependent Variable	Mean Squares							
	Br	FR	Se	Br*FR	Br*Se	FR*Se	Br*Se*FR	Error
BWGg	200467*	160777*	----	21590	----	----	----	11856
RT^{O}C	0.30*	0.45*	2.14*	0.002	0.08*	0.01	0.001	0.01
TCE (No)	9539*	2147	1111	900	822	83	1081	706
AEW (g)	1069*	2.45	12.07	0.81	3.52	9.51	3.16	9.24
EM (g)	2020188	7169899	5269191	1934881	1661359	102624	2229984	1827472
AOEL (days)	108	481*	----	56	----	----	----	29
Mort (%)	277.33	30.73	192.75	0.0001	69.33	146.43	23.24	161.95

*Significantly different at p<0.05; Br-Breed, Se-Season, Br*Se- Breed by Season interaction.

Appendix Table 5. Values of coefficient of variation (CV), root mean square error (RSME) and Mean for various performance traits of Phase II.

Dependent Variable	CV	RMSE	Mean
BWG	11.05	108.9	986
RT^{O}C	0.19	0.08	42.17
TCE	25.85	26.57	103
AEW	6.35	3.04	47.85
EM	27.42	1351.84	4931
AOEL	2.82	5.39	191
Mortality (%)	98.17	12.73	12.96

Appendix Table 6. F and P values of the main effects for various performance traits of Phase II.

Dependent Variable	BR		FR		Se	
	F-V	P	F-V	P	F-V	P
BWG	16.91	0.0034	13.56	0.0062	1.82	0.2142
RT^{O}C	48.39	<.0001	72.60	<.0001	345.09	<.0001
TCE	13.52	0.0012	3.04	0.0939	1.57	0.2278
AEW	115.74	<.0001	0.27	0.6110	1.31	0.2895
EM	1.11	0.3035	3.92	0.0592	2.88	0.0755
AOEL	3.72	0.0897	16.60	0.0036	1.94	0.2009
Mortality (%)	0.71	0.2031	0.19	0.6670	1.19	0.3215

Appendix Table 7. F and P values of the two and three-way interaction effects for various performance traits of Phase II.

Dependent Variable	Br*FR		Br*Se		FR*Se		Br*FR*Se	
	F-V	P	F-V	P	F-V	P	F-V	P
BWG	1.82	0.2142	----	-----	------	------	------	------
RT^{O}C	0.28	0.6020	13.19	0.0001	1.06	0.3613	0.23	0.7975
TCE	1.28	0.2699	1.16	0.3290	0.12	0.8890	1.53	0.2364
AEW	0.09	0.7697	0.38	0.6872	1.03	0.3726	0.34	0.7140
EM	1.06	0.3138	0.91	0.4163	0.06	0.9455	1.22	0.3128
AOEL	1.94	0.2009	----	-----	------	------	------	------
Mortality (%)	0.00	0.9992	0.43	0.6566	0.90	0.4182	0.14	0.8671

Appendix Table 8. Summary of the ANOVA of the main, two and three-way interaction effects on reason of mortality or loss of Phase II.

Dependent Variable	Mean Squares							
	Br	FR	Se	Br*FR	Br*Se	FR*Se	Br*Se*FR	Error
Mort (%)	277.17	30.78	192.68	0.0001	69.29	146.53	23.20	161.95
WM	0.00	0.67	2.67	0.67	2.00	0.67	0.67	46.32
WB	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72
UD	518.70*	37.43	103.65	136.31	97.45	4.96	11.09	63.53
L	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72
BS	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72
Theft	69.47	7.72	0.00	7.72	0.00	30.88	30.88	23.16
AWM	0.00	64.64	258.57	64.64	193.93	64.64	64.64	96.96
AWB	16.16	16.16	16.16	16.16	16.16	16.16	16.16	16.16
AUD	899.61	104.18	171.23	332.94	153.81	29.57	12.15	99.14
AL	16.16	16.16	16.16	16.16	16.16	16.16	16.16	16.16
ABS	16.16	16.16	16.16	16.16	16.16	16.16	16.16	16.16
ATheft	145.44	16.16	0.00	16.16	0.00	64.64	64.64	48.48

*Significantly different at $p<0.05$; Br-Breed, Se-Season, Br*FR- Breed by Feeding Regime interaction, Br*Se- Breed by Season interaction, FR*Se- Feeding Regime by Season interaction, Br*Se*FR- Breed by Season by Feeding Regime interaction.

Appendix Table 9. Least squares mean values for two-way interaction effects on reason of mortality or loss of Phase II (n=36).

Dependent Variable			Mort (%)	WM	WB	UD	L	BS	Th
Br*FR	BB	S	14.82^{a}	3.70^{a}	0.00^{a}	11.48^{a}	0.00^{a}	0.00^{a}	0.00^{a}
		NS	16.66^{a}	5.56^{a}	1.85^{a}	5.52^{ab}	1.85^{a}	1.85^{a}	0.00^{a}
	Kk	S	9.26^{a}	1.85^{a}	0.00^{a}	0.00^{b}	0.00^{a}	0.00^{a}	1.85^{a}
		NS	11.11^{a}	3.70^{a}	0.00^{a}	1.85^{ab}	0.00^{a}	0.00^{a}	3.70^{a}
Br*Se	BB	CS	8.34^{a}	0.00^{a}	0.00^{a}	2.78^{b}	0.00^{a}	0.00^{a}	0.00^{a}
		HSe	19.43^{a}	8.34^{a}	2.78^{a}	8.89^{b}	0.00^{a}	0.00^{a}	0.00^{a}
		MRS	19.45^{a}	2.78^{a}	0.00^{a}	13.89^{a}	2.78^{a}	0.00^{a}	0.00^{a}
	Kk	CS	8.34^{a}	0.00^{a}	0.00^{a}	0.00^{b}	0.00^{a}	0.00^{a}	2.78^{a}
		HSe	11.11^{a}	2.78^{a}	0.00^{a}	2.78^{b}	0.00^{a}	2.78^{a}	2.78^{a}
		MRS	11.11^{a}	8.34^{a}	0.00^{a}	0.00^{b}	0.00^{a}	0.00^{a}	2.78^{a}
FR*Se	S	CS	11.11^{a}	0.00^{a}	0.00^{a}	2.78^{a}	0.00^{a}	0.00^{a}	2.78^{a}
		HSe	11.11^{a}	2.78^{a}	0.00^{a}	6.11^{a}	0.00^{a}	2.78^{a}	0.00^{a}
		MRS	13.89^{a}	5.56^{a}	0.00^{a}	8.34^{a}	0.00^{a}	0.00^{a}	0.00^{a}
	NS	CS	5.56^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}
		HSe	19.44^{a}	8.34^{a}	2.78^{a}	5.56^{a}	0.00^{a}	0.00^{a}	2.78^{a}
		MRS	16.67^{a}	5.56^{a}	0.00^{a}	5.55^{a}	2.78^{a}	0.00^{a}	2.78^{a}

ab: - means with different superscript in a row are significantly different from each other within the two interaction effects.

Appendix Table 10. Least squares mean values for two-way interaction effects on arc sine transformed reason of mortality or loss of Phase II (n=36).

Dependent Variable			AWM	AWB	AUD	AL	ABS	ATh
	BB	S	2.68[a]	0.00[a]	16.08[a]	0.00[a]	0.00[a]	0.00[a]
		NS	8.04[a]	2.68[a]	6.59[ab]	2.68a	0.00[a]	0.00[a]
Br*FR	Koekoek	S	5.36[a]	0.00[a]	0.00[b]	0.00[a]	2.68[a]	2.68[a]
		NS	5.36[a]	0.00[a]	2.68[b]	0.00[a]	0.00[a]	5.36[a]
		CS	0.00[a]	0.00[a]	4.02[ab]	0.00[a]	0.00[a]	0.00[a]
	BB	HSe	12.06[a]	4.02[a]	12.06[ab]	0.00[a]	0.00[a]	0.00[a]
		MRS	4.02[a]	0.00[a]	17.93[a]	4.02[a]	0.00[a]	0.00[a]
Br*Se		CS	0.00[a]	0.00[a]	0.00[b]	0.00[a]	0.00[a]	4.02[a]
	Koekoek	HSe	4.02[a]	0.00[a]	4.02[ab]	0.00[a]	4.02[a]	4.02[a]
		MRS	12.06[a]	0.00[a]	0.00[b]	0.00a	0.00[a]	4.02[a]
		CS	0.00[a]	0.00[a]	4.02[a]	0.00[a]	0.00[a]	4.02[a]
	S	HSe	4.02[a]	0.00[a]	8.04[a]	0.00[a]	4.02[a]	0.00[a]
		MRS	8.04[a]	0.00[a]	12.06[a]	0.00[a]	0.00[a]	0.00[a]
FR*Se		CS	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]
	NS	HSe	12.06[a]	4.02[a]	8.04[a]	0.00[a]	0.00[a]	4.02[a]
		MRS	8.04[a]	0.00[a]	5.87[a]	4.02[a]	0.00[a]	4.02[a]

ab: - means with different superscript in a row are significantly different from each other within the two interaction effects

Appendix Table 11. Least squares mean values for the three-way interaction effects of reason of mortality or loss of Phase II (n=36).

Dependent Variables	Br*FR*Se											
	BB						Koekoek					
	S			NS			S			NS		
	Cold	Hot	MRS	Cold	Hot	MRS	Cold	Hot	MRS	Cold	Hot	MRS
Mort (%)	11.11^{a}	16.66^{a}	16.67^{a}	5.56^{a}	22.20^{a}	22.22^{a}	11.11^{a}	5.56^{a}	11.11^{a}	5.56^{a}	16.67^{a}	11.11^{a}
WM	0.00^{a}	5.56^{a}	0.00^{a}	0.00^{a}	11.11^{a}	5.56^{a}	0.00^{a}	0.00^{a}	11.11^{a}	0.00^{a}	5.56^{a}	5.56^{a}
WB	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	5.56^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}
UD	5.56^{a}	12.22^{a}	16.67^{a}	0.00^{a}	5.56^{a}	11.10^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	5.56^{a}	0.00^{a}
L	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	5.56^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}
BS	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	5.56^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}
Theft	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	5.56^{a}	0.00^{a}	0.00^{a}	0.00^{a}	5.56^{a}	5.56^{a}

a: - means with different superscript in a row are significantly different from each other within the two interaction effects

Appendix Table 12. Least squares mean values of arc sine transformed of the three-way interaction effects of reason of mortality or loss of Phase II (n=36).

	Br*FR*Se											
	BB						Koekoek					
Dependent Variables	S			NS			S			NS		
	CS	HSe	MRS	CS	HSe	MRS	CS	HSe	MRS	CS	HSe	MRS
AWM	0.00[a]	8.04[a]	0.00[a]	0.00[a]	16.08[a]	8.04[a]	0.00[a]	0.00[a]	16.08[a]	0.00[a]	8.04[a]	8.04[a]
AWB	0.00[a]	0.00[a]	0.00[a]	0.00[a]	8.04[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]
AUD	8.04[a]	16.08[a]	24.12[a]	0.00[a]	8.04[a]	11.75[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]	8.04[a]	0.00[a]
AL	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]	8.04[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]
ABS	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]	8.04[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]
ATheft	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]	8.04[a]	0.00[a]	0.00[a]	0.00[a]	8.04[a]	804[a]

a: - means with different superscript in a row are significantly different from each other within the two interaction effects

Appendix Table 13. Values of coefficient of variation (CV), root mean square error (RSME), standard error (SE) and mean for reason of mortality or loss of Phase II.

Dependent Variable	CV	RMSE	SE	Mean
Mort (%)	98.18	12.73	2.00	12.96
WM	183.71	6.81	1.17	3.70
WB	600.00	2.78	0.46	0.46
UD	168.70	7.97	1.45	4.72
L	600.00	2.78	0.46	0.46
BS	600.00	2.78	0.46	0.46
Theft	346.41	4.81	0.78	1.39
AWM	183.71	9.85	1.70	5.36
AWB	600.00	4.02	0.67	0.67
AUD	157.08	9.96	1.88	6.34
AL	600.00	4.02	0.67	0.67
ABS	600.00	4.02	0.67	0.67
ATheft	346.41	6.96	1.13	2.01

Appendix Table 14. F and P value of the main effects of breed, feeding regime and season for reason of mortality or loss of Phase II.

Dependent Variable	BR		FR		Se	
	F-V	P	F-V	P	F-V	P
Mort (%)	1.71	0.2031	0.19	0.6670	1.19	0.3215
WM	0.00	1.0000	0.67	0.4222	2.67	0.0900
WB	1.00	0.3273	1.00	0.3273	1.00	0.3827
UD	8.16	0.0087	0.59	0.4502	1.63	0.2166
L	1.00	0.3273	1.00	0.3273	1.00	0.3827
BS	1.00	0.3273	1.00	0.3273	1.00	0.3827
Theft	3.00	0.0961	0.33	0.5691	0.00	1.0000
AWM	0.00	1.0000	0.67	0.4222	2.67	0.0900
AWB	1.00	0.3273	1.00	0.3273	1.00	0.3827
AUD	9.07	0.0600	1.05	0.3155	1.73	0.1992
AL	1.00	0.3273	1.00	0.3273	1.00	0.3827
ABS	1.00	0.3273	1.00	0.3273	1.00	0.3827
ATheft	3.00	0.0961	0.33	0.5691	0.00	1.0000

Appendix Table 15. F and P values for the interaction effects between breed and feeding regime, breed and season, feeding regime and season and breed, feeding regime and season on the reason of mortality or loss of Phase II.

Dependent Variable	Br*FR		Br*Se		FR*Se		Br*FR*Se	
	F-V	P	F-V	P	F-V	P	F-V	P
Mort (%)	0.00	0.9995	0.43	0.6568	0.90	0.4180	0.14	0.8673
WM	0.67	0.4222	2.00	0.1573	0.67	0.5227	0.67	0.5227
WB	1.00	0.3273	1.00	0.3827	1.00	0.3827	1.00	0.3827
UD	2.15	0.1560	1.53	0.2361	0.08	0.9252	0.17	0.8409
L	1.00	0.3273	1.00	0.3827	1.00	0.3827	1.00	0.3827
BS	1.00	0.3273	1.00	0.3827	1.00	0.3827	1.00	0.3827
Theft	0.33	0.5691	0.00	1.0000	1.33	0.2824	1.33	0.2824
AWM	0.67	0.4222	2.00	0.1573	0.67	0.5227	0.67	0.5227
AWB	1.00	0.3273	1.00	0.3827	1.00	0.3827	1.00	0.3827
AUD	3.36	0.0793	1.55	0.2325	0.30	0.7448	0.12	0.8853
AL	1.00	0.3273	1.00	0.3827	1.00	0.3827	1.00	0.3827
ABS	1.00	0.3273	1.00	0.3827	1.00	0.3827	1.00	0.3827
ATheft	0.33	0.5691	0.00	1.0000	1.33	0.2824	1.33	0.2824

Appendix Table 16. Summary of the ANOVA of breed, feeding regime and the interaction between breed and feeding regime on the absolute and relative weight of ovary and number of ovarian follicles of Phase II.

Source	Mean square			
	Br	FR	Br*FR	Error
WOYAF	187.23*	62.56*	3.63	5.90
WOYAFp	12.18*	1.88	0.09	0.40
WOEYF	48.00*	3.00	3.00	3.25
WOEYFp	5.58*	0.51	0.02	0.19
WOEYWF	13.65*	3.85	0.12	1.12
WOEYWFp	0.28*	0.06	0.01	0.02
WOEYWAF	3.31	2.00	5.20	2.15
WOEYWAFp	0.09	0.03	0.06	0.02
NYF	18.75*	10.08	0.08	2.75
SRT	1.03*	0.59	0.02	0.18
NWOF	1.33	3.00*	1.33	0.50
SRT1	0.21	0.48*	0.21	0.08
NAYF	44.08*	24.08*	4.08	2.75
SRT2	1.39*	0.72*	0.05	0.08
BW	240833	20833	833	8958

*Significantly different at $p<0.05$

Appendix Table 17. Values of coefficient of variation, root mean square error and mean for absolute and relative weight of ovary and number of ovarian follicles of Phase II.

Dependent Variable	CV	RMSE	Mean
WOYAF	4.88	2.43	49.78
WOYAFp	13.37	0.63	4.73
WOEYF	4.51	1.80	40.00
WOEYFp	11.42	0.43	3.79
WOEYWF	26.91	1.06	3.93
WOEYWFp	35.44	0.14	0.39
WOEYWAF	68.39	1.47	2.14
WOEYWAFp	73.47	0.16	0.21
NYF	32.62	1.66	5.08
SRT	18.56	0.43	2.29
NWOF	24.57	1.66	6.75
SRT1	10.61	0.28	2.64
NAYF	38.57	0.71	1.83
SRT2	20.41	0.27	1.34
BW	8.67	94.65	1092

Appendix Table 18. F and P Value for the absolute and relative weight of ovary and number of ovarian follicles of Phase II.

Dependent Variable	BR		FR		BR*FR	
	F-V	P	F-V	P	F-V	P
WOYAF	31.75	0.0005	10.61	0.0116	0.62	0.4553
WOYAFp	30.51	0.0006	4.71	0.0618	0.22	0.6505
WOEYF	14.77	0.0049	0.92	0.3648	0.92	0.3648
WOEYFp	29.86	0.0006	2.74	0.1362	0.10	0.7567
WOEYWF	12.19	0.0082	3.44	0.1007	0.11	0.7518
WOEYWFp	14.77	0.0049	3.23	0.1102	0.50	0.4978
WOEYWAF	1.54	0.2495	0.93	0.3624	2.42	0.1581
WOEYWAFp	3.49	0.0988	1.27	0.2921	2.36	0.1634
NYFN	6.82	0.0311	3.67	0.0918	0.03	0.8661
SRT	5.67	0.0445	3.23	0.1100	0.11	0.7482
WOFN	16.03	0.0039	8.76	0.0182	1.48	0.2577
SRT1	17.71	0.0030	9.20	0.0162	0.58	0.4672
NAYF	2.67	0.1411	6.00	0.0400	2.67	0.1411
SRT2	2.79	0.1331	6.45	0.0348	2.79	0.1331
BW	26.88	0.0008	2.33	0.1658	0.09	0.7682

Appendix Table 19. Summary of the ANOVA of the main effects of breed, feeding regime and the interaction between breed and feeding regime on relative length and weight of Oviduct of Phase II.

Source	Mean Square			
	Br	FR	Br*FR	Error
Infundibulum (Wt)	0.40	0.03	0.65	0.63
Magnum (Wt)	415.36*	7.68	51.25	14.46
Isthmus (Wt)	0.85	7.36*	0.03	0.89
Uterus (Wt)	65.33*	19.76	2.08	5.37
Vagina (Wt)	9.90*	8.50	5.47	1.80
Total (Wt)	1131.02*	146.30	26.11	32.46
Infundibulum (L)	0.52	9.19	3.52	2.88
Magnum (L)	172.52*	88.02	42.19	20.81
Isthmus (L)	21.87*	6.45*	1.47	0.96
Uterus (L)	0.21	5.88	3.00	1.46
Vagina (L)	5.20	4.68	0.02	2.62
Total (L)	414.18*	381.94*	3.31	51.43

*Significantly different at $p<0.05$

Appendix Table 20. Values of coefficient of variation (CV), root mean square error (RSME) and mean for length and weight of Oviduct of Phase II.

Dependent Variable	CV	RMSE	Mean
Infundibulum (Wt)	66.23122	0.794775	1.20
Magnum (Wt)	20.60809	3.802192	18.45
Isthmus (Wt)	21.12085	0.943398	4.47
Uterus (Wt)	22.48783	2.316247	10.30
Vagina (Wt)	32.41623	1.342572	4.14
Total (Wt)	14.33545	5.697148	39.74
Infundibulum (L)	19.47080	1.695582	8.71
Magnum (L)	15.89111	4.562072	28.71
Isthmus (L)	10.07513	0.980646	9.73
Uterus (L)	16.50038	1.210028	7.33
Vagina (L)	23.71259	1.618384	6.83
Total (L)	11.69843	7.172110	61.31

Appendix Table 21. F and P value for relative length and weight of oviduct of Phase II.

Dependent Variable	BR		FR		BR*FR	
	F-V	P	F-V	P	F-V	P
Infundibulum (Wt)	0.64	0.4473	0.05	0.8329	1.03	0.3389
Magnum (Wt)	28.73	0.0007	0.53	0.4869	3.55	0.0965
Isthmus (Wt)	0.96	0.3562	8.27	0.0206	0.03	0.8589
Uterus (Wt)	12.18	0.0082	3.68	0.0912	0.39	0.5505
Vagina (Wt)	5.49	0.0471	4.72	0.0617	3.03	0.1197
Total (Wt)	34.85	0.0004	4.51	0.0665	0.80	0.3960
Infundibulum (L)	0.18	0.6816	3.20	0.1116	1.22	0.3006
Magnum (L)	8.29	0.0205	4.23	0.0738	2.03	0.1923
Isthmus (L)	22.74	0.0014	6.71	0.0321	1.53	0.2514
Uterus (L)	0.15	0.7126	4.02	0.0800	2.05	0.1902
Vagina (L)	1.99	0.1965	1.79	0.2177	0.01	0.9311
Total (L)	8.05	0.0219	7.43	0.0261	0.06	0.8062

Appendix Table 22. Summary of the ANOVA of breed, feeding regime and the interaction between breed and feeding regime on relative empty weight of GIT of Phase II.

Source	Mean square			
	Br	FR	Br*FR	Error
Oesophagus (EW)	0.11*	0.62	0.70	0.01
Crop (EW)	0.02	0.01	0.003	0.02
Proventriculus (EW)	0.29*	0.05*	0.01	0.004
Gizzard (EW)	7.65*	0.74	0.02	1.07
Duodenum (EW)	2.13*	0.08	0.12	0.06
Jejunum (EW)	0.82*	0.05	0.19	0.47
Ileum (EW)	1.43*	0.19	0.06	0.06
Caeca (EW)	1.03*	0.16*	0.11*	0.02
Large Intestine (EW)	0.29	0.09	0.01	0.05
Total (EW)	79.11*	8.72	1.98	4.12
BWg	240833	28333	833	8958

*Significantly different at $p<0.05$

Appendix Table 23. Summary of the ANOVA of the main effects of breed, feeding regime and the interaction between breed and feeding regime on relative length of GIT of Phase II.

Source	Mean square			
	Br	FR	Br*FR	Error
Oesophagus (L)	0.52	28.52*	0.02	3.06
Crop (L)	0.05	0.07	0.01	0.02
Proventriculus (L)	2.24	0.96	1.12	1.42
Gizzard (L)	0.08*	0.05*	0.0001	0.01
Duodenum (L)	1.67	0.01	0.09	0.39
Jejunum (L)	21.92	2.27	0.19	0.80
Ileum (L)	17.69*	1.05	0.01	0.80
Caca (L)	1.23	1.56	1.12	0.32
Large Intestine (L)	0.28*	0.06	0.002	0.04
Total (L)	198.94*	20.54	1.46	7.66
BWg	240833	20833	833	8958

*Significantly different at p<0.05

Appendix Table 24. Values of coefficient of variation (CV), root mean square error (RSME) and mean for relative empty weight of GIT of Phase II.

Dependent Variable	CV	Root MSE	Mean
Oesophagus (EW)	0.70	15.63	0.53
Crop (EW)	0.14	28.25	0.55
Proventriculus (EW)	0.90	11.20	0.61
Gizzard (EW)	0.50	25.66	4.04
Duodenum (EW)	0.82	22.28	1.13
Jejunum (EW)	0.74	15.08	1.44
Ileum (EW)	0.78	20.87	1.15
Caeca (EW)	0.89	19.68	0.72
Large Intestine (EW)	0.48	37.99	0.61
Total (EW)	0.73	18.84	10.77
BWg	0.79	8.67	1091.67

Appendix Table 25. Values of coefficient of variation (CV), root mean square error (RSME) and Mean for relative length of GIT of Phase II.

Dependent Variable	CV	RMSE	Mean
Oesophagus (L)	15.05	11.63	11.63
Crop (L)	25.83	0.13	0.49
Proventriculus (L)	163.15	1.19	0.73
Gizzard (L)	17.40	0.08	0.47
Duodenum (L)	41.67	0.62	1.50
Jejunum (L)	16.80	0.89	5.31
Ileum (L)	18.30	0.89	4.89
Caeca (L)	36.23	0.57	1.57
Large Intestine (L)	24.26	0.20	0.82
Total (L)	16.49	2.77	16.79
BWg	0.79	8.67	1091.67

Appendix Table 26. F and P value for relative empty weight of GIT of Phase II.

Parts of GIT	BR		FR		BR*FR	
	F-V	P	F-V	P	F-V	P
Oesophagus (EW)	15.13	0.01	3.78	0.09	0.00	0.95
Crop (EW)	0.80	0.40	0.31	0.59	0.14	0.72
Proventriculus (EW)	61.78	<.0001	9.78	0.01	2.86	0.13
Gizzard (EW)	7.13	0.0283	0.69	0.4302	0.01	0.9097
Duodenum (EW)	33.76	0.0004	1.32	0.2840	1.90	0.2055
Jejunum (EW)	17.39	0.0031	1.13	0.3191	4.07	0.0782
Ileum (EW)	24.79	0.0011	3.34	0.1050	0.97	0.3529
Caeca (EW)	50.80	<.0001	7.74	0.0238	5.64	0.0448
Large Intestine (EW)	5.41	0.0485	1.64	0.2360	0.21	0.6576
Total (EW)	19.20	0.0023	2.12	0.1838	0.48	0.5082
BWg	26.88	0.0008	26.88	0.0008	0.09	0.7682

Appendix Table 27. F and P values for relative length of GIT of Phase II.

Parts of GIT	BR		FR		BR*FR	
	F-V	P	F-V	P	F-V	P
Oesophagus (L)	0.17	0.6909	9.31	0.0158	0.01	0.9363
Crop (L)	3.23	0.1100	4.49	0.0668	0.42	0.5368
Proventriculus (L)	1.58	0.2447	0.68	0.4338	0.79	0.4009
Gizzard (L)	12.38	0.0079	6.78	0.0315	0.02	0.8916
Duodenum (L)	4.31	0.0715	0.02	0.9000	0.24	0.6365
Jejunum (L)	27.53	0.0008	2.85	0.1298	0.24	0.6362
Ileum (L)	22.12	0.0015	1.31	0.2849	0.01	0.9277
Caeca (L)	3.81	0.0869	4.82	0.0595	3.46	0.1000
Large Intestine (L)	7.01	0.0294	1.44	0.2641	0.05	0.8336
Total (L)	25.97	0.0009	2.68	0.1402	0.19	0.6744
BWg	26.88	0.0008	26.88	0.0008	0.09	0.7682

Appendix Table 28. Summary of the ANOVA of breed, feeding regime and the interaction between breed and feeding regime on absolute weight with contents of GIT of Phase II.

Source	Mean square			
	Br	FR	Br*FR	Error
Oesophagus	3.20	1.08	0.12	1.26
Crop	6.45	5.88	64.4	79.79
Proventriculus	19.76*	5.60	2.80	2.16
Gizzard	197.64	192.80	1100.17	81.23
Duodenum	210.84*	0.52	5.20	5.63
Jejunum	138.04	0.91	3.31	38.03
Ileum	121.60*	0.40	44.85	12.65
Caeca	128.71*	13.02*	1.27	1.73
Large Intestine	2.90	3.97	0.10	3.14
Total	5271.02*	418.90	728.52	265.16

*Significantly different at p<0.05

Appendix Table 29. Values of coefficient of variation (CV), root mean square error (RSME) and mean for absolute weight with contents of Phase II.

Dependent Variable	CV	RMSE	Mean
Oesophagus	19.13	1.13	5.88
Crop	24.82	8.93	35.98
Proventriculus	20.44	1.47	7.18
Gizzard	13.50	9.01	66.74
Duodenum	15.66	2.37	15.14
Jejunum	27.44	6.17	22.48
Ileum	14.88	3.56	23.90
Caeca	11.61	1.32	11.33
Large Intestine	26.23	1.77	6.76
Total	8.12	16.28	200.66
BWg	0.79	8.67	1091.67

Appendix Table 30. F and P values for absolute weight with contents of GIT of Phase II.

Parts of GIT	BR		FR		BR*FR	
	F-V	P	F-V	P	F-V	P
Oesophagus	2.53	0.15	0.85	0.38	0.09	0.77
Crop	0.08	0.78	0.07	0.79	0.01	0.40
Proventriculus	9.17	0.0164	2.60	0.1456	1.20	0.2871
Gizzard	2.43	0.1574	2.37	0.1620	13.54	0.0062
Duodenum	37.48	0.0003	0.09	0.7687	0.92	0.3645
Jejunum	3.63	0.0932	0.02	0.8811	0.09	0.7756
Ileum	9.62	0.0146	0.03	0.8627	3.55	0.0964
Caeca	74.47	<.0001	7.53	0.0253	0.73	0.4167
Large Intestine	0.92	0.3648	1.26	0.2938	0.03	0.8623
Total	19.88	0.0021	1.58	0.2442	2.75	0.1360
BWg	26.88	0.0008	2.33	0.1658	0.09	0.7682

Appendix Table 31. Summary of the ANOVA of breed on fertility and hatchability of the experimental chicken's eggs of Phase II.

	Dependent Variable							
	No of					(%)	Hatchability (%)	
Source	eggs set	fertile eggs	infertile eggs	dead in shells	chicks hatched	Fertility	on fertile eggs	on eggs set
Breed	4.17	1.50	0.67	2.67*	8.17*	24.40	2533.82*	1050.73
Error	4.67	1.33	2.83	0.17	0.67	233.68	35.31	249.35

*Significantly different at $p<0.05$

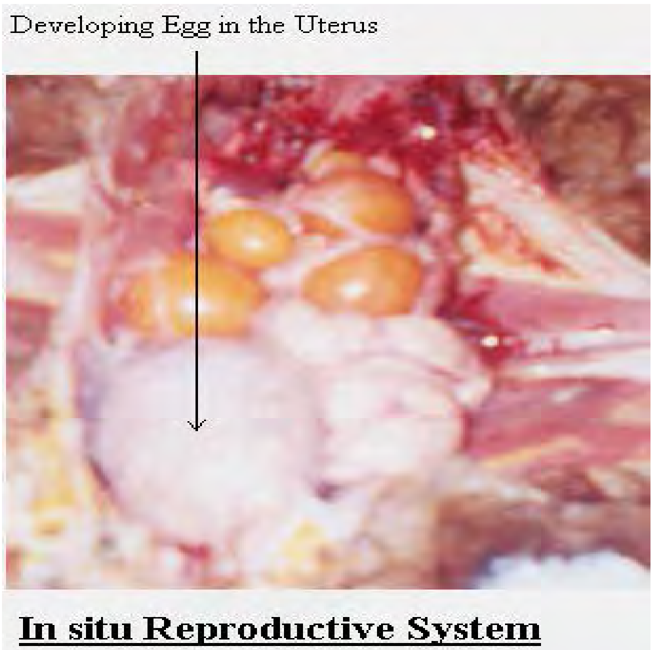
Appendix Table 32. Values of coefficient of variation (CV), root mean square error (RSME) and Mean for fertility and hatchability of the experimental chicken's eggs of Phase II.

Dependent Variable	CV	RMSE	Mean
No of eggs set	31.61	2.16	6.83
No of fertile eggs	30.12	1.15	3.83
No of infertile eggs	56.11	1.68	3.00
No of dead in shells	61.24	0.41	0.67
No of chicks hatched	25.78	0.82	3.174
Fertility (%)	26.72	15.29	57.22
Hatchability on fertile eggs (%)	7.48	5.94	79.45
Hatchability on set eggs (%)	34.32	15.79	46.0

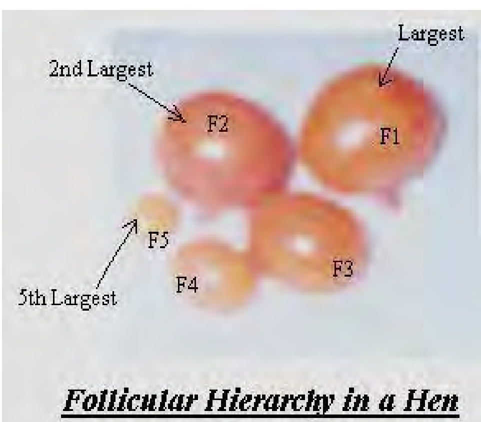
Appendix Table 33. F and P values for fertility and hatchability of the experimental chicken's eggs of Phase II.

Dependent Variable	BR	
	F-V	P
No of eggs set	0.89	0.3982
No of fertile eggs	1.13	0.3486
No of infertile eggs	0.24	0.6530
No of dead in shells	16.00	0.0161
No of chicks hatched	12.25	0.0249
Fertility (%)	0.10	0.7628
Hatchability on fertile eggs (%)	71.75	0.0011
Hatchability on set eggs (%)	4.21	0.1093

Appendix B. Figures



Appendix Figure 1. In situ, female reproductive system



Appendix Figure 2. Follicular hierarchy of a hen

Appendix Figure 3. Dissected out different parts of GIT of a Chicken

Appendix Figure 4. Arrangement of treatments and replications in Phase I (Koekoek chickens)

Appendix Figure 5. Day old chicks upon their arrival in Phase I (BB chicks)

Appendix Figure 6. Adult BB hen (Above) and Adult Koekoek cock and hen (below)

Appendix C. Points Considered for Focus group discussion*s*

Points considered for focus group discussion on the perception of farmers about the chicken genotypes.

1. The type of egg shell colour liked: -
   a) Brown---83.3% (10) b) White---8.3% (1) c) not bother on shell colour---8.3% (1)
2. The preferred meat and egg taste and best marketed egg and poultry

a) Local---58.3% (7) b) exotic---25% (3) c) no difference---16.7% (2)

3. Size of egg a. Small (local) due to good taste---66.7% (8)

   b. large (exotic) not good taste as local---25% (3) c. not bothered 8.3%---(1)
4. Behaviour of the breeds to escape from predators and thieves

a) BB is docile and unable to escape compared to Koekoek ---83.3% (10)

b) no difference between the two---8.3% (1)

c) Koekoek is heavy and unable to escape compared to the BB---8.3% (1)

5. Nesting behaviour a) BB has no permanent nesting site unlike the Koekoek---91.7% (11)

b) Both are same and have no permanent nesting site---8.3% (1)

c) Koekoek has no permanent nesting site unlike the---BB (0)

6. Broody behaviour a) BB has no broody behaviour unlike the Koekoek----91.7% (11)

b) Both have no broody behaviour---8.3 (1)

c) Koekoek has no broody behaviour unlike the---BB (0)

7) Feed consumption a) High in BB---25% (3) b) High in Koekoek---25% (3)

c) same---50% (6).