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PERFORMANCE EVALUATION OF DZ-WHITE SYNTHETIC AND IMPROVED INDIGENOUS HORRO CHICKEN BREEDS UNDER ON-FARM AND ON-STATION MANAGEMENT IN DIFFERENT AGRO-ECOLOGICAL ZONES OF ETHIOPIA

PhD Dissertation

By

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Addis Ababa University, College of Veterinary Medicine and Agriculture,

Department of Animal Production Studies

PhD Program in Animal Production

December, 2020

Bishoftu, Ethiopia

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

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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 Samrawit Mulugeta titled: **'Performance evaluation of Dz-white synthetic and Improved indigenous Horro chicken breeds under on-farm and on-station management in different agro-ecological zones of 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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DEDICATION

I dedicated this PhD dissertation work to my father Mulugeta Shewngzaw and my mother Yodit Getachew and my son Nahom Eyob for their love, patience, understanding and support throughout my study.

STATEMENT OF THE AUTHOR

First, I declare that this dissertation is my bona fide work and that all sources of material used for this dissertation have been duly acknowledged. This dissertation has been submitted in partial fulfillment of the requirements for a PhD degree at Addis Ababa University, College of Veterinary Medicine and Agriculture is deposited in the University/College library to be made available to borrowers under the 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

Samrawit Mulugeta was born on July 23, 1989 in Debrebrhan, Ethiopia. She attended her elementary school education at catholic Elementary School in Dessie and she followed her high school Education at Kidame Gebeya Secondary School and Preparatory education at Memher Acaleweld preparatory school between 1996 and 2008 G.C. After completion of her high school education, she joined Hawassa University, College of Agriculture in 2008 and graduated with a BSc degree in Animal and range Science in 2010.

Soon after graduation, she joined Wolaita Sodo University and worked as graduate assistance up to September 2012 in the Department of Animal and Range Sciences. In September 2012, she joined School of Graduate Studies (SGS) of Addis Ababa University to pursue her second degree majoring in tropical Animal Production and graduated in 2014.

Upon completion of her MSc study, she rejoined Wolaita Sodo University and served as lecturer up to September 2015. Given the opportunity to pursue her PhD study at Addis Ababa University by the institute, she joined the graduate studies of Addis Ababa University, College of Veterinary Medicine and Agriculture in the department of animal production studies in October 2015.

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LIST OF ABBREVIATIONS

ADFI	Average Daily Feed Intake
AEW	Average Egg Weight
AFL	Age at First Lay
BW	Body Weight
BW-F/M	Body Weight of Females/Males
BWG -F/M	Average Body Weight Gain Female/Male
CSA	Central Statistical Agency
DZARC	Debre Zeit Agricultural Research Center
DZ	Debre Zeit
EIAR	Ethiopian Institute of Agricultural Research
EM	Egg Mass
FAO	Food and Agriculture Organization of the United Nations
FCR	Feed Conversion Ratio
GDP	Gross Domestic Product
GIT	Gastro-Intestinal Tract
GLM	General Linear Model
IBD	Infectious Bursal Disease
IH	Improved Horro
ILRI	International Livestock Research Institute
KK	Potchefstroom Koekoek
SAS	Statistical Analysis System
SE	Standard Error,
SNP	Single Nucleotide Polymorphism
TFI	Total Feed Intake
UD	Unidentified Diseases
Wks.	Weeks

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Samrawit Mulugeta
PhD dissertation
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ABSTRACT

In the present study the production and reproduction performance of DZ-white and Improved Horro chickens were evaluated at three different agro-ecological zones (Debre Berhan-L_1, MelkaWerer-L_2 and Mekelle-L_3 characterized as highland, lowland and midland agro ecology respectively). A total of 2400 chickens involving two breed (DZ-white and Improved Horro) (900 days–old unsexed chicks for on-station trials and a total of 1500 chicken (8 weeks both sex)) for on-farm trials were used. Variables studied were feed intake, body weight, body weight gain, feed conversion ratio, carcass characteristics, age at first egg, egg production, egg quality, fertility, hatchability and mortality traits for on-station trials, whereas body weight, body weight gain, age at first egg, egg production and mortality traits were measured for on-farm trials. Data were analyzed by GLM procedure of SAS. Under on-farm trial, age at first egg and egg production trial analysis was done only at L_1 and L_2.The on-station study revealed that effect of breed on feed intake, body weight, body weight gain, feed conversion ratio, carcass characteristics, egg production, egg quality, fertility and hatchability was significant ($P \leq 0.05$). The DZ-white breed consumed more feed and gained higher body weight and body weight gain than those of Improved Horro breeds at all ages of the entire trials. The feed conversion ratio was poor in Improved Horro and better in DZ-white breed. DZ-white obtained significantly higher slaughter weight, carcass weight, breast, drumstick and thigh, wing, neck, back, GIT, and giblet weight than those of Improved Horro. Dressing % and the breast meat composition was found higher in Improved Horro. However, a proportion of drumstick, thigh, wing, neck, back, GIT, and giblet were found non-significant ($P \geq 0.05$) between breeds. Higher number of eggs was *obtained by DZ-white with (124.57 egg/hen/224 days) as compare Improved Horro (104.58 egg/hen/224 days).The egg weight and egg mass were higher in DZ-white than Improved Horro. However, no significant differences were found between DZ-white and Improved Horro breeds for age at first egg and mortality. Internal egg quality parameters including egg length and width, shell weight, yolk weight, albumen weight and yolk height were significantly higher in DZ-white breed than those of Improved Horro. However, shell thickness, albumin height, yolk colour and HU did not differ significantly between breeds. Comparisons of breeds revealed significant differences ($P\leq0.05$) in fertility(%), hatchability from fertile eggs (%), hatchability from set eggs (%), dead in shell (%) and average day old chick weight (g).However, dead in germ (%), normal chicks (%) and abnormal chicks (%) were not significantly ($p>0.05$) different between breeds. Birds kept at L_1 consumed more feed. Significantly ($P\leq0.05$) higher body weight of females and males, body weight gain (during starter phase) and egg production was recorded at L_1 and L_3. Better feed conversion ratio and earlier age at first egg was noted at L_3. Higher value of slaughter and carcass weight was observed in birds kept at L_3 followed by birds kept at L_1 and the least was observed to those birds kept at L_2. Dressing% was significantly ($P\leq0.05$) higher at L_3. Significantly ($P\leq0.05$) higher mortality was recorded at L_2 during starter and grower phase. However, during the laying stages higher mortality was recorded at L_2 and L_3. Significantly ($P\leq0.001$) higher egg weight was observed in birds kept at L_1 followed by birds kept at L_3 and the least was observed to those birds kept at L_2. Internal egg quality parameters including egg length and width, shell weight, shell thickness, yolk weight, albumen weight and yolk height were significantly higher at L_1 and L_3 than those of L_2.However, egg mass, albumin height, yolk colour and HU did not differ significantly among location. Genotype by environment interaction was observed for feed intake (during starter and grower phase), body weight of females (at 16 and 52 weeks of age) and age at first egg. The on-farm trial revealed that effect of breed on body weight, age at first egg, egg production and mortality was significant ($P\leq0.05$). DZ-white breed exhibited higher body of males and females at three ages (12, 16 and 20 weeks). DZ-white started laying eggs seven days earlier than the average of Improved Horro chickens. Higher egg production was obtained by DZ-white chickens (130.84egg/hen/280) as compare to Improved Horro(100.85egg/hen/280). However, body weight gain and mortality were not significant ($P\geq0.05$) between breeds. For the main effect location body weight of males at three* *ages (12, 16 and 20 weeks) and body weight of females at 12 weeks of age were significant ($P \leq 0.05$) among locations. Significantly ($P \leq 0.05$) earlier age at first egg was noted in both chicken breeds kept at L_1 (155.00 day) compared to birds kept at L_2 (163.00 days). Number of eggs/hen was significantly ($P \leq 0.05$) influenced by location. Significantly ($P \leq 0.05$) higher mortality was recorded in chickens kept at L_2 as compare to L_1 and L_3, However, body weight of females at 16 and 20 weeks of age and body weight gain were not significant ($p > 0.05$) among location. Under on-farm trial Genotype by environment interaction was observed only for HDEP during 57-60 weeks of age. In conclusion, the results of this study have demonstrated that DZ-white breeds had significantly enhanced speed of weight gain as well as growth, good feed conversion ratio; better fertility and hatchability (%) and performed well in egg production. Both chicken breeds are well adapted in highland and midland agro-ecology zone and their production performance was better than the chickens kept at lowland agro-ecology zone both under on-station and on-farm management.Thus, DZ-white chickens are recommended to be introduced for farmers as a strategy for the improvement of small scale family poultry in order to improve the livelihood of resource poor farmers in Ethiopia.*

Key words: *Agro-Ecology; DZ-White; Ethiopia; Improved Horro; Performance Evaluation*

1. INTRODUCTION

Animal production in general and poultry production in particular plays important socioeconomic roles in developing countries (Alders, 2004; Kondombo, 2005). Poultry is broadly recognized as the livestock of the poor, and poultry production is part of most smallholder farming systems (Guèye, 2005). Guèye (2005) indicated that more than 90% of rural families in most developing countries keep one or more poultry species. Kyger *et al.* (2010) supported this by stating 85% of the rural households keep chickens or other types of poultry as supplementary to the main livelihood activities in sub-Saharan Africa (SSA). Its low start-up capital and low maintenance costs are among the reasons for keeping chickens by resource poor farmers in Africa (Dwinger *et al.,* 2001; Dolberg, 2003; Nduthu, 2015). Other scholars also mentioned that in most developing countries because of the population growth and landlessness, poultry production has become the investment of choice due to its low land requirements (Permin *et al.,* 2001; Nduthu, 2015). According to Sonaiya (2004), smallholder farming families, landless laborers and people with incomes below the poverty line are able to raise chicken with low inputs and harvest the benefits of eggs and meat via scavenging feed resources.

As in many developing countries, chickens are widely kept in Ethiopia (Halima *et al.*, 2006). Backyard poultry production in Ethiopia represents a significant part of the national economy in general and the rural economy in particular, and contributes 83.5% of the national egg and meat products (CSA, 2016).The total chicken population in the country is estimated to be around 60 million out of which 90.8%, 4.4% and 4.8% were reported to be indigenous, exotic and hybrid, respectively (CSA, 2017). The extensive scavenging systems are the dominant forms of poultry production in Ethiopia (FAO, 2019). This system is generally characterized by birds maintained under scavenging regimens in the backyards with little or no supplemental feeding, no separate shelters except for night enclosures in the family house and lack of health care. The most dominant chicken types reared in this system are local ecotypes, which show a large variation in body colour, comb type and productivity (Halima *et al.,* 2007).

Indigenous chicken are still the major suppliers of poultry products in Ethiopia. About 90.8%of indigenous chickens have been distributed in different agro-ecological zones of Ethiopia (CSA, 2017). And their distributions indicated their adaptive potential to different environmental conditions, diseases and other stresses (Halima, 2007). The diverse agro ecology and agronomic practice prevailing in Ethiopia together with the huge population of poultry, could be a promising attribute to boost up the sector and increase its contribution to the total agricultural output as well as to improve the living standards of the poor livestock keepers (Natnael, 2015).

According to Reta (2009), indigenous chicken of Ethiopia had a lot of conserved traits that fit to cultural, socio economic and environmental condition of the areas. They granted their owners with economic and nutritional benefits such as food security, income generation with no or little input supply in the village scavenging system. Consumers usually prefer products of local chicken to exotic ones because of flavor and taste of the products (egg and meat) (Amsalu, 2003). Even if the indigenous chickens are better to adapt the harsh environment, they are poor in their reproductive and productive performance (Nigussie, 2011). Their low performances masked their potential to uplift the living standards of their owners and contribute to rural developments in Ethiopia. This has been attributed to their low genetic potential, prevalence of diseases and predators, limited feed resources, constraints related to institutional and socio-economic and limited skill management practices (Nigussie *et al.*,2010; Solomon *et al.,* 2013; Nebiyu *et al.,* 2013). For instance, the indigenous chickens revealed slow growth rates and very poor egg productivity.   The mean body weights at 8 and 16 weeks of age could be as low as 242 and 621g, respectively (Nigussie, 2011).The mean annual egg production does not exceed 60 eggs/hen (FAO 2019).

For the past decades, low performances of indigenous chickens have enforced the introduction of exotic breeds from temperate region to improve their performance through crossbreeding with exotic chicken strains, which has been unsuccessful. These may be due to dissemination of inappropriate technologies without understanding of production environments under which indigenous chickens are kept and lack of information on breeding objectives and farmers' trait preferences (Nigussie *et al.,* 2010). Even though exotic temperate breeds have fast growth rates and better egg production potential, they demanded high feed, veterinary care, energy cost and poorly adapted to the low-input chicken management systems that dominate the rural area of the country (Teklemariam, 2017).

This suggests that improving the productive attributes of indigenous poultry could have a significant impact on the poultry sector. The opportunities arising from the existing huge genetic variation within indigenous populations should be exploited. Use of improved genetics is one of the key elements to improving productivity in the poultry sector. For instance, in 2008 a breeding program of indigenous chicken was initiated by Debre Zeit Agricultural Research Center (DZARC) using Horro ecotype chicken from the Horro region. The aim was to improve productivity through selective breeding by developing chicken with higher productivity and a more optimal adaptive capacity to withstand harsh condition than unselected population (Nigussie *et al.,* 2010).At the start of the research, the Horro's egg production was measured at an average 34 eggs per year. According to Wondmeneh *et al.*, 2016, the breeding program of the indigenous Horro chicken at the DZARC successfully increased egg production by 123 percent and body weight by 95 percent during the first 8 generations. In line with this, the center designed a breeding programme since 2009 to develop a synthetic breed named as DZ-*white*. The name DZ-*white* is to re-call the center Debre Zeit and white is to refer the feather color and have been synthesized from Lohman Silver, Koekoek and Rhode Island White (RIW) line. The main purpose of crossing these chickens was to develop breeds for the semi-intensive or the suboptimal production system for contributing to the improvement of living conditions of Ethiopian women and youth farmers.

The work presented here is part of an on-going project to produce a synthetic chicken population through cross breeding scheme. The improved Horro and DZ-white obtained in the breeding program has made tremendous progress within ongoing evaluations made at DZARC for 10 (Improved Horro) and 5 (DZ-white) generations. However, performance of DZ-white has never been evaluated at different agro ecological zones of the country and also the performance of Improved Horro has limited information in different agro-ecological zones. Therefore, this study was made to evaluate the productive and reproductive performance of improved chicken breeds at different agro ecological zones of the country, under on station and farmers condition before they are released to the end users.

General Objectives

To evaluate production and reproduction performance of DZ-white and improved Horro chicken in three different location (agro-ecology) and management systems.

Specific Objectives

- To evaluate growth and egg production performance of DZ-white and improved Horro chicken under on station and farmer management conditions in three different locations (agro-ecology);
- To investigate the effect of the genotype by environmental interaction on the growth, egg production performance traits;
- To evaluate the effect of genotype on hatchability and fertility traits; and,
- To evaluate the effect of breed and location on carcass characteristics and egg quality.

2. LITERATURE REVIEW

2.1. Economic Contributions of the Poultry Sector in Ethiopia

Agriculture is an important source of employment for more than eighty percent of Ethiopians. Within agriculture, livestock comprises an extremely important sector of the economy. Agriculture contributed 40 percent of the national GDP and the contribution of livestock to the agricultural GDP was estimated to be 20.7 percent (MoFEC, 2018). Ethiopia has the largest cattle population in Africa, with around 59.5 million cattle. The country has 30.7 million sheep and about similar number of goats, 1.2 million camels and 59.5 million chickens. Out of the total 60 million chicken population, 90.8%, 4.4% and 4.8% were indigenous, exotic and hybrid, respectively (CSA, 2017).

Poultry production is an important sector in Ethiopia where chickens and their products are important sources for income generation for rural peoples and important source for high quality protein for developing countries. Backyard poultry production in Ethiopia represents a significant part of the national economy in general and the rural economy in particular (CSA, 2016) contributing 98.5% and 99.2% of the national egg and poultry meat production, respectively (Tadelle *et al*., 2002), with an annual output of 72,300 metric tons of meat and 78,000 metric tons of eggs (Hailemariam *et al.*, 2006). Chicken products are affordable quality animal protein sources for the smallholder households (Alemu *et al*., 2008). Eggs are a source of high quality protein for sick and malnourished children under the age of five (Delgado *et al*., 1998), for women post-birth (Jennifer, 2006).

In addition to egg and meat production, poultry production has positive impacts in maintaining soil fertility and has a relative advantage or a lesser impact on climate changes over the other livestock production because of its low greenhouse gas emission to the environment (FAO, 2010; Mengesha, 2011).

Poultry are the most widespread and almost every rural family owns chickens, which provide a valuable source of family protein and income (Tadelle *et al*., 2003). Moreover, due to their small size and fast reproduction compared to most other livestock, chicken can be slaughtered and eaten in the household (Delgado *et al*., 1998).

In developing countries nearly all families at the village level, even the poor and landless, are owners of poultry. Furthermore, poultry are mainly owned and managed by women and are often essential elements of female-headed households. Poultry are socio-culturally important with few religious taboos attached. Production is feasible at village level, where only low cost technology is needed to improve production considerably. Low investments only are required to achieve such change, land ownership is not a constraint, and village production is environmentally friendly (Upton, 2004).

Poultry production offers considerable opportunities in terms of generating employment opportunities, improving family nutrition, empowering women (especially in rural areas) and ultimately ensuring household food security. Extensive scavenging poultry production is often the domain of poor women. Reasons include that it requires little initial investment and that it does not usually conflict with women's other household duties (FAO. 2019). The role of family poultry in poverty alleviation, food security and the promotion of gender equality in developing countries is well documented (Guèye, 2000).

Currently, there is an increased demand for chicken products and poultry production is becoming one of the major income generating enterprise and creating employment opportunities directly and/or indirectly through supplying different inputs. However, chicken production in Ethiopia is much lower than that of the fast-growing human population of the country (Thomas *et al*., 2009; Mengesha *et al*., 2011).

According to (Abubakar *et al*., 2007), the impact of the Ethiopian village chicken in the national economy and its role in improving the nutritional status, family income, food security and livelihood of many smallholders is significant. The diverse agro-ecology and agronomic practices prevailing in the country together with the huge population of livestock in general and poultry in particular, could be a promising attribute to boost up the sector and increase its contribution to the total agricultural output as well as to improve the living standards of the poor livestock keepers (Hunduma *et al*., 2010; Aleme and Mitiku, 2015).

2.2. Structure of the Ethiopian Poultry Production

The poultry sector in Ethiopia can be characterized into three major production systems based on some selected parameters such as breed, flock size, housing, feeding, health, and technology and bio security. These are large scale commercial poultry production system, small-scale commercial poultry production system and village or backyard poultry production system (Bush, 2006; FAO, 2007; Yenesew *et al*., 2015,). These production systems have their own specific chicken breeds, inputs and production properties. Each can sustainably coexist and contribute to solve the socio-economic problems of different target societies (Tadelle *et al*., 2003).

2.2.1. Village or backyard chicken production systems in Ethiopia

It was the largest production system in Ethiopia and dominated by traditional production practices, and local breeds signifying almost 98% of the national flock (Solomon, 2008). Village poultry contributes 98.5% and 99.2% of the national egg and poultry meat production (Tadelle *et al.*,2002). Backyard/village/ chicken production is characterized by low input and output scavenging, with minimal investment in housing, feeding and chicken health care management. The system is only partially market-oriented, production being targeted for both household consumption and the open market (Tadelle *et al.*, 2000; Gezahegn and Rich, 2010,). It was practiced by rural households using family labor (Aklilu, 2007). The system is characterized by short life cycle, quick turn over, small flock size, needs no or less inputs and relatively good outputs levels and accessible at both inter and intra household levels and periodic devastation of the flock by disease and reared in the extensive (scavenging) production systems (Mammo, 2006;Nigussie *et al*., 2009; Fisseha, 2009). It is especially favorable to small holder farmers due to its low capital requirement, high cost efficiency, flexible production systems and low production risk (Emebet, 2015).The system generally does not involve investments beyond the cost of the foundation stock (USAID, 2010). The production occurs largely on small farmer holdings, with an average flock size of 4.1 (CSA, 2005) and with minimal biosecurity (Solomon, 2008). The breeds are mostly indigenous chickens and although some hybrids and exotic breeds (< 50 birds) may be kept under this system and managed by individual farm household management with minimum labor inputs (Dawit *et al.,* 2008). The sources of replacemental stocks were usually through purchasing, household hatching and others. (Halima, 2007; Moreda *et al.*, 2013).

Almost all back yard chicken producers do provide night shelter for their chickens either in part of the kitchen or in the main house making a sort of raised standing material (perch) made of wooden materials. Shading in hand-woven baskets, in bamboo cages or in separate sheds purposely made for chickens is also common. The shelters are usually made of locally available materials such as Eucalyptus poles and branches (Halima, 2007; Moreda *et al.,* 2013).

The dominant system of poultry feeding practiced is free scavenging with supplementary feeding. However, the proportion of those that supplement their chicks with a commercial ration is very small (Moges *et al.,* 2010).

2.2.2. Small-scale commercial poultry production system

There are several emerging small-scale commercial poultry farms in the different countries. These emerging farms have vital contribution to improve the livelihood, food security and poverty reduction as well as providing attractive return in semi-urban and urban areas in the tropics (Pica and Otte, 2010; Emebet, 2015). The small-scale market oriented poultry production system is characterized by medium level of feed, water and veterinary service inputs and minimal to low bio-security. Most small-scale poultry farms get their feed and foundation stock from large-scale commercial farms (Nzietchueng, 2008). Flock sizes usually ranging from 50 to 1000 cross or exotic breeds (FAO, 2007). It is common in the urban and peri-urban areas of Addis Ababa and East Shoa. This production system make a significant contribution, along with the commercial sector, to meet the rapidly growing demand for poultry products especially in large and growing regional cities. The small scale market oriented poultry farms plays a important role in providing poultry meat and eggs to urban markets at a modest price (Alemu and Tadelle, 1997)**.**

This type of chicken production system is better than free ranging production system since it uses inputs like supplemental feed, water and vaccine. Many producers have specialized in meat or egg production and hence have an interest in improved chicken. In addition, mortality and loss rates are relatively low compared with scavenging systems, since the risks of predation, theft and loss caused by poor nutrition are much lower strains. Since the feeds the chickens obtain from the scavenging is very low, they should be supplemented with energy and protein feeds. Since the main objective of the production is to get profit, they should get better health management practice like vaccination against disease than free scavenging system (Mathias, 2004).

2.2.3. Large scale commercial poultry production system

Large scale commercial production usually involves 10,000 or more exotic birds, with a high input management system. Currently the largest producers in Ethiopia are ELFORA, Alema and Genesis farms, which are located in Debre Zeit, near Addis Ababa (Alemu *et al*., 2008). It is a highly intensive production system with a medium to high bio-security level. This system highly depends on imported exotic breeds that need intensive inputs. This system is characterized by higher level of productivity (Bush, 2006).

In Ethiopia, the commercial poultry are run as full time businesses, highly dependent on the market for inputs. The commercial production system holds both commercial layer and broiler chicken. The commercial layer and broiler day old chicks are obtained from their own hatcheries or import from sources that are approved by the veterinary authorities in the country. These commercial layer and broiler poultry farmer have basic skills in the management of broiler and layer flocks. In general intensive poultry industry plays a key role in providing poultry meat and eggs to urban markets and also they export to some Arabian countries and Djibouti. The sector also offers employment for a range of workers, like poultry attendants, truck drivers and professional managers. There are about 18 large scale commercial (With 2,500 to 50,000) poultry farms located in and around the capital city with a collective capacity of 33,500 layers and 208,000 broilers per annum (FAO, 2007).

2.3. Production Performance of Local/Indigenous Chickens

Less than 5% of local birds in Ethiopia are internationally recognized breeds (Wilson, 2010). Each local ecotype comprised chickens with wide range of morphologic or genetic diversity

(Halima *et al*., 2007). The productivity of local chicken production systems in general and the free range system in particular is low (Kondombo 2005). Indigenous flocks are slow in growth rates and very poor in egg productivity. Mean body weights at 8 and 16 weeks of age could be as low as 242 and 621 g, respectively (Nigussie, 2011). The poor production and reproductive performance was characterized by poor growth rate, late maturity, longer age at first mating, small clutch size, small sized eggs, extended brooding period and high mortality of chicks (Meseret, 2010; Addisu *et al*., 2013).

The egg production performance of local chicken is 30-60 eggs/year/hen with an average of 38g egg weight under village management conditions, though exotic breeds produce close to 250 eggs/year/hen with 60g egg weight in Ethiopia (Alganesh *et al*., 2003). Various study indicated that the meat production potential of indigenous chicken was limited (FAO, 2010). Local males reach 1.5 kg live weight at 6 months of age and females about 30% less. The carcass weight of local birds at 6 months of age is 559 g (Forsido, 1986), While the weight of male and female chickens at the age of 10.6 and 13.6 months were 879g and 544g respectively (Bogale, 2008). Ethiopian indigenous chickens reach slaughter age at 8 to 12 months in village management system (GAIN, 2017).

According to Worku *et al.*(2012), under village poultry production system, the average age at first lay for local chicken breeds is 6.6 months with an average clutch number of 3.2 with about 14 eggs are produced per clutch and about 43.2 eggs are produced per hen per year (Forsido, 1986).The average egg weight is low, ranging from 38g to 46g (Teketel, 1986).

Poultry production is affected by so many factors such as breed of chicken used, environmental conditions in poultry house, management follows and feed and feeding management (Bell and Weaver, 2002). The knowledge of performance of economic traits in chicken is important for the formulation of breeding plans for further improvement in production traits. Growth and production potential of bird indicate its genetic makeup and adaptation with respect to the specific environment (Ahmad and Singh, 2007). Different authors reported effect of breeds on egg production; Majaro (2001) and Yakubu *et al*. (2007) stated significant effect of breed on egg production and mortality trait. Moreover, Gwaza *et al.* (2011) reported significant effect of breed on age at peak egg production of layers. Improving the productive attributes of indigenous poultry could have a significant impact on the poultry sector (Wondmeneh *et al.*, 2016).

Table 1.Mean performance of various traits of indigenous chickens under scavenging and semi-scavenging rearing systems.

Characteristics(parameters)	Mean	Rearing Systems	Reference
Average age at 1st egg laying (month)	5.85	Scavenging	(Mammo *et al*., 2008)
Average number of clutch per hen per year	6.25 and 6.45	Scavenging	(Halima, 2007; Fisseha 2009)
Average number of eggs per clutch per hen	3	Scavenging	(Hossen,2010)
	4	Scavenging	(Mammo *et al*.,2008)
Average number of eggs produced per year per bird	12 and 14	Scavenging	(Hossen, 2010; Owande*et al*.,2010)
	15	Scavenging	(Mammo *et al*.,2008)
Average egg wt(g)	48 and 42.8	Semi-intensive	(Olwande *et al.*, 2010 ; Halima, 2007)
Average hatchability (%) from TES	81 and 88	Semi-intensive	(Hossen, 2010; Owande *et al*., 2010)
Av. b.wt. at hatching g per bird	36	Scavenging	(Solomon, 2003)

2.4. Challenges and Opportunities of Chicken Production in Ethiopia

Ethiopian poultry production remain highly immature, unorganized and the country export no poultry meat (Avery, 2004). The economic contribution of the sector is not still proportional to the huge chicken numbers, attributed to the presence of many productions, reproduction and infrastructural constraints (Aberra, 2000; Halima, 2007).

There are many constraints to the development of smallholder poultry production that need to be addressed (Permin *et al*., 2000). The constraints which affect chicken production include diseases, poor management practices, predation and lack of organized markets (Aberra, 2000; Halima, 2007; Nebiyu *et al*., 2013; Solomon *et al.*, 2013); lack of water, lack of health care, extension and veterinary services were the major constraint (Getu and Birhan , 2014). Poultry feed and nutrition was also reported as one of the most serious constraints to poultry production under rural small holder and large-scale systems in Ethiopia. The problem is mostly related with lack of processing facilities, unreliable availability and distribution and sub-standard quality of processed feeds. (Tadelle *et al*., 2002; Demeke, 2004). Alemu and Tadelle (1997) reported that the quality of feed for commercial poultry production is generally poor in Ethiopia. Most formulations do not have vitamin/mineral premixes. Ingredients and processed feeds differ in their nutritive value and there is no fixed quality control mechanism in the country. Absence of feed quality legislation and laboratory facilities for chemical analysis also contributes critically to the poor quality of processed feeds. And over the price of raw materials were the major difficulties (Tadelle *et al*., 2002; Demeke, 2004).

Among the infectious diseases, NCD, fowl pox, salmonellosis and coccidioses are considered to be the main causes of mortality in local chicken whereas predators are other causes of loss (Eshetu *et al.* 2001). According to Tadelle and Ogle (2001), higher mortality of chicks under village chicken production in Ethiopia is due to diseases, lack of feed, inadequate water supply, poor housing parasites and predation.

The domestic market for poultry is constrained by seasonal fluctuations in demand and price. Such fluctuations are mostly associated to the fasting tradition that prohibits consumption of livestock products for up to 250 days of the year to Orthodox Christians, accounting for around 43 percent of the total population (CSA, 2007).

Use of improved genetics is one of the key elements to improving productivity in the poultry sector. Lack of access to productive and adaptable chicken breeds still remain one of the most critical challenges to the increasing the economic contribution of the sector. Most of the chickens kept by smallholder farmers are unimproved indigenous flocks, well-adapted to the local environments but having slow growth rates and very poor egg productivity. Attempts to increase productivity are mainly focused on the introduction of high yielding exotic chickens to replace indigenous stocks. However, the success achieved in terms of improving productivity in villages through the introduction of exotic breeds is still limited due to the failure of imported breeds to adapt to local conditions. Efforts to develop high yielding indigenous chicken breeds are still insufficient (FAO. 2019). However, addressing any one or several of these constraints without attention to all will do little to improve the situation (Permin *et al*., 2000).

2.5 .Chickens Genetic Improvement Activities in Ethiopia

In the recent decades the demand for poultry and livestock products have been improved significantly that leads to poultry-related development interventions (Fasil *et al.*, 2010). Though the indigenous chickens are better to adapt the harsh environmental condition, they are lenient to many diseases; nonetheless they are poor in their reproductive and productive performance (Nigussie, 2011).

There are so many interventions to improve breeds of poultry to meet the existing demands. The major one has been the introduction of improved (exotic) breed (Tamirat, 2015). Several exotic breeds of chicken (White and brown Leghorns, Australoup, Rhode Island Red, New Hampshire, Cornish and Light Sussex) were introduced over the years. The other was to improve productivity of local chicken by using crossbred chickens. This involved crossing of local chicken to different levels of exotic blood (Nigussie *et al.*, 2010).on the other hand using exotic blood also resulted in loss of broody behavior, which has higher economic value under village production systems. Even if the cross breeding programs brings successful results under experiment stations almost all of them were stopped decades ago for several reasons (Nigussie, 2011).

Under evaluations of crossbred chicken at the DZARC, 62.5% White Leghorn crosses showed higher performance than the locals as well as pure white leghorns in terms of egg production (Nigussie*et al* 2010). The past genetic improvement efforts of the Ethiopian village chicken through exotic chicken was constrained by lack of comprehensive poultry technology package extension to the end users (Reta, 2009).

The importance of conserving local breeds was stressed because of their hardiness, disease resistance and ability to cope with harsh environmental conditions. The strengthening of existing informal-traditional systems of breeding and supply of chicks was emphasized for remote rural areas, where regular crossbred chick supply is not possible. Breeds that have low input costs with improved productivity are recommended for semi-intensive systems. These may be crosses of local with exotic breeds or crosses of two exotic breeds/lines designed to contribute improved productivity in line with increased investment (FAO, 2014).

Previously, one of the extension attempts were use of full packages together with exotic breeds. The Extension Department of the Ministry of Agriculture of Ethiopia had preferred Rhode Island Red breed that could be serving as a dual-purpose for both egg and meat production. Moreover, with the expectation of better productivity performance, adaptation and disease resistance than the other exotic breeds Fayoumi breed had also been imported Wilson (2010). Tadesse *et al.* (2013),

The indigenous chicken improvement plan via importation and distribution of cockerels as breeding males in Ethiopian failed due to various reasons like, poor arrangement, lack of clear breeding objectives, lack of sustainable breeding program and lack of adaptation in the village environments. Moreover, farmers were also unwilling to take away their local cocks (Nigussie, 2011).In the mid-2000s, DZARC introduced the Lohman Silver and Koekoek breeds. The Lohman Silver did not adapt to the village production system while Koekoek performed well in several villages (Wondmeneh *et al.*, 2016).

2.5.1. Genetic improvement on reproductive and production traits

Humans are constantly changing the selection pressures on domesticated farm animals, with the aim of achieving the best economic outcome, and evaluating whether populations and species of selected animals are able to adapt accordingly. Animal breeding is a slow process; however, a combination of strong selection and a high degree of heritability can change the relative abundance of genes in a population up to 10% per generation (Wikibooks, 2009). Local chicken genetic potential improvements were done through selection within and/or up grading with exotic breeds. The goal was to combine the adaptive traits of the local chicken with the high producing abilities of the exotic chickens (Matiwos *et al*, 2013).

There is evidence to show that considerable scope for improving the performance of indigenous or local breeds. However, these breeds cannot compete with highly selected commercial hybrids. Thus, a breeding program involving indigenous or local breeds should identify alternative breeding goals and capitalize on the breeds' specific attributes. The breeding goal would be to improve the efficiency of indigenous populations raised under village conditions. This implies improving performance, reproduction capacity and survival. Unlike commercial breeds, indigenous or local breeds are dual-purpose; therefore, improving their performance will be achieved through increasing both the body weight and the egg production of a single population. However, the emphasis given to each of these traits depends on the region in question (Besbes, 2009).

Genetic improvement of indigenous chickens may be achieved through either selection or cross breeding using improved breeds or through employment of both approaches (Munisi *et al.*, 2015). On the other hand cross breeding between indigenous stock and exotic commercial chickens, would take advantage of productive merits which have already been accumulated through selection in the exotic chickens as well as merits for hardiness which have been endowed in indigenous chickens through decades of natural selection (Rajkumar *et al.*, 2011). An alternative improvement approach would be to carry out crossing between two or more populations to create a single population of chickens followed by selection within the crossbred population, a method which is popularly known as synthetic breeding. With synthetic breeding, only one population with all desirable traits has to be maintained instead of two or more parental populations needed in regular crossing programs (Munisi *et al.* 2015).

Indigenous chicken have small body size and are generally considered to be low producers of meat and eggs. The average annual egg production of indigenous chickens measured between 30 and 60 under scavenging management which could be improved to 60-100 under improved management conditions (Negussie and Ogle, 2000). The average egg weight of indigenous chickens was very small, ranging from 38 g to 46 g (Teketel, 1986). Under research station management local birds have showed poor feed efficiency and survival (Brannang and Persson, 1990) but it also demonstrated more constant egg production at times of higher environmental temperatures and improved fertility percentage in local chickens as compared to exotic breeds (Teketel, 1986).

Information on growth performance available so far indicates that average weight of local birds to an age of 22 weeks ranged from 1.0 to 1.5 kg in males and from 0.6 to 0.9 kg in females (Halima *et al*., 2007). This is substantially small compared; for instance, with the RIR which weighed on average 1.7 (males) and 1.3 kg (females) under the same age and management regimen. Between 1 to 2 years of age body weight of local chickens under scavenging systems ranged from 1.4 to 1.7 kg in males and from 1.0 to 1.5 kg in females (Nigussie *et al*., 2009). Owing to such figures indicating lower performance of local chickens in terms of egg production and growth compared to improved breeds improvement programs for increasing local chicken productivity in Ethiopia focused on the use of imported breeds for the past many years. The past approaches were improving the genetic potential of local birds through distribution of exotic origin cockerels, pullets and fertile eggs. However, these approaches have had ill effect because of reducing the brooding ability of local hens, reducing adaptation to low input feeding system and endangering the genetic base of indigenous chicken population (Tadelle *et al*., 1999). Few years back a genetic improvement program has been initiated by the national poultry research institute to improve the productivity of local chickens through selective breeding in order to improve the livelihood of people along with conserve the existing genetic diversity (Nigussie *et al*., 2010).

A crossbreeding program was also conducted to produce dual purpose synthetic chicken breeds for village poultry production in Ethiopia. Fayoumi (F) and Rhode Island Red (R) as dam line, and two indigenous chicken breeds Naked neck (N) and local Netch (W) were used (Fasill *et al.*, 2010).

2.5.2. Genetic improvement on resistance to infection and diseases

High genetic variability was reported within ecotype populations of indigenous chickens in many parts of Africa (Muchadeyi *et al*., 2007; Mwacharo *et al.*, 2007; Halima *et al.* 2009) which shows the possibility for genetic improvement of these chickens through selective breeding.

Infectious and non-infectious diseases were one of the major constrains in poultry rearing. Farmers face a wide range of diseases, which reduced the production of the birds. During last few years several emerging diseases like infectious bursal disease, aflatoxicosis, avian influenza, chicken anemia virus and egg drop syndrome and some unknown cause threatened the industry and cause huge damage to the farmers. Viruses, which affect the mucus membranes of the respiratory and reproductive tract, such as Newcastle disease and infectious bronchitis, not only cause a decrease in egg production, but also cause the shell to become abnormally thin and pale (Butcher and Miles, 2003).

Diseases can lead to substantial economic losses in two ways, firstly there is a reduction in the production of poultry related products, and also the input costs like labour and feed get increased. The impact of these loses in poultry industry is more worse on the livelihood of poor people in the developing countries where up to 25% of monthly income may be lost due to poultry disease (Rist, 2015).

The presence of some diseases may result from strictly genetic control, whereas others may be caused by a combination of genetic predisposition and exposure to pathogens. Disease resistance research has included measurement of genetic control of disease losses, estimation of heritability, and characterization of breed or strain differences. Genetic control of certain diseases may be the result of the presence or absence of receptors that are inherited simply. Resistance to specific subgroups of leukosis virus in chickens seems to be inherited simply and may be the result of not having the receptor for the virus. Depending on the species, breeders routinely select animals. This selection is practiced under challenge environments that may increase the incidence of disease if management is poor. Many researchers have examined approaches to selection for disease resistance. The simplest method would be to observe and select breeding stock for disease resistance under normal production conditions (Bharathi, 2016).

Genetic resistance to infection was ranked in first line amongst traits of economic importance for developing countries (Okeno *et al.,* 2012). It can be either resistance to disease, which eases the development of pathological symptoms in animals infected with the pathogen or resistance to infection, which will inhibit the establishment of pathogen in the animal. Generally, genetic resistance is supposed to be considerably different among breeds with respect to their ability to withstand and survive pathogenic infections (FAO, 2010).

Disease resistant genes are those encoding antibodies, microRNA and other materials that help the host resist the damage caused by pathogens. Recent advances in the field of molecular biology have led to the discovery of many disease resistant genes. In poultry, genes such MHC (major histocompatibility complex) genes, the Nramp1 (Natural resistance-associated macrophage protein 1) gene, IFN (Interferon) genes, Mx (Myxovirus-resistance) genes, anti-ALV (Avian leucosis virus) genes and the Zyxin gene have been linked to disease resistance (Jie, 2011).

Genetic modification offers alternative strategies to traditional animal breeding. This technology is likely to have specific application where genetic variation does not exist in a given population or species and where novel genetic improvements can be engineered. With either approach, the intention would be to enhance the ability of the animals to mount an appropriate immune response against the pathogen (which could require dampening down the immune system at strategic stages) or to generate an effective system that would directly block pathogen entry or directly destroy the pathogen. Indeed, a combination of strategies may prove to be the most successful approach (Ko, 2002).

Indigenous chickens in developing countries are more disease resistant than exotic birds (Khobondo *et al*., 2015). For instance, Mandarah ecotype in Egypt can withstand infectious bursal disease virus Hassan *et al.* (2004) and Kuchi ecotype were resilient to fowl typhoid (Mdegela *et al.,* 2000). It was also reported by Aden (1989) that the Fayoumi breeds were less susceptible to avian leucosis complex.

There are also improvements in use of SNPs for genome wide disease association studies. In Ethiopia, Jarso and Horro indigenous chickens were genotyped with a 620K SNP array. In Jarso chickens, these scans revealed one SNP with genome-wide and two SNP with chromosome-wide significant association with Salmonella resistance, and one SNP with genome wide and three SNP with chromosome-wide significant association with IBD resistance. In Horro chickens, genome-wide scans revealed nine SNP with chromosome-wide significant association with Salmonella resistance and seven SNP with genome wide significant association with IBD resistance. All significant SNP for each region for either disease were found on different chromosomes (Psifidi *et al*., 2014).

2.6. Breeding Objectives and Practices in Ethiopia

There is evidence to show that there is considerable scope for improving the performance of indigenous or local breeds. However, these breeds cannot compete with highly selected commercial breeds. Thus, a breeding program involving indigenous or local breeds should identify alternative breeding goals and capitalize on the breed's specific attribute. The breeding goal would be to improve the efficiency of indigenous population raised under village conditions. This implies improving performance, reproduction capacity and livability or survival (Besbes, 2009).

It can be generalized that the demand for poultry products and livestock products has been increased significantly. This leads to poultry-related development interventions which in turn promotes intensification of traditional poultry systems (FAO, 2009). The introduction of improved breed, improved feed, vaccine and medicaments and credit aiming at increased productivity have been considered as the most important inputs for the sector (Tamirat , 2015). The previous genetic advancement efforts of Ethiopian village chicken through exotic chicken extension were embarrassed by lack of comprehensive poultry technology package extension to the end users (Teklewold *et al.*, 2006; Reta, 2009). Rural farmers didn't widely adopt Exotic chicken due to several socioeconomic and environmental challenges (Teklewold *et al.*, 2006).

Though the indigenous breeds are important in rendering income, posses' cultural value and source of nutrition for the household, they are at risk due to factors such as changing production systems and indiscriminate crossbreeding (Besbes, 2009). Breeding programs for indigenous breeds in Africa and around the world are very few. In Ethiopia, a genetic improvement program has been commenced for favoring productivity of indigenous chickens via selective breeding, as a means to both improve the livelihood of poor people and conserve the existing genetic diversity through utilization. Defining the production environments and identifying the breeding practices, production objectives and trait choices of rural farmers are necessary to develop appropriate animal breeding programs for village conditions (Solkner *et al*., 1998).

Even though it is difficult to control mating of chicken in scavenging production system, farmers have their own criteria and strategies of selecting chickens for breeding (Halima, 2007; Bogale,

2008) based on plumage colour, comb type, egg production and growth rate. Farmers in Ethiopia use four trait categories: plumage color, live weight, comb type, and body conformation for selection of breeding and replacement males and females (Nigussie *et al*., 2011).

Importation of exotic chicken breeds for commercial investments has gradually increased during the past years due to the high local demand for chicken products. This has encouraged a continuous gene flow and genetic erosion of local chicken genetic resources. The replacement of local by exotic breeds and/or uncontrolled breeding with local populations has been posing a serious threat to the existence of few local chicken breeds on small-scale farms, putting these local animal genetic resources at risk of extinction (Kadim *et al*., 2009).

2.6.1. Traits preference

In Ethiopia, indigenous chickens have desirable characters such as thermo tolerant, resistance to some diseases, good egg and meat flavor, hard egg shells, high fertility and hatchability as well as high dressing percentage (Aberra, 2000). Culling and selecting chicken are practiced at any time of the year by farmers with their own criteria and strategies (Halima, 2007). Pigmentation, taste, flavor and leanness of indigenous chickens made them preferred than exotic chickens (Hassen *et al.*, 2009). Among the indigenous chicken ecotypes, farmers also traditionally choose for traits describing the adaptive attributes, genetic merits, production potential, and consumer’s preference in the market. Therefore; understanding smallholder’s breed preference for chicken enables researchers to develop appropriate selection criteria and breeding programs to maintain chickens with the most preferred trait for village conditions (Asmelash, 2018).

2.7. Production Performance of Improved Chicken breeds

2.7.1 Potchefstroom Koekoek

The koekoek chicken breed is important in medium input production system or semi-scavenging production system. It is also a popular breed in South Africa and neighboring countries due to their egg and meat productivity as well as ability to hatch their own offspring (Grobbelaar, 2008).

The Koekoek chicken breed is important in medium input production system or semi-scavenging production system. The hens lay brown egg, about 196 eggs per year with an average egg weight of 55.7g under intensive management system (Globbelaar *et al.*, 2010). The Potchefstroom Koekoek (PK) reaches sexual maturity at 130 days (Ramsey *et al.*, 2000). Potchefstroom Koekoek breed is the most promising breed second to white leghorn and Fayoumi in terms of hen-housed egg production per hen and hatchability, respectively (Grobbelaar *et al.*, 2010).

Different average egg weight at initial laying stage was reported at different locations in Ethiopia, 40.30g at Mehoni Town (Tigray) (Atsbaha *et al*., 2018); 79.8% at Areka areas of SNNPR of Ethiopia (Aman *et al*., 2017); 53.5% at Jimma zone of south western Ethiopia (Kassa *et al*., 2016) and 51.9g DZARC. The Survivability rate from Day old until the 1st eight weeks age was 82.86% with a mortality rate of 17.14%. At the start of egg lying up to the 2nd eight weeks of age was 94.56 with a mortality rate of 5.64%. And the average survivability was 78.18% with a mortality rate of 21.72% (Atsbaha *et al*., 2018). The carcass was attractive with a deep yellow coloured skin. Today the meat of this breed is still very popular among local communities and is preferred to that of the commercial broiler hybrids (Grobbelaar, 2008).

Table 2.Growth and reproductive performance of Koekoek chicken at DZARC.

Trait	Value
Average egg production	NA
Average egg weight (g)	51.9g
Fertility (%)	90%
Hatchability (%)	78%
Age at first egg (days)	147
Mean feed intake at 20 w/bird/day (g)	122.68
Mean body weight at 20 w/bird (g)	1399-1700.71
Mean mortality at 20 w (%)	2.41-2.9

Source: (Wondmeneh *et al.,* 2012)

2.7.2. Improved Horro

Debre Zeit Agricultural Research Center launched a project in 2008 to improve the productivity of the indigenous Horro chickens through selective breeding. Researchers breed the finest layer and the fastest growing cock in each generation; give rise to improved variety of Horro.

Egg production performance of unimproved Horro chicken is 66.5±2.5 eggs per year under improved management system (Wondmeneh *et al.,* 2016). Before the start of the breeding programe, Horro chicken produced an average of 34 eggs per year. According to Wondmeneh *et al.,* 2016, selective breeding of the indigenous Horro chicken at the DZARC increased egg production by 123 percent and body weight by 95 percent during the first 8 generations. Improved local Horro breed can produce about 171±0.57 and 149±0.88 eggs per year under on-station and on- farm performance evaluation, respectively. They also added that average egg weight for improved Horro under on station performance is 52.3±0.3 g (Wondmeneh *et al.,* 2016).

In a selection program in Horro chicken of Ethiopia the strong association between body weight at 16 weeks and egg production from 21 to 28 weeks and low to moderate heritability estimates for different traits indicates that the performance of Horro chicken can be improved through suitable selection program (Nigussie *et al*., 2011).

Table 3.Performances of Improved Horro breed both on station and on farm

Trait	On-station performance	On-farm performance
Hen-housed egg production (12m	48.7	43.46
FCR (kg feed / kg gain)	12.4	NA
Fertility (%)	77.00	NA
Hatchability from set eggs (%)	43.80	NA
Body wt. (g) at 20 w (females)	964.2	NA
Survival 20w (males)	98.8	NA
Survival 24 w (females)	NA	88.8

Source :(Wondmeneh e*t al.,* 2016)

2.8. Impact of Environmental Factors on Poultry Productivity

Tropical and developing countries often relay on exotic germline for breeding purposes they however have climatic conditions, production system and markets different from those where animals were evaluated. Thus, the genotype by environment (G×E) interaction can cause a reduced efficiency of their genetic improvement program. Genotype by environment interaction is usually described as a situation in which different genotypes (Breeds, lines, or strains) respond differently to different environment (Sheridan, 1990).

Livestock animals are required to perform in a wide variety of environmental conditions, regarding climate, housing facilities, social environment, disease pressure, and differences in feed quality and composition (Knap and Wang, 2006; Star *et al*., 2008; Mormède *et al*.,2011). Poultry flocks are particularly endangered to climate change due to a range of thermal conditions which affects the animal's behavioral and physiological activities (Ayo-Enwerem *et al.,* 2017). Hence, birds can only tolerate lowly temperature ranges to sustain the peak of their production for human consumption. The environmental conditions affecting the performance of chicken include temperature, relative humidity and light at a given time (Pragya *et al.,* 2014).

Temperature and humidity are two most significant environmental factors that determine performance of poultry birds (Elijah and Adedapo, 2006). Ambient temperatures significantly influence the survivability and performance of the poultry production (Ahaotu *et al.,* 2017). Poultry birds can only tolerate narrow temperature ranges to sustain the peak of their production, for any deviation from the range they need triggers their thermoregulatory mechanisms for survival which have negative consequence on their performance. Generally, high temperature results in reduction of poultry live weight, growth rate and high mortality in addition to a decrease on productivity, hatchability and quality of eggs (Ozbey and Ozcelik, 2004). The optimum humidity range was found to be between 50-75%, which may vary with breeds. Also, relative humidity level above 75% causes reduction in egg laying. When the temperature falls below the thermo-neutral zone of 12.8°C, the egg production and efficiency of laying hens are affected (Elijah and Adedapo, 2006). Chronic (prolonged period of high ambient temperature) heat stress is more detrimental. During the heat stress period the increase in body temperature has a negative effect on the fertilization process (Karaca *et al*., 2002).

Environmental factors are generally recognized to have a major impact on the production of meat and eggs from poultry. Environmental conditions are not always ideal and as a result animal performance often falls short of genetic potential (CAN, 1981). The general reduction in performance of poultry under the influence of heat is attributable mainly to an inability to give off the entire excess heat. The higher an animal's productivity, the higher is its metabolic rate and thus the amount of heat generated. Excessive heat affects the entire organism by disrupting several physiological processes and factors. The balance between heat production and heat loss, and the effect of food intake on this balance are central to the effect of the physical environment on animal performance. The major direct effects of temperature are through maintenance of this balance. When productivity falls in a hot environment, it is largely because the animal reduces food intake in order to reduce heat production. The most important effect of elevated ambient temperature on laying hens is a reduction in food intake and consequently a decline in egg production, egg weight and shell quality (Donkoh and Atuahene, 1988).

In cold environments hens are stimulated to eat more. Under such conditions marginal deficiencies in nutrients appear to be overcome by the increase in daily nutrient intake (CAN, 1981). Birds exposed to high environmental temperature generate behavioral, physiological and immunological responses which causes more harm to their performance and productivity. It results in heavy economic losses on poultry production as a result of stunted growth (Ahaotu *et al.,* 2017), decrease in hen-day production (Ononiwu *et al.,* 2017), higher cost of production, higher mortality due to depressed immunity and reproductive failure (Nkwocha *et al.,* 2018). On the other hand, hot environments may produce nutrient deficiencies for marginally adequate diets because of the decline in feed intake. Making allowances for these situations by adjustment of nutrient density appears to alleviate some, but not all, of the adverse effects from very hot conditions (CAN, 1981).

Environmental conditions limits the productivity of laying hens, as reflected by egg production and egg quality, as the bird diverts feed metabolic energy to maintain its body temperature constant, resulting in lower egg production, and particularly in lower egg quality (Okonkwo and

Ahaotu, 2019). It could also affect meat quality by either direct effect on organ and muscle metabolism during heat exposure which can persist after slaughter. Furthermore, environmental conditions can cause a decrease in production performance, as well as reduced eggshell thickness, and increased egg breakage (Ebeid *et al.*, 2012). Additionally, it can cause a significant reduction of egg weight (3.24%), egg shell thickness (1.2 %), egg shell weight (9.93%) and egg shell percent (0.66 %). Environmental temperature can also depress growth rate and production as a result of a down-turn in voluntary feed intake in birds (Sohail *et al.,* 2012). High temperature has tremendous effect on prevalence of zoonotic diseases and also increase the insect vectors, prolong transmission cycles, increase the importation of vectors and animal reservoirs (Uzoma *et al.*, 2019).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study was conducted in three different agro-ecological zones of Ethiopia; Debre Berhan**,** Mekelle and Melka Werer which were characterized as highland, midland, and lowland, respectively.

Debre Berhan is located at the distance of 120 km North East of Addis Ababa. The area is located at latitude of 9°36`N and 39°38`E longitude; it is situated at an altitude of 2828 meters above sea level. The mean annual rainfall of the area ranges from 781 to 1279 mm. The maximum and minimum temperature is 24°C and 6.1°C, respectively. It has sub moist humidity 62.3% (EIAR, 2004).

Mekelle is located at the distance of 783 km North East of Addis Ababa. The area is located at 39° 29`E longitude and 13° 30` N latitude and at an altitude of 2000 meters above sea level. The climate is semi-arid with a mean annual rainfall of 619 mm and the annual maximum and minimum temperature is about 29.9°C and 11.8°C, respectively (BoPED, 2011).

Melka Werer is located in the Southern part of the Afar National Regional State, about 280 km east of Addis Ababa. The geographical location of the study area is between 9° 16' N latitude, 40°9' E longitude and at an altitude of 750 meters above sea level. The climate is typically semi-arid with annual average rainfall of 590 mm. The annual maximum and minimum temperature is about 40.8 °C and 26.7 °C, respectively (IAR, 1988).

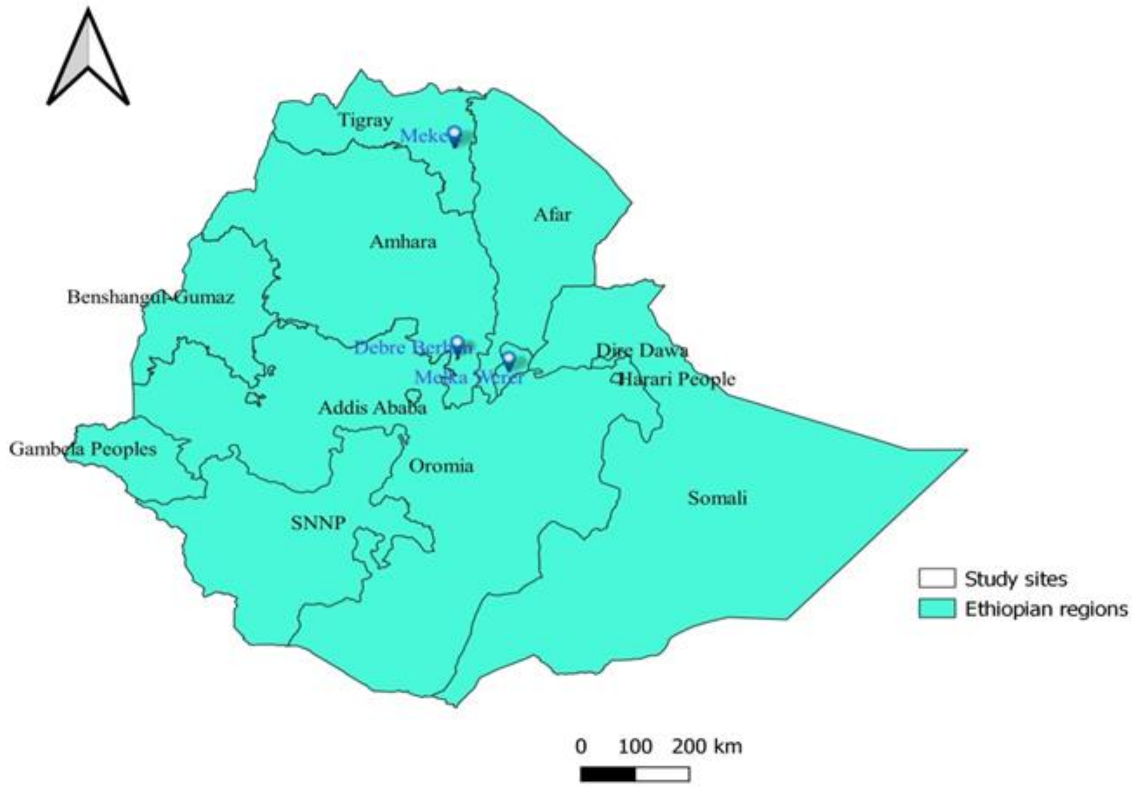

Figure 1.Location map of the study area.

3.2. Experimental Breeds

The chicken breeds used in the study in both phases were Improved Horro and DZ-white (synthetic breed from of Lohman silver, KK and RIW). The Improved Horro chicken breed used for the present study was of 10th generation and DZ-white was of 5thgeneration. The predominant plumage colors for male and female Improved Horro chicken is a reddish brown or medium to light brown. On the other hand the predominant plumage color of DZ-white for both males and female is completely white. A total of 900 day–old chicks were used for on-station trials and a total of 1500 (8 weeks of age) were used for on-farm trials (each household received 10 male and 40 female chicken) (Table 4).

Table 4.Chicken breeds used and their distribution to each trial

Location	Management	Breeds	
		DZ-white	Improved Horro
Debre Berhan (L_1)	on-station	150	150
	on-farm	250	250
Melka Werer (L_2)	on-station	150	150
	on-farm	250	250
Mekelle (L_3)	on-station	150	150
	on-farm	250	250

3.3. Study Design

In both phases the study was arranged in 2×3 factorial arrangement involving two breeds (DZ-white and Improved Horro) and three locations (Debre Berhan- L_1**,** Melka Werer-L_2 and Mekelle-L_3) with three replications for each breed (under on station).

3.4. Housing and Management

3.4.1. On station management

Eggs were hatched using the hatchery units of the poultry division at DZARC following standard procedures of the Pass Reform hatchery machines. After hatching, each chick was vaccinated against Marek's disease with HVT strain, weighed and randomly allocated to the chick box and transported to their experimental location. At the time they reached their experimental location, the chicks were weighed and allocated to pens in corrugated iron house with partial open-side which has a wire net on the open sides. Each location had 6 separate pens of an equal size, each pens were installed using mesh wire partitions. They were placed in deep litter pens, using 15cm teff (*Eragrostis teff*) straw as litter material and light was provided for 6 weeks until fully feathered.All experimental chickens were fed with starter rations for a period of 0-8 weeks and grower ration for period of 9-18 weeks and a layers ration for period of 18 up to the end of the experiment (Table 5).Feeds were formulated at DZARC using Feed Win software®. Feed and water was provided *adlibitum*. The experimental chicks were vaccinated against Newcastle disease on day 5 with HB1 and on day 28, 60,120 and within three months of interval with Lasota strain, against Infectious Bursal disease on day 7 and 21 with Gumboro vaccine, against Fowl typhoid on day 45 and 93 and against Fowl pox on day 70. Antibiotics and vitamins were supplied for all chicken flocks under study when disease was suspected in a pen. The same rearing and vaccination were followed throughout the experimental period for all locations.

Table 5.Proportion of ingredients of experimental diets

Ingredients (%)	Starter (0-8wks)	Grower (9-18 wks)	Layer (19-52 wks)
white maize	58	60	51.75
wheat middling	8	12.57	21
Soybean meal	25.17	18.62	14.25
Nougseed cake	5	5	5
Salt	0.4	0.4	0.4
Limestone	2.48	2.58	6.8
Premix	0.5	0.5	0.5
DL-lysine	0.25	0.3	0.16
DL-methionine	0.2	0.03	0.14

3.4.2. On-farm management

3.4.2.1. Farmers Selection

On-farm trials were conducted within purposively selected 30 farmers (10 from each location) who situated in the areas of Debre Berhan**,** Mekelle and Melka Werer. Criteria for the choice of the farmers were based on consultation with extension officers and willingness of farmers to participate in this study according to the protocol of the experiment, regarding data collection, construction of small scale poultry house from locally available materials, commitment to provide supplement feeding, vaccination and treatment for chicken. Similarly, the willingness of farmers to accept 50 chicken; keeping chicken at the end of the experiment; and possibility of benefiting women were considered.

3.4.2.2. Training

Months before the distribution of the chickens, 3 days training was given to the participant farmers and the respective supervisors about chicken husbandry and management, which focused on general aspects of housing, feeding, health care and data record keeping. Frequent supervision and consultation was made until they finish the construction of the small scale poultry house from locally available materials and made ready for the experiment and manual and data collection sheets were given to each trainer.

3.4.2.3. Management of experimental animals

Eggs were hatched using the hatchery units of the poultry division at DZARC following standard procedures of the pass reform hatchery machines. After hatching, each chick was vaccinated against Marek's disease with HVT strain, weighed and transferred to brooder house. In brooder house, they were placed in deep litter pens, using a teff (*Eragrostis teff*) straw as litter material and light was provided for 6 weeks. All experimental chickens were fed with starter rations (Table 5) for a period of 0-8 weeks. Feed and water was provided adlibitum during the brooding phases. The experimental chicks were vaccinated against Newcastle disease on day 5 with HB1 and on day 28 with Lasota strain; against Infectious Bursal disease on day 7 and 21; with Gumboro vaccine. Antibiotics and vitamins were supplied for all chicks under study when disease was suspected.

At the age of 8 weeks, chick was weighed and randomly allocated to the chicken box and transported to their experimental location. At the time they reached to their experimental locations chicken were distributed to households. Before the distribution the, farmers constructed a poultry house with a run made from wood, mud, corrugated iron. Each farmer received 50 chicks (only one type of breed). The households had visited every 2 weeks for 52 weeks to collect data on performance and for medication, vaccination, and ensuring that birds were managed by farmers according to the protocol of the experiment. Feeds were provided *ad-libitum* with diet prepared by household from the locally available feed. Chickens had vaccinated against Newcastle disease on day 63 and 120 with Lasota strain, against Fowl typhoid on day 93 and against fowl pox on day 73.The farmers collected the egg (after the birds had laid their first egg from the start of lay until the end of the experimental period) and mortality data by themselves. The enumerators visited each household every two weeks to measure weight and to collect the recorded data sheet.The same raring and vaccination were followed throughout the experimental period for all locations.

3.5. Data Collection

3.5.1. Body weight

For on-station trial, Birds were weighed in group at the beginning and on weekly basis until the 16 weeks in both sexes and at 52 weeks of age in female by using a sensitive balance measurement. For on-farm trial, body weights were recorded every 2 weeks starting from 8 weeks up to 20 weeks of age in both sexes. Average BW gain was calculated as the difference between the two successive weights.

3.5.2. Feed intake

The daily as well as total feed consumptions of the birds were recorded as the difference between the amount of feed offered and refused under on station management. Feed conversion ratio (feed consumed or required to produce a unit of gain) were calculated by dividing the average feed intake per gram over average body weight gain. And after the hen start egg laying Feed conversion ratio were calculated by dividing the amount of feed consumed over the gram of egg produced and body weight gain (16-52).

3.5.3. Age at first egg

The number of days to the production of the first egg was calculated from the hatching date of the hen to the production of the first egg laid (at least 5% of birds) by the flocks both on farm and on station.

3.5.4. Egg production

Eggs laid were collected two times a day (between 8:30-10:30 in the morning and 14:30-16:30 in the afternoon) from start of lay up to end of the experimental period both on station and on-farm management and the number of eggs were recorded. Hen-day egg production was calculated as the total number of egg produced by the birds, divided by the number of birds alive at the time of egg collection (Hunton, 1995). Similarly, Total number of eggs for on station and on farm trial were calculated as total number of eggs/hens over 32wks = overall %lay × 224 (the number of days in 20-52 weeks for on-station trials) and total number of eggs/hens over 40wks = overall %lay × 280 (the number of days in 20-60 weeks for on-farm trials) (Dawud, 2019).

3.5.5. Egg Weight

Under on station management, daily collected eggs were weighted immediately after collection for each pen by using an electronic digital balance in a gram base and average egg weight was calculated by dividing the total egg weight to the number of eggs.

3.5.6. Mortality

Mortality recorded as encountered throughout the experimental period both on station and on farm and mortality percentage was calculated as number of dead birds divide by number of total birds multiplied by 100.

3.5.7. Measurement of carcass characteristics

Under on station management, at the end of 16 weeks of age, three male birds from each replicate were randomly selected for carcass analysis. The selected birds were starved for twelve hours and weighted before slaughtering. The slaughter BW was taken before slaughtering. The birds were humanly slaughtered by severing the jugular vein, weighed, scalded in hot water for 2–3 minutes to facilitate easy plucking and de-feathered by hand plucking. Carcasses were manually eviscerated (removing of feet, head, heart, crop, pancreas, kidney, lungs, proventriculus, small intestine, large intestine, caeca and urogenital tracts) and suspended from the evisceration line and allowed to drain for 15 minutes prior to weighing.

The dressed carcass, breast, thighs and drumsticks were weighed inclusive of bones. The wings were removed by a cut through the shoulder joint at the proximal end of humerus. The breast portion was obtained as described by Hudspeth *et al.* (1973). The thigh and drumstick portions were obtained by cutting through the joint between the femur and ilium bone of the pelvic girdle. The drumstick was separated from the thigh by a cut through the joint formed by the femur, fibula and tibia. The dressing percentage was calculated as weight of the carcass (without head, feathers, feet and visceral organs) divided by live body weight multiplied by 100, while carcass traits were expressed as in grams and as the percentages of the carcass weight. The giblets (heart, gizzard and liver) were weighed and the percentage was calculated as the proportion of slaughter weight. The fat around the proventriculus, gizzard, and abdominal wall were collected and weighed; and fat percentage was calculated as the proportion of the slaughter weight.

3.5.8. Evaluation of egg quality parameters

Under on station management, eggs from both breed of chickens were collected for quality parameter test. A total of 10 eggs from each replication (a total of 180 eggs) were taken for quality parameter test. Eggs were weighed individually using digital balance, Egg length and width was taken using digital caliper. Shape index were then computed according to Panda (1996). After external quality trait measurement, each egg was carefully broken on a glass sheet by making an opening around the sharp end of the egg, large enough to allow passage of both the albumen and the yolk through it without mixing their contents together. The yolk was carefully separated from the albumen and placed in a petri dish for weighting. Albumen was placed on another petri dish and weighted. The parameters such as: yolk height, albumen height, and yolk color were taken. Yolk and albumen height was measured at its top point by a spherometer. Shell thickness was measured by digital caliper at the sharp-end, equatorial, and blunt-end regions after shell membrane was removed, and the mean of these three points was recorded.

Yolk colour was measured by using the Roche Colour Fan (range 1-15) (Roche scale). Individual Haugh unit was also calculated according to the following equation of Haugh (1937).   .

$$HU = 100 \log (AH - 1.7EW)^{0.37} + 7.57$$

Where, AH = albumen height, HU = Haugh unit, and EW = egg weight

3.5.9. Measurement of hatchability traits

Under on station management, a total of hatching eggs 1325 eggs; 677 hatching eggs from DZ-white and 648 hatching eggs from Improved Horro breeds of chicken were collected at week 32, 35, 38 and 40. Selection of hatching eggs was done based on their uniform size, good shape and clean shell. Eggs were then stored for 7 days in a cool room at approximately 17°C and 75 relative humidity (RH). The hatching eggs were then fumigated with potassium permanganate and Formalin before set. The incubator both the setter and hatcher were washed and fumigated with Potassium permanganate and formalin. Standard relative humidity, temperature and egg turning were programmed on the setter and hatcher. The average weight of hatching eggs was calculated after weight of all eggs was taken in gram by using digital balance .Eggs were candled on the 18th days of incubation to identify and remove infertile and eggs with dead embryos (dead in germ). The rest of eggs were transferred from the setter to the hatcher on the 18th day of incubation. At the end day 21 the hatcher was opened. The number of hatched chicks including the normal, weak, abnormal chicks, dead chicks after hatch and the un-hatched eggs were counted to each breeds and recorded. Very small and defective chicken on beaks, eyes, legs etc., were counted as abnormal chicks. All abnormal chicks were discarded and the rest of the chicks were counted as normal. Calculations were made of fertility, hatchability, dead in germ, and dead in shell, abnormal chicks, and normal chicks. The average weight of day-old chicks (gram) was calculated after their weight taken by using digital balance.

3.6. Statistical Analyses

The collected data were subjected to the analysis of variance test for each parameter by using a factorial 2×3 arrangement, with breeds (DZ-white and Improved Horro) as first factor and location (Debre Berhan- L_1**,** Melka Werer-L_2 and Mekelle-L_3) as the other. Based on General Linear Model's procedures of Statistical Analysis System (SAS) version 9.3 (SAS, 2010) and data were fitted to a model that included the effects of breeds, location and breeds by location. Significant differences among treatment means were separated using Tukey's Studentized Range (TSR) test. A $P<0.05$ was considered significant.

The ANOVA for on -station trial was conducted according to the following model:

$$Y_{ijk}=\mu+\alpha_i+\beta_j+(\alpha\beta)_{ij}+e_{ijk}$$

Where: Y_{ijk}= the dependent variables (body weight, body weight gain,feed intake, feed conversion ratio, carcass characteristics, age at first egg, egg production, egg quality and mortality)

μ = overall mean

α_i= the i^{th} effect of genotype (DZ-white and Improved Horro)

β_j= is the j^{th} effect of the environment (Debre Berhan- L_1**,** Melka Werer-L_2 and Mekelle-L_3)

$(\alpha\beta)_{ij}$= interaction of main effects

e_{ijk}= random error specific to the particular observation and assumed to be normally and independently distributed with mean zero and variance σ^2 ie.σ^2~NID(0, σ^2_e).

The ANOVA model forfertility and hatchability traitwas conducted according to the following model:

$$Y_{ik}= \mu + g_i+ e_{ik}$$

Where, Y_{ik} = the y^{th} observed response

μ = Overall mean

g_i = the i^{th} effect of genotype (DZ-white and Improved Horro)

e_{ik}= random error specific to the particular observation and assumed to be normally and independently distributed with mean zero and variance σ^2 ie.σ^2~NID(0, σ^2_e).

For on-farm trials, body weight, body weight gain, age at first egg, egg production and mortality traits were measured. Age at first egg and egg production trial analysis was done only at L_1 and L_2.The analysis of age at first egg and egg production trial for L_3 was not included in the current result due to incomplete data.

$$Y_{ijk}=\mu+\alpha_i+\beta_j+(\alpha\beta)_{ij}+e_{ij}$$

Where: Y_{ijk}= the dependent variables (body weight, body weight gain,age at first egg, egg production and mortality)

μ = overall mean

α_i= the ith effect of genotype (DZ-white and Improved Horro)

β_j= is the jth effect of the environment ((Debre Berhan- L_1**,** Melka Werer-L_2 and Mekelle-L_3)

e_{ijk}= random error specific to the particular observation and assumed to be normally and independently distributed with mean zero and variance σ^2 ie.σ^2~NID(0, σ^2_e).

4. RESULTS

4.1. Performance Evaluation Under On -Station Management

4.1.1. Feed intake

Average daily feed intake (ADFI, g/bird/day) of the two breeds in each of three phases and TFI (kg/bird/364days) for the main effect breed and location were presented in Table 6.Significantly ($P<0.05$) higher ADFI was observed in DZ-white chicken compared to the Improved Horro during the three phases.Similarly, the main effect location revealed Significant ($P<0.05$) ADFI difference among location.

The total feed intake was significantly ($P\leq0.05$) higher in DZ-white with the mean 35.71 kg/hen over the trials period(364 days) and significantly ($P\leq0.05$) lower TFI was exhibited by Improved Horro with the means 33.85 kg/hen/364 days. There was also a significant ($P\leq0.05$) differences among locations where birds kept at L_1 consumed more feed compared to L_2 and L_3 (Table 6).

The interaction of main effects (breed and location) showed significant ($P\leq0.05$) difference in ADFI during the starter and grower phase. During the starter Phase DZ-white consumed significantly ($P\leq0.05$) higher ADFI at L_1 and in both breeds lower ADFI was recorded at L_3. Improved Horro breed revealed lower intake at L_1 and L_2 during the grower phase. However, the interaction between breed and location did not show significant differences ($P\geq0.05$) intotal feed intake (Table 7).

4.1.2. Feed conversion ratio (FCR)

As shown in (Table 6), the main effect breed showed that DZ-white had significantly ($P\leq0.05$) improved feed conversion ratio (FCR) over Improved Horro during the starter, grower and layer phase. On the other hand, the main effect location revealed significantly ($P\leq0.05$) higher FCR in chickens kept at L_3 as compared to birds kept at L_1 and L_2 during the starter and layer phase. However, during the grower stages FCR showed values with no significant differences ($P\geq0.05$).

Furthermore in the current study, the interaction between breed and location did not show significant differences ($P \geq 0.05$) in FCRin all phases (Table7).

4.1.3. Body weight

The effects of breed on BW of chickens during the production phase are significant (Table 8). The highest body weight at 8, 16 and 52 weeks of age in both male and female were exhibited by DZ-white. In the current study, male and female of DZ-white chickens exhibited an average body weight of 1558.93g, 1186.01g at 16 week of age and 1805.33g at 52weeks of age, respectively. From Location main effect, there was a significant ($P \leq 0.05$) effects of location on body weights of male and female chickens at 8 and 16 weeks of age and body weights of female at 52 weeks of age (Table 8).

The present result also shows that, interactions between main effects (breed and location) were not significantly influenced body weights at 8 weeks and body weights of male chicken at 16 weeks of age (Table 9). However, interaction between breed and location were significant for body weights of female at 16 and 52 weeks of age (Table 9). The highest body weights at 16 weeks of age were exhibited by DZ-white at L_1, followed by the same breed at L_2 and L_3. In the current study, female DZ-white breed exhibited an average body weight of 1932 gm, 1700.66gm and 1783.35gm at L_1, L_2 and L_3, respectively at 52weeks of age. Nevertheless, improved Horro exhibited the lowest average body weight of females at 16 and 52 weeks of age.

Table 6.Least square means and standard error values for the main effects of breed and location onaverage daily feed intake (ADFI), total feed intake (TFI) and FCR during the entire trial.

Parameter	Age in week	Breed			Location			
		DZ-white	IH	P value	L_1	L_2	L_3	P value
ADFI, (g/bird/day)	0-8	30.94±2.04[a]	29.24±1.38[b]	0.0004	35.61±1.05[a]	30.72+0.34[b]	23.94±0.31[c]	<.0001
	8-16	70.41±1.07[a]	66.89±0.37[b]	<.0001	69.79±1.70[a]	66.56±0.49[b]	69.61±0.73[a]	0.0006
	16-52	119.19±2.05[a]	112.95±2.24[b]	0.0061	123.19±2.01[a]	111.61±2.05[b]	113.42±2.04[b]	0.0006
TFI kg/bird/364 days	0-52	35.71±0.65[a]	33.85±0.60[b]	0.0021	36.95±0.63[a]	33.58±0.54[b]	33.82±0.53[b]	0.0001
FCR	0-8	3.44±0.23[b]	3.74±0.21[a]	0.0190	4.09±0.11[a]	3.92±0.13[a]	2.72±0.10[b]	<.0001
	8-16	4.75±0.05[b]	5.30±0.12[a]	0.0022	5.05±0.17	5.11±0.21	4.90±0.10	0.4712
	16-52	4.16±0.19[b]	5.62±0.16[a]	<.0001	5.02±0.43[a]	5.15±0.40[a]	4.25±0.40[b]	0.044

[*a,b,c] means *within a row with different superscripts are significantly different (P<0.05), DZ-white= Debre Zeit white, IH= Improved Horro,L= location,* L_1 *=Debre Berhan,* L_2 *= Melka Werer,* L_3 *= Mekelle, , FCR = Feed conversion ratio, SE = Standard error of the mean, P = Probability.*

Table 7.Least square means and standard error values for the interaction effects of breed and location on average daily feed intake (ADFI), total feed intake (TFI) and FCR during the entire trial.

2-way interactions		ADFI, (g/bird/day)			TFI, kg/bird/364 days	FCR		
		0-8 wk	8-16wk	16-52wk	0-52wk	0-8wk	8-16wk	16-52wk
DZ-white	L_1	37.92±0.26[a]	73.43±1.02[a]	126.86±1.73	38.20±0.45	4.02±0.11	4.73±0.05	4.24±0.43
	L_2	31.07±0.38[c]	66.67±0.92[c]	113.82±0.40	34.15±0.09	3.73±0.09	4.76±0.10	4.47±0.26
	L_3	23.85±0.65[d]	71.13±0.37[b]	116.90±0.78	34.78±0.22	2.56±0.10	4.74±0.13	3.77±0.09
IH	L_1	33.31±0.33[b]	66.15±0.31[c]	119.52±1.97	35.69±0.47	4.17±0.21	5.37±0.22	5.76±0.09
	L_2	30.37±0.56[c]	66.45±0.55[c]	109.41±4.00	32.99±1.05	4.11±0.19	5.46±0.31	5.84±0.21
	L_3	24.04±0.23[d]	68.08±0.47[c]	109.94±2.84	32.86±0.68	2.96±0.01	5.06±0.10	5.27±0.30
P- value		0.0003	0.0007	0.7898	0.5294	0.6313	0.5360	0.945

*[a, b, c] means *within a row with different superscripts are significantly different* ($P<0.05$), DZ-white= Debre Zeit white, IH= Improved Horro, *L= location*, L_1 =Debre Berhan, L_2 = Melka *Werer*, L_3 = *Mekelle, FCR = Feed conversion ratio, SE = Standard error of the mean, P = Probability.*

4.1.4. Body weight gain

The result from analysis of variance indicates there is significant difference ($P \leq 0.05$) between breeds on body weight gain recorded in both sexes (Table 8). Higher body weight gain was noted in DZ-white chickens as compared to Improved Horro in all Phases. From location main effect, BW gain of male chickens was significantly ($P \leq 0.05$) higher at L_1 and L_3 and significantly ($P \leq 0.05$) lower at L_2 during the starter and grower phase. However, BW gain of female both at grower and layer phases showed non significant difference (Table 8). On the other hand, interaction between breeds and location did not show significant differences ($P \geq 0.05$) inbody weight gain for both sexes in all phases (Table 9).

4.1.5. Carcass analysis

A significant genotype effect was observed in slaughter weight, dressing% and carcass weight (Table 10). DZ-white presented a higher value of slaughter weight, and carcass weight as compared to Improved Horro. However, Improved Horro exhibited significantly ($P \leq 0.05$) higher dressing% than DZ-white. The main effect location revealed Significant ($P<0.05$) difference in slaughter weight, dressing% and carcass weight among location (Table 10). Higher value of slaughter weight was observed in birds kept at L_3 followed by L_1 and the least was observed at L_2. The dressing% was significantly ($P \leq 0.05$) higher at L_3 and lower at L_1 and L_2.A higher value of carcass weight was registered at L_3 followed by L_1 and significantly (($P \leq 0.05$) Lower at L_2.

Genotype brought a difference in carcass weight which was observed on breast, drumstick and thigh weight (Table 10). DZ-white was significantly ($P \leq 0.05$) superior in breast, drumstick and thigh weight to their Improved Horro counterpart. Regarding the proportion of breast, a significant difference was observed between breeds. However, the proportion of drumstick and thigh of both breed has no statistical difference. From location main effect, breast was significantly ($P \leq 0.05$) higher at L_1, followed by L_2 and lower at L_3. Drumstick was significantly ($P \leq 0.05$) higher at L_1 and L_3 and lower at L_2.

Table 8.Least square means and standard error values for the main effects breed and location on body weight and body weight gain under on station management.

Parameter	Age in weeks	Breed			Location			
		DZ-white	IH	P value	L_1	L_2	L_3	P value
Initial BW(g)	-	34.96±0.10[a]	29.27±0.18 [b]	0.0001	32.36±1.17	31.92±1.42	32.10±1.26	0.1540
BW(g)	8	540.78±10.84[a]	469.55±10.47[b]	0.0001	521.79±21.45[a]	473.00±16.23[b]	520.71±16.49[a]	0.0046
BWG (g)	0-8	505.80±10.84[a]	440.28[b]±10.33[b]	0.0001	489.43±20.39[a]	441.08±15.08[b]	488.61±15.24[a]	0.0045
BW-M (g)	16	1558.93±30.38[a]	1354.56±28.89[b]	<.0001	1464.72±65.24[a]	1371.70±38.42[b]	1533.81±45.88[a]	0.0012
BW-F (g)	16	1186.01±26.33[a]	1005.19±13.14[b]	<.0001	1139.82±58.91[a]	1043.99±40.57[b]	1102.99±30.54[a]	0.0048
	52	1805.33±36.46[a]	1509.55±12.26[b]	<.0001	1725.01±94.31[a]	1596.33±48.79[b]	1651.43±61.32[b]	0.0011
BWG-M (g)	8-16	1018.15±22.55[a]	885.01±27.85[b]	0.0007	942.94±49.88[ab]	898.70±31.17[b]	1013.10±30.82[a]	0.0259
BWG-F (g)	8-16	645.23±19.88[a]	535.64±14.86[b]	0.0003	618.03±42.18	570.99±32.01	582.28±15.37	0.2287
	16-52	619.31±20.96[a]	504.36±12.06[b]	0.0003	585.18±39.95	552.34±19.62	548.01±35.19	0.3808

[*a, b,] means *within a row with different superscripts are significantly different (P<0.05), DZ-white= Debre Zeit white, IH= Improved Horro, L= Location,* L_1 *=Debre Berhan,* L_2 *= Melka Werer,* L_3 *= Mekelle, SE = Standard error of the mean,* BW=body weight, *P = Probability.*

Table 9.Least square means and standard error values for the interaction effects of breed and location on body weight and body weight gain under on station management.

Parameter	Age in weeks	DZ-white			IH			p-value
		L_1	L_2	L_3	L_1	L_2	L_3	
Initial BW(g)	-	34.95±0.19	35.09±0.24	34.92±0.17	29.77±0.29	28.75±0.22	29.28±0.10	0.0557
BW(g)	8	564.21±12.12	501.33±6.67	556.81±6.07	479.36±18.82	444.67±21.67	484.61±4.40	0.5866
BWG(g)	0-8	529.26±12.11	466.25±6.47	521.89±5.91	449.59±18.60	415.91±21.48	455.33±4.38	0.5557
BW-M (g)	16	1596.20±16.70	1449.82±26.89	1630.77±29.05	1333.24±60.95	1293.59±23.53	1436.85±16.73	0.2902
BW-F(g)	16	1269.93±5.14[a]	1121.69±45.36[b]	1166.42±21.36[b]	1009.70±19.86[c]	966.30±11.66[c]	1039.57±13.6[c]	0.0339
	52	1932.00±39.15[a]	1700.66±17.62[c]	1783.35±19.18[b]	1518.14±9.64[d]	1492.36±26.57[d]	1518.31±30.3[d]	0.0048
BWG-M(g)	8-16	1031.99±24.13	948.48±28.58	1073.97±25.02	853.88±62.68	848.92±39.53	952.24±20.50	0.5545
BWG-F(g)	8-16	705.72±11.42	620.36±39.70	609.61±16.26	530.34±32.78	521.63±33.29	554.96±13.05	0.1162
	16-52	662.06±43.47	578.97±27.77	616.91±29.66	508.30±13.50	525.73±21.07	479.09±23.38	0.1996

*[*a,b, c,d]* Means *within a row with different superscripts are significantly different (P<0.05), DZ-white= Debre Zeit white, IH= Improved Horro, L= location, L_1 =Debre Berhan, L_2 = Melka Werer, L_3 = Mekelle, SE = Standard error of the mean,* BW=body weight*P = Probability.*

Higher value of thigh weight was observed in birds kept at L_3, followed by L_1 and the least was observed at L_2. In terms of the proportion of breast, a significant difference was observed among locations. However there was no significant ($P \geq 0.05$) difference for drumstick and thigh among locations.

As shown in (Table 10), Wing, neck and back weight was significantly ($P \leq 0.05$) affected by breed. DZ-white exhibited significantly ($P \leq 0.05$) higher wing, neck and back weight as compared to the Improved Horro chicken. In terms of the GIT and giblet, DZ-white showed higher weight than Improved Horro. However, there were no significant ($P \geq 0.05$) differences between the breeds for proportion of wing, neck, back, GIT and giblet. Similarly, abdominal fat weight and proportion has no differences between breeds. From location main effect, Wing, neck, back, GIT, giblet and Abdominal fat weight and their proportion except giblet (%) were significantly ($P \leq 0.05$) affected by location. Significantly higher wing (%) and back (%) was recorded at L_1, followed by L_2 and the lowest at L_3. Furthermore, abdominal fat weight and its proportion showed higher value at L_2 and L_3 and no abdominal fat was recorded at $L_1$for both breeds (Table 10).

4.1.6. Age at first lay

The mean ages of the hens (days) to the production of their first egg was presented in (Table 11 and 12). There were no significant ($P \geq 0.05$) differences between breeds in mean age to the production of the first egg. However, in the location main effect, significantly ($P \leq 0.05$) earlier age at first egg was noted at L_3 (139.83 days) compared to L1 (150.33) and L_2 (151.00) (Table 11). Among the two-way interaction effects of breed and location (Table 12), Improved Horro showed significantly ($P \leq 0.05$) earlier age at first egg at L_3, followed by DZ-white across the location and the last were Improved Horro at $L_1$and L_2.

Table 10.Effect of breed and location on carcass analysis of male chickens at16 weeks of age (**N**=54).

Parameter	Breed			Location			
	DZ-white	IH	P value	L_1	L_2	L_3	P value
Slaughter weight (g)	1699.89±35.72[a]	1389.81±38.55[b]	<.0001	1570.83±53.72[b]	1388.94±42.63[c]	1674.78±58.42[a]	<.0001
dressing%	65.23±0.84[b]	67.76±0.74[a]	0.0005	64.03±0.68[b]	64.35±0.77[b]	71.11±0.48[a]	<.0001
Carcass weight (g)	1112.52±32.86[a]	942.96±30.06[b]	<.0001	1003.33±31.33[b]	890.50±22.98[c]	1189.39±40.36[a]	<.0001
Breast weight (g)	286.96±13.05[a]	269.89±12.44[b]	0.0412	340.00±7.59[a]	295.44±6.34[b]	199.83±7.59[c]	<.0001
Breast %	17.13±0.85[b]	19.75±0.98[a]	<.0001	21.86±0.46[a]	21.45±0.48[a]	12.01±0.34[b]	<.0001
Drumstick weight (g)	180.74±4.60[a]	153.11±4.25[b]	<.0001	172.56±5.04[a]	147.72±4.06[b]	180.50±6.89[a]	<.0001
Drumstick (%)	10.62±0.13	11.04±0.16	0.4228	11.05±0.20	10.68±0.20	10.77±0.14	0.3080
Thigh weight (g)	199.11±4.94[a]	166.52±4.95[b]	<.0001	184.44±6.21[b]	164.11±5.69[c]	199.89±7.10[a]	<.0001
Thigh (%)	11.72±0.16	12.01±0.20	0.2838	11.77±0.20	11.82±0.19	12.00±0.29	0.7534
Wing weight (g)	76.85±2.00[a]	68.59±2.11[b]	0.0002	83.06±2.50[a]	65.33±1.51[b]	69.78±1.97[b]	<.0001
Wing %	4.54±0.11[b]	4.96±0.12[a]	0.0001	5.32±0.11[a]	4.73±0.08[b]	4.20±0.09[c]	<.0001
Back weight (g)	162.67±4.95[a]	132.41±5.11[b]	<.0001	166.39±6.09[a]	130.61±5.46[c]	145.61±7.18[b]	<.0001
Back %	9.59±0.24	9.53±0.23	0.8160	10.59±0.15[a]	9.40±0.23[b]	8.68±0.27[c]	<.0001
Neck weight	80.44±2.75[a]	64.19±2.14[b]	<.0001	78.44±3.66[a]	75.44±3.79[a]	63.06±2.01[b]	0.0002
Neck (%)	4.79±0.20	4.66±0.15	0.4430	4.98±0.14[b]	5.41±0.18[a]	3.80±0.11[c]	0.0001
Giblet weight (g)	84.27±2.54[a]	66.60±1.66[b]	<.0001	78.63±2.99[a]	65.77±2.28[b]	81.89±3.49[a]	<.0001
Giblet%	4.94±0.07	4.82±0.09	0.2968	5.01±0.08	4.75±0.11	4.88±0.09	0.1752
GIT weight (g)	91.88±6.27[a]	70.35±5.37[b]	<.0001	65.95±3.73[b]	58.28±2.34[b]	119.11±5.32[a]	<.0001
GIT %	5.33±0.29	4.98±0.31	0.5490	4.16±0.13[b]	4.19±0.11[b]	7.12±0.21[a]	<.0001
Abdominal fat weight (g)	3.45±1.09	3.56±1.21	0.9367	0.00±0.00[b]	3.85±1.92[a]	6.67±1.02[a]	0.0021
Abdominal fat%	0.19±0.06	0.26±0.09	0.5515	0.00±0.00[b]	0.28±1.44[a]	0.39±0.05[a]	0.0104

4.1.7. Egg production

Table 11 shows that, total number of eggs/hen differed significantly ($P \leq 0.05$) between breeds. The highest total number of eggs/hen was obtained by DZ-white (124.57 egg) as compare to Improved Horro (104.58 egg). The main effect location revealed significantly ($P<0.05$) higher number of eggs for birds kept at L_1 (118.32) and L_3 (120.42) and lower at L_2 (105.07 eggs)(Table 11). On the other hand, there was insignificant ($P \geq 0.05$) difference between the interaction of breed and location on total number of eggs/hen (Table 12).

As observed in this study, hen-day egg productions (per live hens) were significantly ($P \leq 0.05$) higher for DZ-white as compared to Improved Horro chickens in all age groups, except during 44-47 weeks (no statistical difference).During the 21-27 weeks, the two breeds showed a higher variation on hen-day egg productions with a value 41.85% and 22.56% for DZ-white and Improved Horro, respectively (Figure 2). During the 36-39weeks, Significantly ($P \leq 0.05$) higher hen-day egg production was recorded for DZ-white (62.43%) and lower for Improved Horro(52%). Starting from 40 week's, hen-day egg production declined in both breeds (Figure 2).Among the locations, significant differences ($P \leq 0.05$) were obtained during 21-27, 28-31 and 32-35 weeks of age (Figure3). However during the rest laying period hen-day egg production did not show significant differences ($P \geq 0.05$) among location. During the 21-27 weeks significantly ($P \leq 0.05$) higher hen-day egg production were recorded for chickens kept at L_3, followed by L_1 and the least at L_2. During the 28-31 weeks hen-day egg production were higher for chickens kept at L_3 and lowest was recorded at L_1 and L_2.Furthermore, during 32-35 weeks of age higher hen-day egg production was recorded for chickens kept at L_1, followed byL_3 and the lowest at L_2 (Figure 3).The interaction between breed and location did not show significant differences on hen-day egg production in all (7) age categories except during the 21-27 weeks (Table 13).

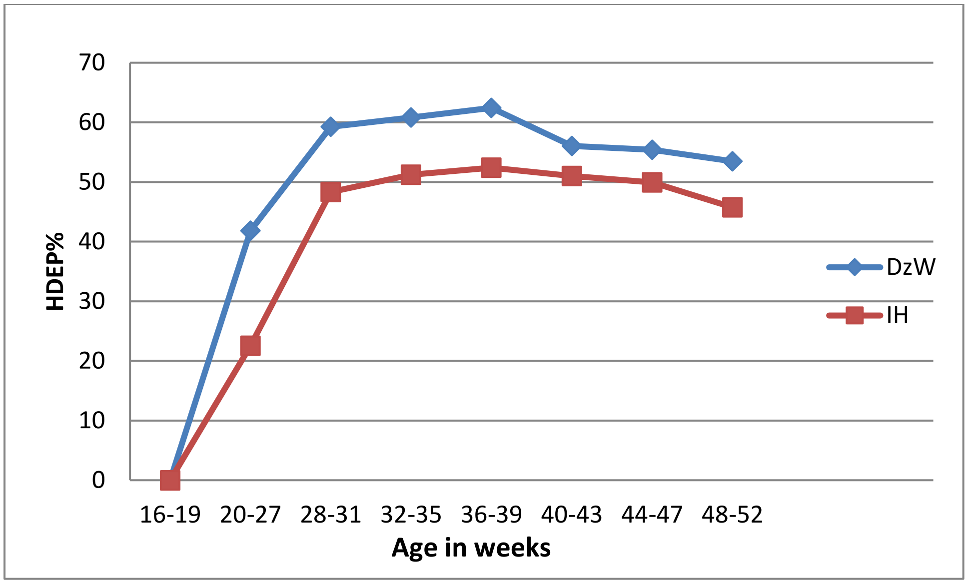

Figure 2.Least square means of HDEP% for DZ-white and Improved Horro chickens at 8 age periods of the trial under on station management.

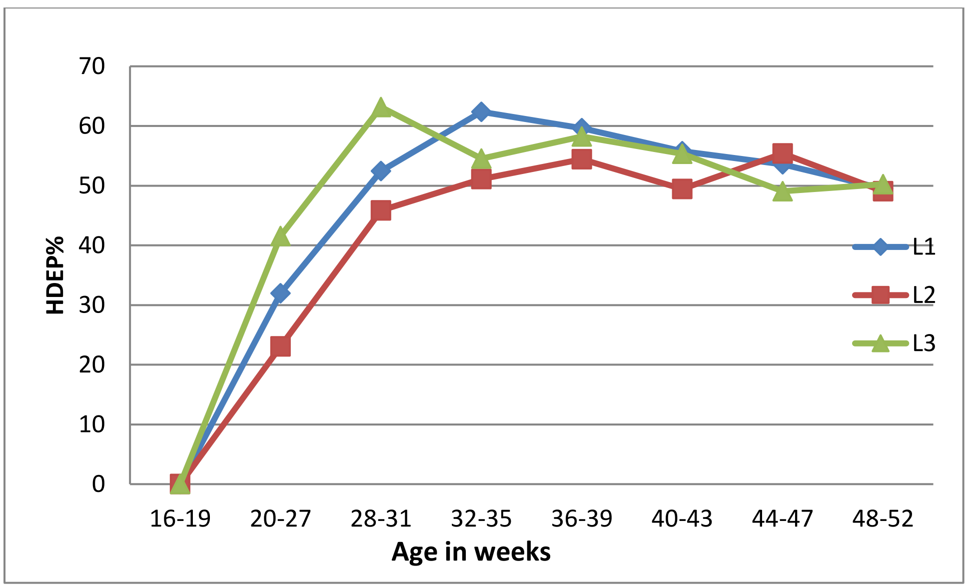

Figure3.Least square means of HDEP% at L_1, L_2 and L_3 during 8 age periods of the trial under on- station management.

Table 11. Least square means and standard error values for the main effects of breed and location on age at first egg (AFL in days), egg number, average egg weight (AEW in g) and egg mass (EM/kg) under on- station management.

Parameter	Breed			Location			
	DZ-white	IH	P value	L_1	L_2	L_3	P value
AFL(days)	145.56±1.23	148.56±3.04	0.0804	150.33±2.09[a]	151.00±1.95[a]	139.83±1.82[b]	0.0001
Egg number / hen up to 52 weeks of age	124.57 ±4.23[a]	104.58 ±2.90[b]	0.0007	118.23±6.79[a]	105.07±4.97[b]	120.42±4.97[a]	0.0318
AEW(g)	52.47±0.52[a]	44.93±0.33[b]	<.0001	50.18±1.81[a]	47.52±1.52[c]	48.41±1.76[b]	<.0001
EM(kg)	6.46±0.30[a]	4.49±0.16[b]	<.0001	5.72±0.63	4.92±0.41	5.78±0.43	0.0693

[*a,b,c] Means *within a row with different superscripts are significantly different ($P<0.05$), DZ-white= Debre Zeit white, IH= Improved Horro, L= location,* L_1 *=Debre Berhan,* L_2 *= Melka Werer,* L_3 *= Mekelle, SE = Standard error of the mean, P = Probability*

4.1.8. Average egg weight and egg mass

DZ-white yielded significantly (P≤0.05) higher AEW (52.47g) as compared to the Improved Horro chicken (44.93g) (Table 11). There was also a significant (P≤0.05) difference in the main effects location for AEW. Birds kept at L_1exhibited heavier AEW (50.18g) than L_3(48.41g) and the least was exhibited at L_2 (47.52g) (Table 11).

As shown in table 11, the average EM of DZ-white chickens was higher than Improved Horro. There was insignificant (P≥0.05) difference among locations on EM (Table 11).Similarly, the interaction of breed and location did not bring significant (P≥0.05) difference on AEW and EM (Table 12).

Table 12. Least square means and standard error values for the interaction effect of breed and location on age at first egg (AFL in days), egg number, average egg weight (AEW in g) and egg mass (EM/kg) during the entire trial under On-station management.

2-way interactions		AFL(days)	Egg number / hen up to 52weeks of age	AEW(g)	EM(kg)
DZ-white	L_1	146.33 ± 1.33^b	129.02±9.69	54.19±0.45	6.97±0.60
	L_2	147.67 ± 1.45^b	114.84±5.27	50.92±0.24	5.72±0.47
	L_3	142.67 ± 2.73^{bc}	129.86±4.70	52.31±0.50	6.70±0.25
IH	L_1	154.96 ± 2.03^a	107.45±4.51	46.18±0.28	4.48±0.37
	L_2	154.33 ± 2.40^a	95.31±0.76	44.12±0.08	4.12±0.02
	L_3	137.00 ± 1.00^c	110.97±3.53	44.51±0.21	4.86±0.19
P- value		0.0072	0.9675	0.1844	0.4890

^{*a,b,c} means *within a row with different superscripts are significantly different (P<0.05), DZ-white= Debre Zeit white, IH= Improved Horro, L= location, L_1=Debre Berhan, L_2 = Melka Werer, L_3 = Mekelle, SE = Standard error of the mean, P = Probability*

Table 13. Least square means and standard error values for the interaction effect of breed and location on HDEP (%) under on-station management.

Age in weeks	DZ-white			IH			p-value
	L_1	L_2	L_3	L_1	L_2	L_3	
20-27 wks	49.28±2.02[a]	26.72±2.19[bc]	49.56±5.32[a]	14.63±0.34[c]	19.46±1.08[c]	33.59±5.14[b]	0.0041
28-31 wks	57.79±5.00	48.35±2.11	71.71±4.36	47.06±3.62	43.30±1.89	54.63±4.87	0.3290
32-35 wks	69.26±4.45	56.00±5.04	57.23±3.48	55.48±5.25	46.26±1.94	51.85±1.75	0.5764
36-39 wks	63.13±6.41	61.11±3.84	63.04±1.05	56.09±4.83	47.72±2.43	53.39±2.35	0.7229
40-43 wks	56.36±4.31	53.52±1.63	58.21±0.36	55.14±5.17	45.39±1.49	52.47±1.37	0.5134
44-47 wks	55.54±5.73	60.66±5.34	50.05±4.23	51.57±3.97	50.13±0.58	48.07±3.60	0.5904
48-52 wks	51.83±2.72	52.52±1.55	56.03±3.82	47.19±1.32	45.58±2.26	44.45±2.74	0.4082

[*a,b,c] means *with in a row with different superscripts are significantly different (P<0.05), DZ-white= Debre Zeit white, IH= Improved Horro, L= location,* L_1 *=Debre Berhan,* L_2 *= Melka Werer,* L_3 *= Mekelle, SE = Standard error of the mean, P = Probability and* wks=weeks.

4.1.9. Egg quality

As shown in Table 14, there were a significant ($P \leq 0.05$) differences between breeds for all egg quality traits except egg shape index, shell thickness, albumin height, haugh unit and yolk color. Eggs from DZ-white chickens were significantly ($P \leq 0.05$) heavier than Improved Horro. Similarly, DZ-white exhibited higher value for all egg-size-related measurements: egg width, length, yolk weight, albumen weight and shell weight. In terms of the yolk height, eggs from DZ-white chicken exhibited higher (18.82mm) value as compare to Improved Horro (18.07mm).

Furthermore, the main effect location revealed that there was higher significant ($P \leq 0.05$) difference among locations for egg quality traits studied except albumin height, haugh unit and shell ratio (table 14). Higher egg and yolk weight were recorded at L_1 and the lowest measures were reported at L_2.The egg of chicken at $L_1$and L_3 had much thicker shell than the egg shell of L_2. Shell weight values at L_1, L_2 and L_3 were 6.37 g, 5.62 g and 6.32 g, respectively. L_1 and L_3 showed significantly higher ($p<0.05$) albumin weight, yolk height, egg length and width than that of L_2. On the other hand the interaction of main effects (breed and location) did not show significant ($p>0.05$) difference in on all egg quality traits,

4.1.10. Mortality

In the present study, there was no significant ($p>0.05$) difference between breeds on mortality in all phases. However, there was significant ($P \leq 0.05$) difference among location. Higher mortality was observed in birds kept at L_2 as compared to L_1 and L_3 during starter and grower phase. During the layer phase, mortality was high at L_2 and L_3 and lower at L_1 (Table 15). Furthermore, the interaction of main effects (breed and location) showed no significant ($p>0.05$) difference on mortality in all phases (Table 15)

Table 14.Effect of breed and location on egg quality traits (**N**=180).

Parameter	Breed			Location			P- value
	DZ-white	IH	P value	L_1	L_2	L_3	
Egg Weight (g)	53.11±0.65[a]	46.40±0.49[b]	<.0001	52.35±0.81[a]	46.22±0.70[c]	50.70±0.88[b]	<.0001
Egg Length (mm)	54.26±0.30[a]	51.94±0.27[b]	<.0001	53.64±0.44[a]	52.22±0.34[b]	53.43±0.38[a]	0.0070
Egg Width (mm)	41.49±0.30[a]	39.75±0.21[b]	<.0001	41.50±0.30[a]	39.33±0.33[b]	41.02±0.31[a]	<.0001
Egg Shape index	76.10±0.46	76.41±0.41	0.8704	77.46±0.55[a]	75.36±0.58[b]	76.81±0.42[ab]	0.0173
Shell Weight (g)	6.41±0.09[a]	5.80±0.08[b]	<.0001	6.37±0.10[a]	5.62±0.10[b]	6.32±0.11[a]	<.0001
Shell Thickness (mm)	0.40±0.09	0.41±0.01	0.1369	0.47±0.01[a]	0.38±0.01[b]	0.46±0.01[a]	<.0001
Albumin Height (mm)	6.89±0.17	6.53±0.13	0.0934	6.63±0.19	6.54±0.18	6.96±0.20	0.2462
Yolk Height (mm)	18.82±0.15[a]	18.07±0.12[b]	<.0001	18.76±0.20[a]	17.92±0.14[b]	18.65±0.16[a]	0.0003
Yolk Weight (g)	15.08±0.23[a]	14.33±0.18[b]	0.0018	15.57±0.27[a]	13.58±0.20[c]	14.98±0.18[b]	<.0001
Albumin Weight (g)	31.08±0.49[a]	25.57±0.34[b]	<.0001	29.54±0.60[a]	26.03±0.62[b]	29.41±0.70[a]	<.0001
Haugh unit	84.31±1.08	84.56±0.80	0.8511	83.05±1.14	84.68±1.03	85.58±1.28	0.3046
Yolk Ratio (%)	28.44±0.32[a]	30.95±0.36[b]	<.0001	29.81±0.42	29.55±0.55	29.72±0.43	0.8998
Albumin Ratio (%)	58.40±0.38[a]	55.07±0.38[b]	<.0001	56.32±0.43[b]	56.11±0.65[b]	57.78±0.48[a]	0.0206
Shell Ratio (%)	12.08±0.14[a]	12.50±0.12[b]	0.0260	12.21±0.16	12.18±0.17	12.50±0.16	0.2991

[*a,bc] means *within a row with different superscripts are significantly different (P<0.05), DZ-white= Debre Zeit white, IH= Improved Horro, L= location,* L_1 *=Debre Berhan,* L_2 *= Melka Werer,* L_3 *= Mekelle, SE = Standard error of the mean, P = Probability.*

Table 15.Least square means and standard error values of mortality for the main effect breed and location at 3 age periods of the trial under on station management.

Parameter	Age in weeks	Breed			Location			P- value
		DZ-white	IH	P value	L_1	L_2	L_3	
Mortality (%)	0-8	7.36±2.35	4.69±1.14	0.2301	5.02±0.76 [b]	10.78±2.83 [a]	2.28±1.15 [b]	0.0187
	8-16	5.42±2.47	9.52±4.17	0.2645	2.37±1.25 [b]	17.66±5.03 [a]	2.38±0.85 [b]	0.0051
	16-52	14.87±3.56	17.91±3.69	0.2933	3.65±1.77[b]	23.84±2.21[a]	21.68 ±2.71[a]	0.0001

Table 16. Least square means and standard error values for two-way interactions effect of breed and location at 3 age periods of the trial under On- Station management.

2-way interactions		Mortality (%)		
		0-8 Wk	8-16 Wk	16-52 Wk
DZ-white	L_1	6.34±0.04	2.27±1.31	3.01±3.1
	L_2	13.56±5.31	12.50±5.59	22.38±2.77
	L_3	2.17±2.17	1.48±1.48	19.22±5.23
IH	L_1	3.69±1.08	2.47±2.47	4.28±2.50
	L_2	8.00±2.00	22.82±8.29	25.31±3.84
	L_3	2.38±1.37	3.27±0.80	24.13±1.88
P-value		0.5528	0.4700	0.8664

4.1.11. Fertility and Hatchability

Comparisons of breeds revealed a significant differences (P≤0.05) on average eggs weight (g), fertility(%), hatchability from fertile eggs (%), hatchability from set of eggs (%), dead in shell (%) and average day old chick weight (g) .Nevertheless, there was no significant (p>0.05) difference between breeds on dead in germ (%), normal chicks (%) and abnormal chicks (%)(Table 17).Significantly (P≤0.05) higher fertility (%) were exhibited by DZ-white (87.73%) as compared to the Improved Horro (78.77%). Similarly, DZ-white revealed highest hatchability (%) from fertile eggs (85.65%) than Improved Horro (77.20). average day old chick weight (g) were highest in DZ-white with value of 32.33 gas compared to Improved Horro (28.33 g).

Table 17. Effects of breed in different hatchability traits (**N**=1325**)**.

Parameters	Breeds		
	DZ-white	IH	P-value
Average egg weight (g)	51.79 ± 0.50^{a}	48.65 ± 0.35^{b}	0.0021
Fertility (%)	87.73 ± 2.48^{a}	78.77 ± 2.26^{b}	0.0369
Hatchability from set egg (%)	75.12±1.95a	60.88±3.47b	0.0117
Hatchability from fertile egg (%)	85.65 ± 0.55^{a}	77.20 ± 3.14^{b}	0.0380
Dead in germ (%)	5.67±0.35	8.22±1.61	0.1720
Dead in shell (%)	6.94 ± 0.75^{b}	9.49 ± 0.69^{a}	0.0470
Normal chicks (%)	95.84±1.40	99.05±0.63	0.0817
Abnormal chicks (%)	2.73±1.11	0.95±0.63	0.2117
Average chick weight(g)	32.33 ± 0.72^{a}	28.38 ± 0.66^{b}	0.0067

4.2. Performance Evaluation Under on -Farm Management

4.2.1. Body weight

As shown in Table 18,the effects of breed on body weight of males and females during the production phase are significant($P \leq 0.05$).The highest body weight at 12, 16 and 20 weeks of age in both male and female were exhibited by DZ-white chicken. In the current study, male and female of DZ-white chickens exhibited an average body weight of 1313.87g, 964.87at 16 week of age and 1536.01 g and 1234.69 g at 20 weeks of age, respectively.From Location main effect, there was a significant ($P \leq 0.05$) effect of location on body weights of male chickens at 12, 16 and 20 weeks of age and body weights of female at 12 weeks of age. The highest body weights of male chickens at 12, 16 and 20 weeks of age were exhibited at L_3 and lower at L_1 and L_2.Similarly, female chickens at 12 weeks of age exhibited highest body weight at L_3 . However at 16 and 20 weeks of age body weight of females showed values with no significant differences ($P \geq 0.05$)among location.The present result also shows that, interaction between main effects (breed and location) were not significantly influenced body weights of males and females at 12, 16 and 20 weeks of age (Table 19).

4.2.2. Body weight gain

There was insignificant ($p > 0.05$) difference in body weight gain of both male and female during 12-16 and 16-20 weeks of age in all of the breed and location main effects and the two-way interaction effects of breed and location(Table 18 and 19).

4.2.3. Age at first lay

The present study revealed that, there were significant ($P \leq 0.05$) differences between breeds in mean age to the production of the first egg (Table 20). DZ-white started laying eggs earlier than the average of Improved Horro chickens.The main effect location revealed significantly ($P \leq 0.05$) earlier age at first egg at L_1 (155.00 days) as compared to L_2 (163.00 days) (Table 20).

Table 18. Least square means and standard error values for the main effects of breed and location on body weight and body weight gain on- farm management.

Parameter	Age in weeks	Breed			Location			P value
		DZ-white	IH	P value	L_1	L_2	L_3	
BW-M (g)	12	1001.27±10.96[a]	927.73±19.26[b]	0.0009	936.50±21.32[b]	946.60±21.30[b]	1010.40±17.61[a]	0.0096
	16	1313.87±28.01[a]	1131.07±34.37[b]	0.0002	1181.80±55.83[b]	1186.70±53.32[b]	1298.90±20.80[a]	0.0470
	20	1536.01±24.07[a]	1412.54±35.10[b]	0.0023	1478.00±40.12[ab]	1409.02±42.28[b]	1535.80±30.73[a]	0.0297
BW-F (g)	12	765.53±27.04a	660.60±20.95[b]	0.0026	694.20±25.70[b]	670.30±23.66[b]	774.70±41.99[a]	0.0293
	16	964.87±13.74[a]	835.20±33.12[b]	0.0016	895.70±39.30	865.00±34.51	939.40±36.82	0.2662
	20	1234.69±16.63[a]	1059.73±21.61[b]	<.0001	1154.80±34.53	1120.93±42.63	1165.90±33.58	0.3590
BWG-M (g)	12-16	312.60±28.38	203.33±23.94	0.0789	245.30±46.83	240.10±38.44	288.50±19.59	0.5367
	16-20	222.15±30.56	281.47±26.71	0.1531	296.20±41.80	222.32±33.67	236.90±30.61	0.3010
BWG-F (g)	12-16	199.33±17.73	174.60±19.24	0.3394	201.50±27.36	194.70±21.83	164.70±18.39	0.4635
	16-20	269.82±17.50	224.53±24.48	0.1573	259.10±26.25	255.93±27.52	226.50±27.67	0.6444

[*a, b,c] means *within a row with different superscripts are significantly different (P<0.05), DZ-white= Debre Zeit white, IH= Improved Horro, L= location,* L_1 *=Debre Berhan,* L_2 *= Melka Werer,* L_3 *= Mekelle, SE = Standard error of the mean,* BW=body weight,*P = Probability.*

Table 19.Least square means and standard error values for the interaction effects of breed and location on body weight and body weight gain under on farm management.

Parameter	Age in weeks	DZ-white			IH			p-value
		L_1	L_2	L_3	L_1	L_2	L_3	
BW-M (g)	12	978.00±13.71	992.80±22.77	1033.00±12.25	895.00±31.17	900.40±23.52	987.80±31.46	0.5834
	16	1298.00±69.98	1291.80±48.99	1351.80±19.99	1065.60±48.78	1081.60±69.81	1246.00±12.89	04171
	20	1543.80±44.76	1524.84±35.79	1539.40±52.46	1412.20±55.46	1293.21±35.20	1532.20±38.52	0.0584
BW-F (g)	12	743.00±39.14	702.60±28.6	851.00±48.82	645.40±15.84	638.00±34.33	698.40±51.37	0.5194
	16	954.60±24.02	942.60±21.03	997.40±23.45	836.80±68.10	787.40±43.69	881.40±62.21	0.8852
	20	1215.20±39.66	1245.47±17.25	1243.40±29.80	1094.40±44.36	996.40±15.23	1088.40±34.42	0.1384
BWG-M (g)	12-16	320.00±76.24	299.00±46.50	318.80±20.33	170.60±35.66	181.20±52.46	258.20±29.24	0.6378
	16-20	245.80±75.71	233.04±45.20	187.60±39.54	346.60±29.35	211.61±53.94	286.20±37.95	0.3796
BWG-F (g)	12-16	211.60±21.50	240.00±29.11	146.40±28.79	191.40±53.32	149.40±16.51	183.00±22.93	0.1444
	16-20	260.60±38.58	302.87±20.30	246.00±29.67	257.60±40.16	209.00±43.53	207.00±48.73	0.4946

*DZ-white= Debre Zeit white, IH= Improved Horro, L= location, L_1 =Debre Berhan, L_2 = Melka Werer, L_3 = Mekelle, SE = Standard error of the mean, BW=bodyweight, P = Probability.

Among the two-way interaction effects of breed and location, age at first lay did not show significantly ($P \geq 0.05$) differences (Table 21).

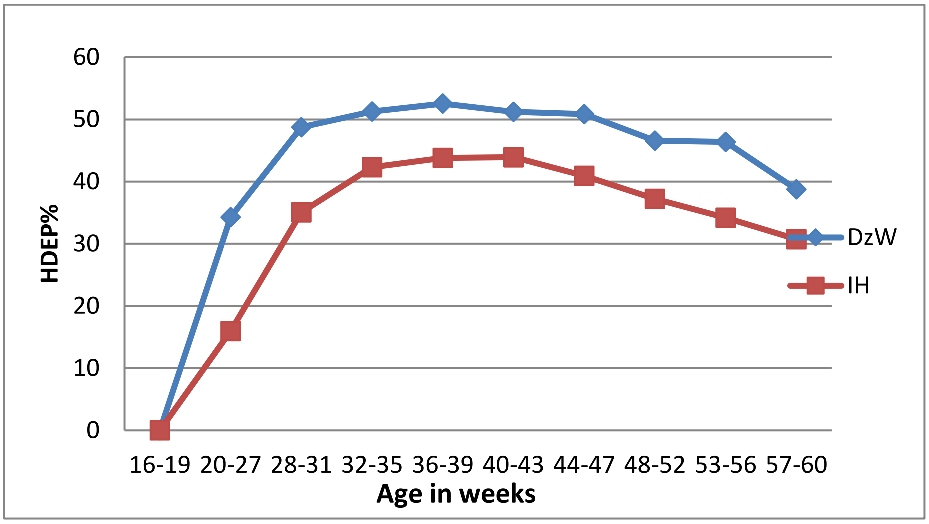

Figure 4. Least square means of HDEP% for DZ-white and Improved Horro chickens at 8 age periods of the trial under on farm management

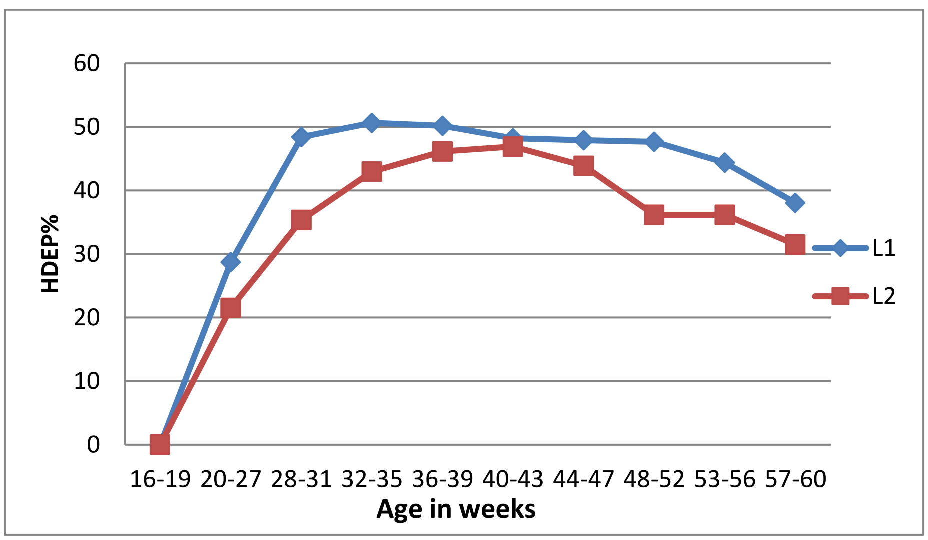

Figure 5.Least square means of HDEP% at L_1 and L_2 during 8 age periods of the trial under on-farm management.

4.2.4. Egg production

Table 20 shows that, total number of eggs/hen differed significantly ($P \leq 0.05$) between breeds. The highest total number of eggs/hen was obtained by DZ-white (130.84egg) as compare to Improved Horro (100.85egg). The main effect location revealed significantly ($P<0.05$) higher number of eggs for birds kept at L_1 (125.74 egg) and lower at L_2 (105.95 eggs)(Table 20). On the other hand, there was insignificant ($P \geq 0.05$) difference between the interaction of breed and location on total number of eggs/hen (Table 21).

Average means of HDEP %of for the main effect breed and locations are presented in figure 3 and 4. The result shows high significant difference ($P \leq 0.05$) between breeds on hen-day egg production in all age groups except during 36-39 and 40-44 weeks. The highest hen-day egg production was obtained by DZ-white chicken than Improved Horro chickens (figure 3).Among the locations, significant differences ($P \leq 0.05$) were obtained in all age groups except 36-39, 40-43 and 44-47 weeks. Significantly ($P \leq 0.05$) higher hen-day egg productions were recorded for chickens kept at L_1 and lower at L_2(figure 3).On the other hand, the interaction between breed and locationdid not show significant differences ($P \geq 0.05$) inhen-day egg productions in all age groups except during 57-60 weeks of age (Table 22).

Table 20. Least square means and standard error values for the main effects of breed and location on age at first egg (AFL in days) and egg number under on-farm management.

Parameter	Breed			Location		P- value
	DZ-white	IH	P value	L_1	L_2	
AFL(days)	155.00±2.43[b]	162.60±3.29[a]	0.0529	154.60±3.02[b]	163.00±2.63[a]	0.0421
Egg number / hen up to 60 weeks of age	130.84±6.03[a]	100.85±5.80[b]	0.0007	125.74±9.13[a]	105.95±5.02[b]	0.0124

Table 21.Least square means and standard error values for the interaction effects of breed and location on age at first egg (AFL) and egg number under on farm management.

2-way interactions		AFL(days)	Egg number / hen up to 60weeks of age
	L_1	150.40±3.43	144.48±7.65
DZ-white	L_2	159.60±2.08	117.19±3.60
	L_1	158.80±4.54	106.99±9.79
IH	L_2	166.40±4.59	94.71±6.00
P value		0.8360	0.2913

Table 22. Least square means and standard error values for the interaction effect of breed and location on HDEP (%) during 20-60 weeks of egg production under on-farm management.

Age in weeks	DZ-white		IH		P value
	L_1	L_2	L_1	L_2	
20-27 wks	40.40±4.42	28.13±3.16	17.08±3.78	14.87±1.40	0.1625
28-31 wks	56.53±7.32	40.93±4.05	40.29±7.18	29.82±4.32	0.6631
32-35 wks	55.71±3.64	46.82±2.26	45.58±4.73	39.09±5.10	0.7642
36-39 wks	56.93±7.31	48.13±1.89	43.39±5.09	44.19±4.83	0.3437
40-43 wks	51.17±5.95	51.26±2.04	45.30±2.70	42.56±4.57	0.7252
44-47 wks	53.26±5.66	48.41±2.05	42.54±2.84	39.32±3.18	0.8222
48-52 wks	53.81±3.82	39.35±1.77	41.49±2.91	32.94±2.16	0.2923
53-56 wks	51.66±3.03	41.06±1.39	37.05±4.19	31.30±2.65	0.4109
57-60 wks	44.93±1.95^{a}	32.60±1.62^{b}	31.16±1.73^{b}	30.32±1.66^{b}	0.0060

4.2.5. Mortality

In the current study; there was no significant ($P \geq 0.05$) difference on breed main effect for mortality during the production period However, there was significant ($P \leq 0.05$) difference among location. Higher mortality was observed in birds kept at L_2followed by L_3 and the least was observed at L_1 (Table 23). On the other hand, the interaction of main effects (breed and location) showed no significant ($p>0.05$) difference on mortality (Table 24).

Table 23.Least square means and standard error values for the main effect breed and location on mortality under on-farm management.

Parameter	Breed			Location			
	DZ-white	IH	P value	L_1	L_2	L_3	P value
Mortality (%)	29.83±2.27	25.54±2.49	0.1517	21.3±2.74^{b}	34.1±1.4^{a}	27.7±3.10^{ab}	0.0057

Table 24. Least square means and standard error values for two-way interactions effect of breed and location on mortality during the entire trial under on- farm management.

2-way interactions		Mortality (%)
	L_1	25.62±3.92
	L_2	34.52±1.70
DZ-white	L_3	29.33±5.09
	L_1	17.04±3.03
IH	L_2	33.58±2.40
	L_3	26.00±4.00
P- value		0.5528

5. DISCUSSION

5.1. Performance Evaluation Under On -Station Management

5.1.1. Feed intake

In the current study, breed significantly ($P<0.05$) influenced feed intake. This result was in agreement with the findings of Abiola *et al.* (2008), who observed increased daily feed intake in different breeds of chicken. The effect of breed on feed intake among chickens was also reported by several authors (Tadelle *et al*., 2003; Reta *et al*., 2012; Wondmeneh *et al.*, 2016). In the current study, Improved Horro chickens had the lowest TFI and ADFI in all age groups than DZ-white chickens which was in line with the report of Tadelle *et al*. (2003) who reported higher feed consumption of the exotic chicken (Fayoumi) than indigenous (Chefe and Jarso) chicken. The average daily feed intake (ADFI) of Improved Horro chickens, from 0 - 8, 9 - 16 and 17-52 weeks of age and the TFI during the experiment was greater than the reports of Wondmeneh *et al.* (2016) for the same breed but lower than un improved Horro chickens from the same study. Similarly, DZ-white chickens have got higher TFI than the one reported by Wondmeneh *et al.* (2016) for cross breed chicken at the same age. Feed intake was significantly related to bird initial weight (Mendes, 2011). The difference in feed intake between chicken breeds in the current study could be due to the variation in body size among the chicken breeds at the start of the experiment.

The mean feed consumption of DZ-White chicken breed at the starter, grower and layer phase 30.94, 70.41, 119.19 g/day respectively, was lower than the report of Tesfa and Usman (2018) who reported 56.4, 84.3 and 124g/day for Koekoek chickens at Adami Tulu Research Center for the same growth phase. Similarly the mean feed consumption of Improved Horro 29.24, 66.89 and 112.95 g/day in the current study for the three phases (starter, grower and layer) was less than the one reported by Halima (2007) for seven indigenous breeds and RIR breed.

In the current study, ADFI and TFI variation was observed in different chicken breeds when measurements of same trait was taken at different location .This finding was in line with the report of Osti (2017), who reported significant difference in feed intake among different climatic zones. Similarly, Kayitesi (2015) reported that chickens raised in different districts of Ruwanda (Gulu district) had a higher feed intake than those in Kiryandongo). In this study, Chickens reared at L1 (highland) had a higher TFI and ADFI in all age group than those reared at L_2 and L_3 (lowland and mid land). This finding is in line with the report Nardone *et al.* (2006) who found an increase in ambient temperature promote a reduction in feed intake. The higher TFI and ADFI at L_1could be due to the coldest environment at L_1. Feed intake can be affected by many factors, but the main one is the environmental conditions such as the weather including the temperature of the region (Ferket and Gernat, 2006). Environmental factor like temperature was found to contribute about 97.2% showing that it has the greatest effect on feed intake. This explains why the feed intake was different among location during the study period

5.1.2. Feed conversion ratio (FCR)

Results on FCR in the present study were significantly (P≤0.05) different in the two breeds at all age groups. DZ-white was significantly better in FCR than Improved Horro. The observed breed effects in FCR were in agreement with the reports of several authors (Taha *et al.*, 2011; Anita *et al.,* 2012 and Udeh *et al.,* 2015). FCR was better at early age of rearing period (0 to 8 weeks) than later age of growing and laying period which is in line with the findings of Wondmeneh, (2015) and Maliwan *et al.(*2017), who reported higher feed conversion ratio at early age than in advanced age. Wondmeneh (2015) found that feed conversion ratio of 3.0 for Improved Horro at age of 8 weeks and it was almost similar with the present study.

This study further showed significant difference in FCR among location. Except FCR at the age of 9-16 weeks, the results of the current study disagree with the report of Kayitesi, (2012) who reported insignificant difference in FCR between Gulu and Kiryandongo chickens from 1-20 weeks of age. Chickens reared at L_3(mid land) had a better FCR (2.72 during 0-8 weeks and 4.95 during 16-52 weeks) than those at L_1 and L_2(highland and low land) which has 4.09, 3.92, 5.52 and 5.74 respectively. This result agreed with (Sahil, 2017) who indicated poor FCR at high altitude. These differences in FCR could also be attributed to the environmental condition.

5.1.3. Body weight

Body weight is the direct reflection of growth and it influences the production and reproduction traits of birds. In the present study significant ($P \leq 0.05$) differences in body weight were observed between DZ-white and Improved Horro chicken at eight weeks of age. The significant genotype differences in body weight between the two chicken breed showed that, body weight trait is highly influenced by genetic factors and this agrees with reports of several authors (Devi and Reddy, 2005; Adedeji, *et al*., 2006; Chatterjee *et al*., 2007). Wondmeneh (2015) also reported differences in body weights among different chicken breeds from 8 to 20 weeks of age. DZ-white chicken in the current study recorded higher average body weight than the Improved Horro chickens counterparts. The mean average weight recorded for the unsexed DZ-white chicken at 8 weeks of age was 540.78g.This was significantly higher ($P \leq 0.05$) than unsexed Improved Horro chicken. The higher body weights in DZ-white chickens could be due to the exotic inheritance prevailing in the birds. This result agrees with the report of Munisi *et al.* (2015) which indicates exotic chicken hashigher body weight than indigenous chickens and their crossbreds. The body weight of Improved Horro chicken (469.55g) at the age of 8 weeks in this study was higher than 428.9g, 341.42g and 281.87g reported by Wondmeneh (2015), Kedija *et al.* (2018) and Demissu (2020),respectively for the same breed under on station management. Similarly, at the age of 8 weeks DZ-white chickens have higher BW (540.78g) than (320.85g) reported by Demissu (2020) under on station management.

Average body weight of male and female chicken at 16 weeks and that of female at 52 weeks of age in the present study was significantly ($P \leq 0.05$) different in the two breeds. The body weights of DZ-white chickens at 16 weeks of age in this study, was comparable with the weight of Potchefstroom Koekoek at 20 weeks of age (1399-1700.71g), which was reported by Wondmeneh *et al*., (2012). On another hand, the observed body weight of DZ-white chickens (902g) and (1230.1g) at 12 and 16 weeks respectively was higher than the one reported by Wondmeneh (2015) for Bovans brown commercial egg layers in DZARC.

In this study chickens kept at L_1 and L_3(highland and mid land) had higher body weight than chickens kept at L_2(lowland) in all phases. The variation on average body weight among the three agro ecologies was in agreement with the report of Kayitesi (2015) who reported Kuroiler chickens reared in Gulu district were significantly heavier ($P<0.05$) than those Kuroiler chickens reared in Kiryandongo district. The lower average body weight in all phase at L_2(lowland) could be due to the hottest environment of L_2 (lowland)which may interfere with feed intake of birds. This is in agreement with the findings of Nardone *et al.* (2006) who reported that an increase in ambient temperature promote a reduction in body weight.

5.1.4. Body weight gain

In this study breeds of chickens have different genetic potential for growth. This explains why DZ-white chicken had faster rate of growth as compared to Improved Horro chickens at all age. The lower chick weight and weight gain of Improved Horro chickens in this study might be attributable to breed difference. Correspondingly, this has also been shown by Nigussie *et al.* (2011) who reported that the growth of chickens is moderately dependent on genetics of the chickens. Reta *et al.* (2012) also got different performance between two breeds of chicken in Ethiopia. Moreover, differences in weight gain among different breeds and strains has been reported by (Bekele *et al*., 2010; Enaiat *et al*., 2010; Ewonetu, 2017). In the current study body weight gain of the Improved Horro chickens at the age of 8 weeks (440.28 g) was higher than the report of Wondmeneh (2015) and Kedija *et al.* (2018), who reported 428.9g and 312.72g respectively. Similarly, in the consecutive age of 8- 16 weeks the study showed higher performance. The average body weight gain of DZ-white in the present study was higher than the report of Wondmeneh (2015) for Bovan brown and crossed breed chicken (RIR with Horro).

The growth performance of chicken at L_1 and L_3 (highland and mid land) were better than those at L_2(lowland) during 0-8 weeks of age. This result is in agreement with those of Mutayoba *et al.* (2012) who reported significantly ($P< 0.05$) different growth rate of local chickens in Tanzania between locations. Lower BW gain in a chicken reared at L_2(lowland) could be due to the hot environment at L_2. This is in line with the report of Doni *et al.* (2015) who reported temperature more than 28°C reduce body weight gains. However, there was no variation in BW gain among location during 8-16 weeks in both sex and during 16-52 weeks in females; this is in line with Lu *et al*., (2007) who reported similar BW gain of chickens exposed to different levels of temperatures.

5.1.5. Carcass analysis

The result of this study shows that slaughter weight (g), dressing % , carcass weight (g), breast weight (g), breast %, drumstick weight (g), thigh weight (g), wing weight (g), wing %, back weight (g), neck weight, giblet weight (g) and GIT weight (g) were statistically significant between breeds. The slaughter (1699.89 g) and carcass weight (1112.52g)of DZ White was significantly higher as compared to the slaughter (1389.81g) and carcass weight (942.96) of Improved Horro breed. Similarly, Karima and Fathy (2005) reported significant differences in live body weight between breeds. The slaughter weight for Improved Horro in the current study was in consistece with the one reported by Halima (2007) for different indigenous male chicken ecotypes in northwest Amhara of Ethiopia (1045-1292g). The existence of difference slaughter weight of the two chicken breeds might be attributed to their variation in the genetic makeup. The dressing percentage of Improved Horro (67.8%), was significantly higher than DZ-White (65%) regardless of the lesser initial slaughter weight. This could be due to the higher feather weight of DZ White chicken. This result was in agreement with Halima (2007) which indicated local chickens had a higher dressing than the RIR chickens. However, the dressing percentage of both Improved Horro (67.8%) and DZ-White (65%) was lesser as compared to the one reported by Dawud (2019) for Koekoek (68.1%) and Novogen Color (70.2%). Similarly Kefyalew *et al*., 2015 reported 71% dressing percentage for commercial broilers which was higher than the present finding.

The proportion of breast, thigh and drumstick are the most valuable meat part that determines the chicken meat quality (Holvman *et al*., 2003). In the current study proportion of breast of the two breeds differed significantly ($P \leq 0.05$). The observed breed effect in proportion of breast was in agreement with the reports of Dawud *et al.* (2018) who reported significant difference in the weight of breast % among seven breeds. Drumstick (%), thigh (%), back %, neck (%), giblet %, GIT %, and abdominal fat % were not significantly different between breed. In line with the present study Stringing *et al*. (2003) reported non-significant differences on carcass yield or cuts between breeds. Likewise, Moreira *et al*. (2003) find no significant difference on the carcass yield when breeds selected for conformation were slaughtered.

5.1.6. Age at first lay

Age at first egg lay or age at sexual maturity is an important trait in egg-producing strains from the economic standpoint. In the current study, non-significant (p>0.05) difference between breeds was observed for age at first lay under on station management. This finding disagrees with the finding of Dawud (2019) and Wondmeneh (2015) who found significant breed differences on age at first lay under on station management. The age at sexual maturity for DZ-white chickens were 145.56 days while Improved Horro chickens mature at 148.56days. The age at first lay of DZ-white breed in the current study was lower than the report of Dawud (2019) who reported 147.0, 161.0, 150.5 days of age at 5% lay for Dominant Red Barred, Dominant Sussex and Koekoek respectively, under on station management. Wondmeneh *et al*. (2016) reported higher average age at first egg lay (153 days) than the present study forImproved Horro chicken breed under on station management.

In the current study, significantly (P≤0.05) earlier age at first egg was noted in both chicken breeds at L_3(mid land)(139.83 days) compared to birds kept at L_1 and L_2(highland and low land) (150.33 and 151.00 days). This result was in agreement with Negussie (1999) and Zaman *et al*. (2004) who stated the affection of sexual maturity by several factors like temperature.

5.1.7. Egg production

Economic success for a production flock is measured with total number of produced eggs (Monira *et al.,* 2003). In the present study the total number of eggs/hen of the two breeds differed significantly (P≤0.05). The highest total number of eggs/hen was obtained by DZ-white with 124.57 egg followed by improved Horro 104.58. The number of egg produced by both breeds was much higher than the average number of eggs produced per year by local chicken (30-60) and less than the one produced by exotic breeds (250) as reported by (Alganesh *et al*., 2003).Egg production of DZ-white chickens in the present study was (124.57), which is much lower than the 187.04eggs per year reported by Dessalew *et al*. (2013) and 195.9 eggs per year reported by Grobbelaar *et al*. (2010).The variation in performance of the breeds may arise from the difference in the number of days.

Hen-day egg production was significantly higher for DZ-white chickens than that of improved Horro. This could be attributed to difference in genetic potential of this breed. This is in agreement with Grobas *et al.* (2001) and Yakubu *et al*. (2007) who also found **s**ignificant hen-day egg production between breeds.

5.1.8 Average egg weight and egg mass

Egg weight is among the most important parameters not only for consumers, but also for egg producers as well (Genchev, 2012) and genetically linked to all three of the major components: shell, albumen, and yolk (Washburn, 1990). In the current study DZ-white yielded significantly higher AEW (52.47g) as compared to the Improved Horro chicken (44.93g). The average egg weight of both breeds in this study was higher than the average weight reported for local chicken (38g) and less than the one reported for exotic breed (60g) by Alganesh *et al. (*2003). The result obtained in this study for Improved Horro (44.93g) is comparable with the one reported by Geleta *et al*., (2013), for Fayoumi chicken under Adami Tulu Research center (44.3 g) and to Fayoumi (43 g), whereas the egg weight obtained from DZ-white (52.47g) was comparable with the one reported by Yayneshet and Abraham (2010) for Rhode Island Red (52.5 g) and White Leghorn (52.1 g) in Northen Ethiopia. The significant differences in egg weight between experimental breeds in this study could be influenced by hen’s breed and genetic factors.

The current finding revealed that egg weights have a significant difference across the agro ecology which is in line with Gezahegn (2016) who reported egg size is a moderately heritable trait influenced by genotype and environment.

The significant difference of egg mass between breeds found in this study was supported by many research workers such as Grobas *et al.*(2001) and Solomon (2004). In the current study DZ-white yielded significantly higher egg mass than Improved Horro. Lower egg mass obtained by Improved Horro could be due to the fact that the lower total number of egg (104.58) and lower average egg weight (44.93).

5.1.9. Egg quality

The results of the present study showed that difference in breed of chicken had significant effect on the different egg quality parameters. In this study, the egg weight of DZ-white was heavier than Improved Horro breeds.

The egg length and width varied between the genotypes with higher ($P<0.05$) values recorded for DZ-white. Egg shell index between DZ-white and Improved Horro was not significant. The values obtained in the study for egg shell index was comparable with the standards reported by Altuntas and Sekeroglu (2007) which was 72-76. However, from location main effects, significant differences were observed on egg shell index among locations.

Eggs with thick and strong shells are usually the most in demand and very important economical trait in commercial egg production. The result of the study showed that, shell thickness were not significantly ($P \geq 0.05$) affected by genotype, rather it's highly influenced by different in location. This is in line with the work done by Garba *et al.* (2016) who reported no significant differences ($P> 0.05$) among breeds. On the other hand, results of the current study revealed that birds kept at L_1 and L_3 were better in eggshell quality traits than those birds kept at L_2. This finding is supported by Pereira *et al.* (2008) and Aberra *et al.* (2010) who reported shell thickness is highly affected by environmental temperatures. Similarly, Franco-Jimenez *et al.* (2007) reported lower egg shell thickness and strength at high temperatures.

Among the internal egg quality parameters, Albumen heights indicate no significant differences between breeds. Similar to the present study Garba *et al.* (2016) indicated lack of significant differences among three species of laying hens. The height of albumen in fresh egg should not be less than 0.5cm (Maria and Dmowski, 2005). The values reported in this study for both breeds (6.89–6.53 mm) were higher than the recommended value of 0.5cm in fresh egg and it indicates a freshness of an egg.

Albumen weight and yolk weight recorded in this study showed significant differences between breeds. DZ-white recorded the highest albumen weight and yolk weight compared to the Improved Horro. According to Pandey *et al.* (1986), the weight of an egg is a direct proportion of albumen, yolk and shell that it contains and this varies significantly between strains of hen. On the other hand, results of the current study revealed that L_1 and L_3 showed significantly higher ($p<0.05$) albumen weight and yolk weight than that of L_2. This is In line with Pereira *et al.* (2008) who reported effect of air temperature and relative humidity on egg quality.

There were no significant differences in Haugh unit and yolk colour for the main effect breed and location. In the present study the color of the yolk scores indicated very light (pale) color. This could be attributed to the type of diets and absence of scavenging (its intensive management). This is supported by Garba *et al.* (2016) who reported type of diets and nature of managements as important factors in determining the yolk colour. Brandt *et al* (1991) reported that eggs of inferior quality have Haugh Unit less than 40% and a Haugh Unit 79% and above is an indication of good quality. The higher the value of the Haugh unit, the better the quality of eggs will be; the values reported in this study (84.31-84.56) were higher than the recommended value of 79%.

5.1.10. Mortality

The results of the current study were in-line with the reports of Olawumi and Dudusola (2010), Del Castilho *et al.* (2013) and Benyi *et al.* (2015) who found that mortality rate was not affected by breed. On the other hand the study disagreed with a report of (Tabbaa *et al.*, 2007;

Wondmeneh, 2015; Ewonetu, 2017) who found significant differences in mortality for different breed. In this study, the rate of mortality for both breed was much higher in the layer phase than the starter and growth period. This is in disagreement with Halima (2007), who stated much higher mortality of indigenous and RIR chickens in the grower phase than layer periodunder intensive management system. Wondmeneh (2015) reported the mortality percentage of Improved Horro to be 1.2% during the 20 weeks of age and 12.4 during the layer phase under on station management conditions, which were lower than the present finding. Demissu (2020) reported mortality percentage of 11.6% during 10-20 weeks of age for DZ-white chicken under on station management, which was higher than the present finding. In Ethiopia, the mortality of different exotic breeds (Lohmann Brown, RIR and Fayoumi) under semi-scavenging conditions was 27.6, 32.6 and 25.2%, respectively (FAO 2005). Similarly Geleta *et al.* (2013) reported mortality rate of 7.1% for Fayoumi chicken under Adami Tulu Research center.

Geographic location can influence the survival rate of chickens. This explains why location had effect on mortality in present studies. This is in-line with Makarechian *et al.* (1983) who stated that environmental factors contribute to the rate of mortality. These findings are different from the results of Kayitesi, (2012) who reported no significant difference on mortality between Gulu and Kiryandongo chickens. In the current study, variation in the mortality % of the breeds was observed when measurements on the same trait were taken in different locations. The high mortality rate of chickens kept at L_2 is in agreement with the findings of Yunis and Cahaner (1999) and Azoulay *et al*. (2011) who found high mortality rate under hot environmental conditions. In-line with Ajakaiye *et al*. (2011) and Tao and Xin (2003), high mortality is influenced by heat stress, also depends on the physiological state and adaptability of the breed to its prevailing environmental conditions.

5.1.11. Fertility and hatchability

As shown in the present study, difference in breeds had significant effect on the different hatchability parameters. Fertility was one of the hatchability traits significantly affected by genotypes. Similar observations were made by Durmus *et al*. (2010), Wondmeneh *et al.* (2011)

and Dawud (2019). The result for DZ-white chicken (87.73%) was comparable with the fertility result reported by Wondmeneh *et al.* (2011) for Horro, 77.00%, Fayoumi, 91.35%, Lohmann silver 85.56 and 77.0% for Potchefstroom koekoek. According to the results obtained, the current study showed significant difference between breeds with respect to hatchability on fertile egg and hatchability on total egg set, this is in line with Heier and Jerp (2001) who stated that hatchability is influenced significantly by genetic factors. The current finding on hatchability of fertile eggs and total egg set is in agreement with Wondmeneh *et al. (*2011) and Dawud *et al*. (2018). Similarly breed had significant effect on the day old chick weight. Average day-old weight was higher for DZ-white chicken than Improved Horro. Similar to this finding Wondmeneh *et al.* (2011) reported significantly higher day-old weights for exotic chickens (Koekoek, 40.04g) than Ethiopian indigenous (Horro30.15g). The day-old weight for Improved Horro chickens (28.38g) in the current study was similar with the report of Kedija (2018) which was 28.70g. The day-old weight for DZ-white chickens in the current study (32.33g) was higher than the report of Demissu (2020) which was 28.74g. The probable reason for heavier hatching weight of DZ-white chickens could be due to larger egg size of DZ-white chicken than Improved Horro.This is in agreement with Raju *et al*., (1997) who reported day old chick's weight increased significantly with increase in egg weight.

According to the results obtained, there appears no effect of genetic factors on dead in germ (%) between breeds, These results are in line with the findings of Islam *et al*., (2002) who reported no significant difference in dead in germs (%) among breeds, however the present findings differ with Durmus *et al*. (2010) and Wondmenh *et al.* (2011) who reported genetic constitution had some effect on early embryonic mortality (dead in germ (%)).

Furthermore, the results showed non-significant deviation in abnormal chicks and normal chicks (%) between breeds, This is in line with Islam *et al*., (2002) who state chick abnormality may be due to management and environmental factors than genetic difference. on the other hand it contradicts with Wondmeneh *et al.* (2011) who found significant difference in abnormal chicks and normal chicks among breeds. Normal chicks (%) obtained in the present study were higher than the one reported by Wondmeneh *et al.* (2011). The authors obtained slightly lower percentage of healthy normal chicks and higher percentage of abnormal chicks (%) as compared to the present study.

5.2. Performance Evaluation Under on -Farm Management

5.2.1. Body weight

The effects of breed on BW of males and females at three ages (12, 16 and 20 weeks) were significant ($P \leq 0.05$). Significantly higher average body weight in both sexes was recorded in DZ white than Improved Horro breed. At the age of 20 weeks, male and female DZ-white breed exhibited an average body weight of 1536g and 1234.69g. The result obtained from the present study for DZ- White (1.53 kg and 1.23 kg for male and females) was less than the one reported by Hassen, (2019) for Potchefstroom Koekoek at 20 weeks age (2.23kg for male and 1.91kg for females) under agro pastoral management condition. Similarly the mean body weight of DZ-White is less than that of RIR which weighed on average 1.7 (males) and 1.3 kg (females) at 22 weeks of age under farmers management regime (Nigussie *et al*., 2009). However the result of this study was better than the one reported by Aman *et al.,* 2016, for male (1.5kg) and for female (1.1kg) chickens of the same breed at 20 weeks in Araka area.

Improved Horro breed in the current study exhibited average body weight of 1412.54g and 1059.73g for male and female respectively. This result is higher than the mean body weights of Horro chicken 701.1g and 572.7g for male and female chickens respectively reported by Dana *et al.,* 2011. Similarly, the current result is superior as compared to the mean body weights of indigenous chicken breeds 701 (528) grams in males (females) reported by Wendimeneh (2015) and average weight of local birds to an age of 22 weeks from 1.0 to 1.5 kg in males and from 0.6 to 0.9 kg in females reported by Halima *et al*., 2007.

The main effect location revealed that the body weight of male chicken at three ages and female chicken at 12 weeks of age were significantly differ among locations. Body weight of male chicken at 12 and 16 weeks and body weight of female chicken at 12 weeks of age were higher for the birds kept at L_3 (Midland) as compared to those birds kept at L_1 (Highland) and L_2 (lowland). The higher bodyweight recorded in the midland in the current study was in agreement with the report of Alem, 2014, who reported higher average weight of chickens at midland agro-ecological zones of central Tigray.

5.2.2. Age at first lay

The mean age at first lay recorded in this study under farmer's management has significant difference between DZ-White (155 days) and Improved Horro (162 day).This is in agreement with the reports of Halima. (2007), Fasill *et al.* (2010) and Lemlem and Tesfaye (2010) who reported significant difference of age at first lay among breeds. The result for Improved Horro (162 day) was comparable with the result reported by Nebiyu *et al.* (2013) for local chicken (159.9) and less than the one reported by Mekonnen (2007), for the local chickens (212) and cross between Fayoumi and Necked neck (196 days),Rhode Island Red and any local (198.3 days) reported by (Addis and Malede 2014). In comparison Wondmeneh, (2015) reported (156.6 days) of age at first egg laying for the same breed under on farm management condition. However the mean age at first lay recorded for DZ-White (155 days) is consistent with the report of Desalew (2012) who reported 153 days of age at first egg lying of Koekoek chicken and less than the one reported by Mekonnen (2007) and Nebiyu *et al.,* 2013 for local chickens and for cross breeds reported by (Addis and Malede 2014).

5.2.3. Egg production

In this study the average egg production of DZ-White (130.84) and improved Horro (100.85) under on- farm management system has significant difference. This result was lower than the one reported by Lemlem and Tesfaye (2010) for White leghorn (173eggs /year/ hen), Red Island Red (185 eggs/year/ hen) and Fayoumi (144 eggs/year/ hen) under village household condition. The variation in performance of the two breeds may arise from the difference in the number of days. However, the number of eggs produced by DZ-white in the current study (130.84) was higher than the one reported by Alem (2014) for average egg production per year per hen of exotic chicken (RIR) (118.6) in the lowland agro ecological zone of central Tigray and comparable with the one reported for highland agro ecology (148.2). Moreover, the result of this study disagree with the high number of eggs reported for Rhode Island Red (185) and White Leghorn (176) reported by Yayneshet and Abraham (2010). The average number of eggs per hen per 40 weeks (100.85) of improved Horro chicken in the current study is higher than the one reported by Tadelle *et al.* (2000) in Ethiopia, according to his report, a local scavenging hen lays about 36–40 eggs/year on average and Halima (2007) reported an average total egg production ranging from 18–57 eggs/year per hen for local hens in North-West Ethiopia.

5.2.4. Mortality

The current study revealed that, there was no significant ($P \geq 0.05$) difference on breed main effect for mortality. The mortality % of DZ-white and Improved Horro chickens were 29.83% and 25.54%. These results were higher than the one reported by Demsu (2010) for Koekoek (16.67%), DZ White-feathered chicken (15.33%).However, the mortality % of Improved Horro in the current study was lower than than the mortality %of Improved Horro chicken (28%) reported by Demsu (2010) under On-farm management condition.

Similarly, the mortality rate recorded on the current study was higher than the mortality rate recorded for Fayoumi-crosses (15.8%) and RIR-crosses (25.9%) in south western Ethiopia by Alewi and Melesse (2013). However, the death rate (28%) recorded at the same study area for Improved Horro chicken during their 10-20 weeks age by Alewi and Melesse (2013) is higher than the mortality rate of improved Horro in the current study and the one documented for local chickens (17.8%) in south western Ethiopia.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

The overall results of the present study revealed that the effect of breed on feed in take was significant and DZ-white chicken had higher feed intake. It also has improved feed conversion ratio (FCR) than Improved Horro during all the production phase. DZ-white chicken had superior growth performance than Improved Horro chickens from day old up to the end of the study. It exhibited superior body weight in both sex under on-station and on-farm management at all age periods. DZ-white chicken has also higher BW gain in both sex during the three phases of chicken development. Additionally, DZ-white has a higher carcass weight than Improved Horro whereas Improve Horro has higher dressing %. Under on station management, there was no difference between breeds in mean age of first egg production. However, under the on farm management condition, there were effects of breed for age at first lay where DZ-white started laying eggs earlier than the average of Improved Horro. In both management systems, breeds had effect on egg production. The highest total number of eggs/hen was obtained by DZ-white. Regarding egg parameters, DZ-white yielded significantly higher average egg weight (53.11g) than Improved Horro eggs (46.40g). Similarly, DZ-white exhibited higher value for all egg-size-related measurements and yolk height as compared to the improved Horro eggs. Mortality was not affected by breed difference both under on-station and on-farm management. Fertility and hatchability percentage was affected by chicken breed. DZ-white has higher fertility and hatchability percentage than Improved Horro breed.

Location has effect on feed intake and breeds kept at L_1 (highland) have significantly higher feed intake. Similarly, the feed conversion was influenced by location and better FCR was registered for chickens kept at L_3 (midland) as compared to birds kept at L_1 and L_2 (highland and lowland) both in the starter and layer phase. However, FCR has no effect in the grower stages.location affected the body weight of male and female chickens at different age, higher BW was registered at L_1 and L_3 (highlandand midland) under on-station and on-farm management. Location influenced the body weight gain of chickens and higher body weight gain was recorded at L_1 and L_3 (highland and midland) under on-station management. In contrary, body weight gain of male and female chickens under on-farm management and female chickens at grower and layer phases under on-station management were not affected by location.The slaughter weight, dressing% and carcass weight of chickens varies among locations. Higher value of slaughter weight was obtained at L_3 (midland). Location also affected age at first egg and significantly earlier age at first egg was prominent at L_3(midland).Under on- farm management condition birds kept at L_1(highland) has earlier AFE (155 days) as compared to birds kept at L_2(lowland)(163 days).In both management systems, Location had effect on egg production. The highest total number of eggs/hen was obtained at L_1 and L_3 (highlandand midland) under on station management and at L_1 (highland) for on farm management. Location also affected AEW and L_1 (highland) exhibited heavier AEW. Correspondingly location also affected all egg-size-related measurements. Mortality varies based on location and higher mortality under on station management was recorded at L_2 (lowland) during starter and grower phase and at L_2 and L_3 (lowlandand midland) during the laying phase. However, for on farm management higher mortality was recorded at L_2 (lowland).

Breed by environment interaction affected certain production performance traits under on-station management. The interaction affected ADFI during the starter and grower phase where DZ-white was superior at L_1 (highland). The interaction also influenced body weights of female chicken at 16 and 52 weeks of age. Similarly, it affected age at first lay. In both breeds significantly earlier age at first egg was registered at L_3 (midland). However, TFI, BW gain, total number of eggs/hen, FCR, AEW and mortality under on-station and on-farm managements were not influenced by the two way interaction.

Generally the study have demonstrated that DZ-*white* breeds had significantly enhanced speed of weight gain as well as growth, better feed conversion ratio and good egg production compared to the improved *Horro* ecotype. The study also showed that both chicken breeds are well adapted in highland and midland agro-ecology zone and their production performance was better than the chicken kept in lowland agro-ecology zone.

6.2. Recommendations

Within the limits of the findings of this study, the following recommendations are made.

- To enhance the current chicken production potential, DZ-white chickens are recommended under the semi-scavenging poultry production conditions in the study area and similar environment.

- Farmers under indoor production system should be aware of the benefits of maintaining a poultry house room temperature in order to improve production efficiency.
- For better performance under farmers' management system, feed availability should be assessed before determining the chicken breed and their distribution to farmers.

Scope for future research

- Some parameters whose measurements were not clearly taken like reason of mortality in chickens should be given due attention in future studies
- Additional investigation on farmer's perception and preference on introduced breed should be identified by making focus group discussion.

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8. APPENDICES

Appendix A.Statistical analyses

Appendix A1.Summary of ANOVA for the main and two -way interaction effects on average daily feed intake (ADFI) and total feed intake (TFI) during the entire trial.

variables	Age in week	Source	Breed	Location	BR*LO	Error	Corrected Total	R2	CV
	0-8	DF	1	2	2	12	17	0.98	2.49
		Type III SS	13.06	412.29	19.48	6.74	18069		
		Mean square	13.06	206.14	9.74	0.56			
		F value	23.24	366.81	17.33				
	9-16	DF	1	2	2	12	17	0.89	1.68
ADFI		Type III SS	55.69	39.43	37.97	16.07	149.16		
		Mean square	55.68	19.71	15.99	1.34			
		F value	41.58	14.72	14.18				
	17-52	DF	1	2	2	12	17	0.77	3.43
		Type III SS	174.93	465.49	7.649	190.68	838.75		
		Mean square	174.93	232.75	3.82	15.89			
		F value	11.01	14.65	0.24				
TFI	0-52	DF	1	2	2	12	17	0.82	2.91
		Type III SS	15.62	42.41	1.38	12.35	71.78		
		Mean square	15.62	21.20	0.69	1.02			
		F value	15.17	20.59	0.67				
		Pr>F	0.0021	0.0001	0.5294				

Appendix A2.Summary of ANOVA for the main and two -way interaction effects on FCR during the entire trial.

variables	Age in week	Source	Breed	Location	BR*LO	Error	Corrected Total	R2	CV
	0-8	DF	1	2	2	12	17	0.91	6.68
		Type III SS	0.42	6.31	0.05	0.69	7.48		
		Mean square	0.42	3.15	0.02	0.06			
		F value	7.34	54.87	0.48				
	9-16	DF	1	2	2	12	17	0.59	6.01
FCR		Type III SS	1.37	0.14	0.12	1.09	2.73		
		Mean square	1.37	0.07	0.05	0.09			
		F value	15.02	0.80	0.66				
	17-52	DF	1	2	2	12	17	0.87	8.43
		Type III SS	12.82	1.99	0.003	2.49	17.32		
		Mean square	12.82	0.99	0.001	0.20			
		F value	61.78	4.82	0.01				

Appendix A3.Summary of ANOVA for the main and two -way interaction effects on body weight and body weight gain under on station management.

Variables	Age in weeks	Source	Breed	Location	BR*LO	Error	Corrected Total	R2	CV
BW	8	DF	1	2	2	12	17	0.83	4.58
		Type III SS	22837.40	9314..66	597.80	6429.52	39179.3		
		Mean square	22837.40	4657.33	298.90	535.79			
		F value	42.62	8.69	0.56				
BW-M	16	DF	1	2	2	12	17	0.87	3.88
		Type III SS	187952.9	79407.98	8788.53	38375.8	31452.3		
		Mean square	187952.9	39703.9	4394.26	3197.99			
		F value	58.77	12.42	1.37				
BW-F	16	DF	1	2	2	12	17	0.87	3.88
		Type III SS	147139.8	28037.22	14799.11				
		Mean square	147139.8	14018.61	7399.55				
		F value	90.36	8.61	4.54				
BW-F	52	DF	1	2	2	12	17	0.95	2.67
		Type III SS	393680.2	50039.11	33799.11	23608.0	501126.4		
		Mean square	393680.2	25019.55	16899.55	1967.33			
		F value	200.11	12.72	8.59				

Appendix A4.Summary of ANOVA for the main and two -way interaction effects onage at first egg (AFL in days), egg number, average egg weight (AEW in g) and egg mass (EM/kg) under On- station management.

Variables	Source	Breed	Location	BR*LO	Error	Corrected Total	R2	CV
AFL	DF	1	2	2	12	17	0.83	2.26
	Type III SS	40.50	470.77	170.33	133.33	814.94		
	Mean square	40.50	235.38	85.16	11.11			
	F value	3.64	21.18	7.66				
Egg number	DF	1	2	2	12	17	0.71	8.21
	Type III SS	1799.83	826.54	5.87	1064.21	3696.46		
	Mean square	1799.83	413.27	2.93	88.68			
	F value	20.29	4.66	0.03				
AEW	DF	1	2	2	12	17	0.98	1.16
	Type III SS	255.54	22.11	1.24	3.83	282.74		
	Mean square	255.54	11.05	0.62	0.31			
	F value	798.65	34.56	1.95				
EM	DF	1	2	2	12	17	0.80	11.71
	Type III SS	17.56	2.76	0.62	4.93	25.89		
	Mean square	17.56	1.38	0.31	0.41			
	F value	42.68	3.36	0.76				

Appendix A5.Summary of ANOVA for the main and two -way interaction effects onbody weight at 16 weeks of age under on farm management.

Variables	Source	Breed	Location	BR*LO	Error	Corrected Total	R2	CV
BW-M	DF	1	2	2	24	29	0.54	9.18
	Type III SS	250618.80	87750.86	22849.80	302328.0	663547.46		
	Mean square	250618.80	43875.93	11424.90	12597.00			
	F value	19.90	3.48	0.91				
BW-F	DF	1	2	2	24	29	0.39	11.10
	Type III SS	126100.83	27958.46	2448.86	239760.80	396268.96		
	Mean square	126100.83	13979.233	1224.43	9990.033			
	F value	12.62	1.40	0.12				

Appendix A6.Summary of ANOVA for the main and two -way interaction effects onage at first egg (AFL in days) and egg number, under on- farm management.

Variables	Source	Breed	Location	BR*LO	Error	Corrected Total	R2	CV
AFL	DF	1	1	1	16	19	0.36	5.35
	Type III SS	288.80	352.80	3.20	1156.40	1801.20		
	Mean square	288.80	352.80	3.20	72.27			
	F value	4.30	4.88	0.04				
Egg number	DF	1	1	1	13	16	0.67	12.07
	Type III SS	3786.59	1648.62	2.37.00	2546.799	7937.13		
	Mean square	3786.59	1648.62	237.00	195.90			
	F value	19.33	8.42	1.21				

Appendix A7.Least squares mean values for two-way interaction effects on carcass analysis of male chicken's at16 weeks of age.

Variables	DZ-white			IH			P value
	L_1	L_2	L_3	L_1	L_2	L_3	
Slaughter weight (g)	1744.44	1442.55	1777.55	1397.22	1230.33	1450.77	0.3505
dressing%	1146.31	902.74	894.97	959.24	807.35	777.71	0.2932
Carcass weight (g)	65.73	62.65	50.30	68.76	65.31	53.76	0.9220
Breast weight (g)	363.33	301.77	207.44	332.22	290.33	192.22	0.6314
Breast %	20.81	20.925	11.62	23.80	23.49	13.29	0.2201
Drumstick weight(g)	185.78	156.56	199.89	159.33	138.89	161.11	0.2297
Drumstick (%)	10.65	10.40	10.82	11.43	10.96	10.73	0.1978
Thigh weight (g)	200.89	180.00	219.44	168.00	148.22	183.33	0.9952
Thigh (%)	11.51	11.95	11.70	12.02	11.97	12.31	0.3358
Wing weight (g)	88.88	67.88	73.77	78.33	62.00	65.77	0.6526
Wing %	5.10	4.72	4.15	5.62	5.00	4.559	0.6465
Back weight (g)	199.44	143.55	158.11	151.00	117.66	133.11	0.2040
Back %	11.46	9.91	8.90	10.82	9.52	9.10	0.4362
Giblet%	5.34	5.21	5.49	5.14	5.27	5.19	0.4487
GIT weight (g)	76.91	65.95	132.77	54.98	50.60	105.44	0.3856
GIT %	4.39	4.59	7.47	3.91	4.08	7.29	0.7213
Abdominal fat weight (g)	0.38	9.33	8.00	0.00	10.27	5.33	0.4927
Abdominal fat%	0.02	0.646	0.44	0.00	0.81	0.36	0.4568

* *DZ-white= Debre Zeit white, IH= Improved Horro, L= location,* L_1 *=Debre Berhan,* L_2 *= Melka Werer,* L_3 *= Mekelle, P = Probability*

Appendix A8.Least squares mean values for the main effect on HDEP (%) under on-station management.

Age in weeks	Breed			Location			
	DZ-white	IH	P value	L_1	L_2	L_3	P value
20-27	41.85	22.56	<.0001	31.96[b]	23.09[c]	41.57[a]	0.0004
28-31	59.28	48.33	0.0045	52.42[b]	45.83[b]	63.17[a]	0.0024
32-35	60.83	51.20	0.0107	62.37[a]	51.13[b]	54.54a[b]	0.0381
36-39	62.43	52.40	0.0085	59.61	54.42	58.22	0.4154
40-43	56.03	51.00	0..0589	55.75	49.46	55.34	0.0972
44-47	55.42	49.92	0.1045	53.56	55.40	49.06	0.3431
48-52	53.46	45.74	0.0029	49.51	49.05	50.24	0.8950

Appendix A9.Least squares mean values for the main effect on HDEP (%)under on-farm management.

Age in weeks	Breed			Location		
	DZ-white	IH	P value	L1	L2	P value
20-27	34.27	15.97	0.0001	28.74	21.50	0.0527
28-31	48.73	35.06	0.0337	48.41	35.37	0.0413
32-35	51.26	42.33	0.0405	50.64	42.95	0.0717
36-39	52.53	43.79	0.0968	50.16	46.16	0.4268
40-43	51.22	43.93	0.0870	48.23	46.91	0.7419
44-47	50.84	40.93	0.0152	47.90	43.87	0.2756
48-52	46.58	37.22	0.0041	47.67	36.15	0.0009
53-56	46.36	34.17	0.0009	44.36	36.18	0.0132
57-60	38.77	30.74	0.0005	38.05	31.47	0.0024

[*] *DZ-white= Debre Zeit white, IH= Improved Horro, L= location, L_1 =Debre Berhan, L_2 = Melka Werer, L_3 = Mekelle, P = Probability*

Appendix A10. Least squares mean values for two-way interaction effects on egg quality traits.

Parameter	DZ-white			IH			P value
	L_1	L_2	L_3	L_1	L_2	L_3	
Egg Weight (g)	55.61	48.89	54.84	49.09	43.55	46.57	0.1788
Egg Length (mm)	55.01	53.09	54.66	52.27	51.35	52.20	0.5623
Egg Width (mm)	42.38	39.89	42.20	40.63	38.78	39.85	0.2908
Egg Shape index	77.07	75.16	77.26	77.85	75.57	76.36	0.4901
Shell Weight(g)	6.57	5.92	6.74	6.18	5.32	5.91	0.2284
Shell Thickness(mm)	0.36	0.39	0.44	0.37	0.38	0.49	0.1242
Albumin Height(mm)	6.83	6.69	7.14	6.42	6.39	6.78	0.9778
Yolk Height (mm)	19.17	18.06	19.23	18.36	17.78	18.08	0.1415
Yolk Weight (g)	16.43	13.47	15.35	14.71	13.69	14.61	0.0046
Albumin Weight(g)	32.05	28.42	32.76	27.03	23.63	26.06	0.2524
Haugh unit	83.10	84.63	85.19	82.99	84.72	85.97	0.9606
Yolk Ratio (%)	29.61	27.70	28.00	30.02	31.41	31.43	0.0073
Albumin Ratio (%)	57.58	57.94	59.69	55.07	54.28	55.87	0.5351
Shell Ratio (%)	11.81	12.13	12.30	12.60	12.22	12.70	0.3127

[*] *DZ-white= Debre Zeit white, IH= Improved Horro, L= location, L_1 =Debre Berhan, L_2 = Melka Werer, L_3 = Mekelle, P = Probability*

Appendix B. Pictures during research works

Appendix B1.Picture of On-Station experimental house at L_1

Appendix B2.Picture of On-Station experimental house at L_2

Appendix B3.Picture of on-station experimental house at L_3

Appendix B4.Picture for fertility and hatchability test

Appendix B5.Picture during carcass and egg quality evaluation

Appendix B6.Samples pictures from the On-farm experimental house at L_1 and L_2

Appendix B7. Research participant farmers' training

Appendix C. Published article

Samrawit Mulugeta, Gebeyehu Goshu and Wondmeneh Esatu. (2020): Growth performance of DZ-white and Improved Horro chicken breeds under different agro-ecological zones of Ethiopia *Journal of Livestock Science*, **11**: 45-53

Titles of manuscripts prepared for publications

Egg Production Performance of DZ-white and Improved Horro chicken breeds under different agro-ecological zones of Ethiopia.