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**PHENOTYPIC CHARACTERIZATION AND ON-STATION EVALUATION OF
INDIGENOUS CHICKEN ECOTYPES IN GAMBELLA REGIONAL STATE,
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

June 2023

Bishoftu, Ethiopia

**PHENOTYPIC CHARACTERIZATION AND ON-STATION EVALUATION OF
INDIGENOUS CHICKEN ECOTYPES IN GAMBELLA REGIONAL STATE,
ETHIOPIA**

**A Dissertation Submitted to the College of Veterinary Medicine and Agriculture of
Addis Ababa University for the Partial Fulfillment of the Requirements for the
Degree of Doctor of Philosophy in Animal Production**

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ETHIOPIA**

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DEDICATION

This dissertation is dedicated to my mother ***Ayantu Geleta Guta*** for nursing me with affection, unreserved help and for her enthusiastic encouragement in my academic carrier. Since she was passed during academic career work, she is unlucky to share with me the success I have been achieving in academic endeavors. I pray to God to rest her soul in peace.

BIOGRAPHICAL SKETCH

Getachew Bekele was born on the October 10, 1986 in West Shoa Zone, Chelia district. He attended his Elementary and Secondary School educations at Jarso Dire Geda and Gedo High Schools, respectively. In 2004, he completed secondary high school education successfully, and joined Ambo University in 2007 to pursue his BSc study and graduated with BSc degree in Agriculture (Animal Production) in July 2010. Soon after graduation, he was employed as Junior Instructor at Mizan Agriculture Technical Vocational Educational and Training College (MATVETC).

During his stay, he also served as Head of Animal Science Department in the college. After serving for 1 year in the position, he joined the School of Graduate Studies of Haramaya University in October, 2012 to pursue his MSc study and graduated with MSc degree in Agricultural Science (Specializing in Animal Genetics and Breeding) in July, 2014.

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STATEMENT OF AUTHOR

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

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I have always believed that the endowment, love and prayer of my families, my father Bekele Fereja, sisters and brothers (Aberash, Beletech, Zenati, Gudo, Abdisa, Gudeta, Tilahun, Zeleke, Motuma and Kenenisa) has supported me to reach this level. Last but by no means is the least the contribution of my wife; **Alemitu Gezahegn**, and my kids **Urji** and **Yerosan** have made my life easier and is beyond words can I express.

Finally, all the people mentioned were important for the task accomplished. Within the space provided, it is difficult to thank all individuals who directly or indirectly contributed to the success of my work. Note that it is not a deliberate ignorance of your contribution. I thank you all.

ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
AOAC	Association of Analytical Chemists
AMSA	American Meat Science Association
ASWAPT	Actual Sample Weight after Pressure Treatment
ASWBPT	Actual Sample Weight before Pressure Treatment
CF	Crude Fiber
CP	Crude Protein
CSA	Central Statistical Authority
DAD-IS	Domestic Animal Diversity Information System
DFD	Dark Firm Dry
DL	Drip Loss
DM	Dry -Matter
DNA	Deoxyribonucleic Acid
DOC	Day Old Chicks
FAO	Food and Agriculture Organization
FCR	Feed Conversion Ratio
FSWT	Final Sample Weight
GLM	General Linear Model
GPRS	Gambella People's Regional State
HDEP	Hen - Day Egg Production
HHEP	Hen - Housed Egg Production
HU	Haugh Units
IBD	Infectious Bursal Disease
ISO	International Organization for Standardization
ISWT	Initial Sample Weight
Kcal/kg	Number of Calories in Each Kilogram of Food
ME	Metabolizable Energy
PSE	Pale Soft Exudative

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ETHIOPIA**

Getachew Bekele Fereja

PhD Dissertation

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ABSTRACT

This study was conducted in Gambella Regional State, Ethiopia, to characterize the phenotypic and on-station evaluation of indigenous chicken ecotypes. Four districts were purposively selected from 13 districts of the regional state namely: Abobo (Ab), Gambella Ketema Zuria (GKz), Itang (It), and Lare (La). A total of 384 households (96 households from each district) keeping indigenous chicken strains were randomly sampled for interview. Cross-sectional and retrospective types of studies were conducted to collect data using the questionnaire. On-farm observations, on-station evaluation, and laboratory analysis were also conducted on the relevant data. moreover, phenotypic characterizations of both qualitative and quantitative traits of local chicken populations was conducted on 600 indigenous chickens of both sexes with 150 chickens (50 males and 100 females) from each district on chickens with approximately six months and above were collected following the FAO's descriptor list for chicken genetic resources. A total of 880 eggs (220 eggs from each district) were collected and incubated using the artificial incubator. A total of 120 eggs (30 eggs from each district) which was collected from households were used to egg quality investigation. A total of 649 indigenous chicken ecotypes of four (4) namely Abobo (181), Gambella Ketema Zuria (169), Itang (151), and Lare (148) were hatched and kept at the on-station for growth, egg production performance, and carcasses evaluation by using complete randomized design arrangement. Thirty-two matured live chickens (4 males and 4 females from each chicken strains) indigenous chicken strains were taken at random for nutritive value investigation. The meat color and pH measurement parameters were obtained using a digital colorimeter. All data collected was

subjected to Analysis of Variance (ANOVA) using the General Linear Model (GLM) procedures of the Statistical Analysis System (SAS) version 9.3. The results were expressed as $LSM \pm SE$. All statements of statistical differences in quantitative data were based on $p < 0.05$. The survey results indicated that, the overall mean of the flock size per household in the study area was 13.59 and the overall number of hens, cocks, cockerels, pullets, and chicks in the study areas was 4.89 ± 0.06 , 1.72 ± 0.05 , 1.52 ± 0.01 , 2.01 ± 0.02 , and 3.44 ± 0.09 , respectively. According to the current study, the mean age at first egg was significantly ($P < 0.05$) different among the study districts. The normal feather distribution observed in the chicken populations was dominantly 88.67 %, 94 %, 90 % and 92.67 % in Abobo, Gambella Ketema Zuria, Itang and Lare districts, respectively. The overall mean body weight of adult males and females was $1.38 \text{ kg} \pm 0.02$ and $1.16 \text{ kg} \pm 0.04$, respectively. The mean values of egg weight and shell thickness were 39.15 g and 0.28mm, respectively. The overall mean value of the egg fertility was 83.64 %. The overall mean value of the day-old body weight was $26.55 \text{ g} \pm 0.24$. The final overall mean body weight for on-station of adult males and females chicken strains was $1187 \text{ g} \pm 0.25$, and $1094 \text{ g} \pm 0.24$, respectively. The overall mean of the dressing percentage was male (69.06) and female (69.27). The male (49.25 ± 0.28) breast meat had a significantly ($P < 0.05$) lighter score (L^*) than the female (48.65 ± 0.45). The crude protein (CP) contents of breast meat were significantly higher than those of the thigh and drumstick meat part at ($p < 0.05$). It is recommended that a further molecular characterization should be used to back up the present findings and determine genetic variation within and among the chicken strains. Finally, genetic differences should be considered to develop effective utilization and conservation strategies of programs. From the nutritive value of chicken's meat, since the protein content is very crucial for human diet it is better to eat the meat which was produced from the breast meat part of chickens.

Key words: Characterization, district, egg quality, Gambella region, growth performance, indigenous chicken, meat

CHAPTER 1. INTRODUCTION

1.1. Background of the Study

There are some 25.8 billion chickens in the world twice, up from about 13.9 billion chickens in 2000 (FAO, 2021), chickens are important in the improvement of food security and livelihood Zemelak *et al.*(2016), and contributing about 28-30 % of all animal protein consumed in the world (FAO, 2011). Like as, poultry play important socio-economic roles for generating additional cash incomes, religious/cultural functions, and as protein source Aberra, (2014). There are no religions or cultural taboos of any kind relating to the consumption of poultry meat and eggs. Local chickens are broadly distributed in the rural areas of sub-tropical and tropical countries, majority of chickens which are found in the hand of the rural dwellers Ajayi, (2010).

Comprising the most advantages of local chickens is their ability to adapt to harsh environments, hardiness, capability to survive on little or no inputs, in terms of feed, medications, shelter, and minimal management Ajayi, (2010) and Apuno *et al.* (2011). The local chickens represent valuable resources for livestock development especially in the rural areas. This is due to their extensive genetic diversity which allows for production under different environmental conditions Ajayi, (2010). The local chickens serve as an investment for households in addition to their use as egg and meat sources both for selling and consumption Moula *et al.* (2011). These native chickens are generally kept under scavenging or extensive management system with no inputs or few for feeding, health care, and housing. The local breeds are well adapted to the local feed, climatic conditions, and management stresses, with better resistance to diseases Iqbal and Pampori, (2008).

The first step of local chicken characterization involves the identification of populations based on morphological descriptors that can also give useful information on the suitability of breeds for selection Ajayi *et al.* (2012). About 68.46 % of the annual meat produced comes from poultry and the egg productions are contributed by local chicken, hybrid, and exotic breed with an average annual output of 123,623,566, 210,564,137, and 34,606,373

of egg production, respectively (CSA, 2020/21). Despite their low productivity, local chickens possess desirable characteristics such as resistance to some diseases, thermo-tolerance, presence of hard egg shells, good meat and egg flavor, high fertility and hatchability as well as high dressing percentage Aberra *et al.* (2011). The production of both chicken's meat and egg has certainly assisted in reducing the gap in the supplies of animal source protein for human consumption Leta and Bekana, (2010).

The quality characteristics of an egg can be measured using internal and external quality parameters Monira *et al.* (2003). The internal quality characteristics of an egg are measured on the basis of the quality of the albumens as indicated by Haugh Units (HU), the relative size of the different internal components and the integrity of the egg shell membranes. Various studies have been conducted on egg quality in chickens such as on the effects of changes in the micro environment provided at an early incubation and during storage, and how these affect hatchability Reijrink *et al.*(2008). In Ethiopia, the chicken population estimated at about 57 million, constituted 78.85 % local, 12.03 % hybrid and 9.11 % exotic breeds (CSA, 2021). Still, this giant population of local chickens is found in backyard production systems. Native chickens are poor in production and reproduction performance such as small-sized eggs, slow rate of growth, late maturity, little clutch size, poor egg production, and high mortality of chicks Tadelle, (2003) and Zemene *et al.* (2012).

The egg production capacity of native chickens is 30-60 eggs in keeping with chicken/year in the village situations in Ethiopia with a mean of 38g egg weight, but distinct bird breeds might also additionally produce round 250 eggs in keeping with yr per bird with a mean of 60g egg weight Alganesh *et al.* (2003).With this capacity of indigenous chicken, the need for egg and chicken meat of Ethiopian populations can't be satisfied Geleta *et al.* (2013). Pullets and cockerels reached sexual maturity at a mean age of 6.4 months and 5.7 months, respectively. Chicken production is a key supply of eggs and meat in each rural and urban regions of Ethiopia, in addition to a supply of income, specifically for women. Currently, increasing consumer interest in eating healthier meat has resulted in an increasing interest in indigenous chicken breeds, because the meat of indigenous chicken breeds has higher

protein and low fat contents as well as unique flavors compared with broiler breeds Jayasena *et al.* (2013). Therefore, indigenous chicken breeds are regarded as good sources of meat with high nutritional value Jung *et al.* (2013). An egg contains an important part of human diet because of its high quality protein Forson *et al.* (2011). Chickens egg is a cheap source of good quality animal protein fulfilling the requirements of the rapidly growing human population. Consumers prefer egg with better egg quality which is determined by their physical structure and chemical composition. Generally, the morphological traits, characterization, identification, egg quality (including fertility and hatchability), embryonic death, growth, egg production and proximate composition of meat under intensive management level in the study area have never been conducted. Therefore, the objectives of the study were generating baseline information on the on-farm phenotypic characterization and on-station evaluation of indigenous chicken ecotypes in Gambella Regional State, Ethiopia.

1.2. Statement of the Problem

Indigenous chickens are crucial sources of protein and income in Gambella regional state, Ethiopia. Unfortunately the region is not given priority for the indigenous chicken strains characterization and on-station evaluation for improving the production and productivities of the chicken strains in the study areas. Therefore, the present study was targeted to characterize and evaluate indigenous chicken ecotypes of Gambella.

1.3. Objectives of the Study

The study was aimed at addressing the following general and specific objectives.

General objective

- ✚ To characterize and evaluate indigenous chicken ecotypes in Gambella Regional State, Ethiopia.

Specific objectives

- ✓ To characterize indigenous chicken ecotypes of the study area;
- ✓ To evaluate the egg quality of the indigenous chicken ecotypes under traditional production system;
- ✓ To assess on-farm growth, reproduction, and egg production of indigenous chickens;
- ✓ To evaluate egg fertility, on-station growth and egg production performances of indigenous chicken ecotypes; and,
- ✓ To determine the carcass characteristics and meat composition of the indigenous chicken ecotypes.

1.4. Research Questions

1. What are the phenotypic characteristics of indigenous chicken ecotypes of the study area?
2. What is the on-farm production performance of the indigenous chickens in the study area?
3. What is the egg quality of indigenous chicken ecotypes in the study area?
4. What are on-station production performances of indigenous chicken ecotypes?
5. What are the carcass characteristics and meat proximate composition of the indigenous chicken ecotypes under improved management system?

1.5. Scope of the Study

The scope of a study gives boundaries for the research problem and makes a fence around the research findings, for instance the locations selected, environmental factors and variables that cannot be controlled. This study focused on on-farm phenotypic characterization and on-station evaluation of indigenous chicken ecotypes in selected districts namely (Abobo, Gambella Ketema Zuria, Itang and Lare) of the Gambella region, Ethiopia. The results may not be generalized to other areas where the materials and environmental conditions may be different. The study dealt with only the information aspects of indigenous chicken strains intensive management, and their production potential of the study area.

1.6. Significance of the Study

The study results would contribute to solid awareness to different stakeholders who are working with indigenous chicken production in the study area. The present findings would contribute to enhance the production performance of the indigenous chicken strains among farmers in the study area for increasing protein sourced food, income generating and sustainable livelihood. The findings would also be important for governmental policy makers, nongovernment Organizations to formulation of policies and identify the necessity of initiating projects aimed at promoting indigenous chicken ecotypes production in the county. The findings also would be serving as a source of reference to scholars/scientists, researchers and student's interested in poultry production and management.

CHAPTER 2. LITERATURE REVIEW

2.1. The Origin of Indigenous Chicken in the World

The Chicken breeds (*Gallus domesticus* or *Gallus gallus domesticus*) are common domestic animals globally. At the time of 2017, the global chicken population was greater than 25.8 billion (FAO, 2021). Chickens are bred on all continents and countries except Antarctica and Vatican City Lawler, (2015). To fulfill the growing demand for animal foods, high-yielding commercial chicken breeds were developed in recent decades for meat and egg production. Nearly in 1,600 different local chicken breeds are internationally recognized (FAO, 2020).

Chickens were originated in Southeast Asia and were introduced to the rest of the world by sailors and traders Crawford, (1990). Nowadays, indigenous chickens are the result of centuries of cross-breeding with exotic breeds and random breeding within the flock. As a result, it is not viable to standardize the traits and efficient overall performance of indigenous chickens. There is no comprehensive information on the categories of breeds identities and geographical distributions of many animal populations including chicken in the developing countries of the world, thus some of them are commonly referred to as non-descript breeds (FAO, 2011).

2.2. Population Size and Distribution of Chicken in Ethiopia

The total poultry population at country level is estimated to be about 57 million. Most of the poultry are laying hens (34.26 %), followed by chicks (32.86 %). Pullets are estimated to be about 6.47 million in the country. Cocks and cockerels are also estimated separately, and are 6.38 million and about 3.27 million, respectively. The others are non-laying hens that make up about 4.59 % (2.61 million) of the total poultry population in the country. With regard to breed, 78.85 %, 12.02 %, and 9.11 % of the total poultry were reported to be indigenous, hybrid and exotic, respectively (CSA, 2021).

Chicken populations from the different study regions showed that a large variation in body structure, feather distribution, plumage color, comb type, production, and productivity Tadelles and Ogle, (2001). The same authors state that there are many ecotypes, breeds, and strains of indigenous poultry that are well adapted to their production environments in the tropics. According to the report of Getu and Birhan,(2014) the flock structure of indigenous chickens are composed of chicks, pullets, cockerels, cocks, and hens with an estimated mean of about 9.07 ± 0.59 , 2.47 ± 0.26 , 1.02 ± 0.15 , 1.04 ± 0.06 , and 2.79 ± 0.19 , respectively with a total 16.43 ± 0.92 population per households.

2.3. Ethiopian Indigenous Chicken Ecotypes

According to DAD-IS and DAGR-IS, few Ethiopian indigenous chicken ecotypes were listed such as Tilili, Horro, Chefe, Jarso, Tepi, Gelila, Debre-Elias, Melo-Hamusit, Gassay/Farta, Guangua, Mecha, Konso, Mandura, and Sheka Addis *et al.*,(2015). According to the Ethiopian Biodiversity Institute (2016), only 7 ecotypes (Farta, Horro, Jarso, Konso, Mandura, Tepi, and Tillili) were registered as Ethiopian chicken ecotypes/breed in the DADIS. There are no comprehensive current and previous conservation and breeding programs that targets indigenous chicken genetic resources development in the country, except some awareness creation campaigns at farmer's level and limited attempts made on indigenous chicken improvement eg. Horro chicken. On the other hand, little or insufficient efforts were made to the selection based genetic improvement of indigenous chicken populations due to the vast importation of exotic chicken genetic resources (White and brown Leghorns, Rhode Island Red, New Hampshire, Cornish, Australorp Light Sussex). For these reasons, conservation practices were given less consideration Alemneh and Getabalew, (2019). This uncontrolled distribution of the exotic chicken genetic resources over the country leads to the dilution of the indigenous chicken genetic resource. Still intensive research on both phenotypic and DNA (genetic) levels has to be conducted to know the extent. The native chicken production systems in Africa are mostly focused on scavenging almost in households of the rural areas.

Chicken production are an integral part of the farming systems requiring low inputs with outputs obtained at both within household and intra-household conditions. Chickens also fulfill a number of other importance's for which it is difficult to replace any monetary value. Native chickens are underestimated because of their poor productivities. Due to this reasons they have been neglected and little attention has been given to them by researchers, development workers and policy-makers Tadelles, (2003). Some authors Tadelles, (2003); Halima, (2007) and Dana *et al.*(2009) have made phenotypic and characterization of local chicken in some locations of Ethiopia. There is lack of information on the diversity of different native chicken strains. On top of that, the local chicken populations of Ethiopia have been undergoing genetic erosion, especially in the central and other locations of the country following the dilution of improved breeds from developed countries Emebet, (2015). Moreover, no real efforts have been made to conserve these chicken genetic resources Eskinder *et al.*(2013). The present and future improvement and sustainable utilization of local chicken are dependent upon the accessibility of these genetic variations Benitez, (2002). Therefore, characterization, utilization and conservation of local genetic resources are paramount Halima, (2007), improvement and conservation of indigenous chicken resource needs characterization of the available genotype.

The native chickens in Ethiopia are entirely non-descript strains closely related to the jungle fowl (*Gallus gallus*); show a great difference in their body size, plumage colour, comb type, and feather cover Halima (2007). As Reta, (2006) and Halima (2007) reported that the names of the local chicken groups were being called as chicken-ecotypes and native-chickens, respectively. Based on their main habitat, thus the chickens are named after their location of geographical origin, for example; Tilili, Horro, Jarso, Tepi, Gelila, Debre-Elias, Melo-Hamusit, Gassay/Farta, Guangua and Mecha Halima (2007). Based on morphological characteristics for identification specially feather type and color, for example as; Tikur (black), Nech (white), and Key (Red) in Ethiopia Nigussie *et al.* (2010). The Horro, for example, is an indigenous chicken ecotype named after the geographic region of origin located in the western part of Ethiopia near the Blue Nile gorge. There were about 30,000 chickens restricted to this original environment Nigussie *et al.*(2009).

2.3.1. Morphological characterization of native chicken

Native chickens have different morphological identities, carrying genes that have adaptive values to their environment Aklilu *et al.*(2013). Native chicken populations are often described and grouped according to geographical areas or phenotypic characteristics, while their classification into types is limited Manyelo *et al.* (2020). They also exhibit great difference in performance in various qualitative and quantitative traits of economic importance Faruque *et al.* (2010). Local chicken exhibits numerous observable attributes including plumage, shank, earlobe colour, comb type, head shape, and other qualitative traits. The indigenous chickens of Ethiopia have various names and are characterized on different grounds, as in many other parts of Africa Melesse and Negesse, (2011). The exceptional adaptation characteristics and morphological differences of Ethiopian native chicken population have been recently reported by Bekele *et al.* (2015) on the basis of plumage color, morphological features, and morphometric traits. The native chickens, which are commonly grouped world-wide as non-descriptive types due to shortage of information, differ widely in body size, body conformation, plumage color and many other phenotypic characteristics, which is important in livelihood and household food security in rural farm families (FAO, 2012).

Additionally, their distribution shows their diverse adaptive potential to the prevailing environment, diseases and other conditions. Most of the local chickens have evolved through adaptation to different agro-ecologies. As stated by Egahi *et al.* (2010) the local chickens possess genes and special adaptations not found in other improved exotic breeds. As Melesse and Negesse, (2011) reported that identification and characterization of the local chicken genetic resources generally needs information on their adaptation to a specific environment, possession of unique traits of current or future economic value and socio-cultural functions, which are important inputs to decisions on conservation and utilization. Differences in morphological traits such as outline and feather contours, shank and ear-lobe colours, and comb types are common among local chicken populations. These morphometric traits give basis for categorizing the local chickens according to their phenotypic and morphological characteristics.

2.4. Purposes of Keeping Native Chicken

The diverse agro-ecology and agronomic practice prevailing in Ethiopia together with the huge population of livestock in general and poultry in particular, could be a promising attribute to boost up the poultry sector and enhances its contribution to the total agricultural output as well as to improve the living standards of the poor livestock keepers Fisseha, (2009) and Fulas *et al.* (2018). The importance of local chicken production in the national economy and its role in upgrading the nutritional status and incomes of many small farmers and landless households has been recognized by different authors and rural development agencies for the past few decades Melesse and Negesse, (2011). Local chickens in Ethiopia are distributed across various agro-ecologies managed in the traditional management system showings that they are useful avian resources reared as a source of animal protein and income generation to many of the households Fisseha, *et al.* (2010). Although there is variation in socio-economic status, growth, and density of population, accessibility of social services, facility and infra-structure among urban, rural and peri-urban residents may make variation in small scale poultry management practices, relatively no or little research has been carried out to characterize understand and improve small scale poultry management based on location Nega *et al.* (2016).

The information on farmers breeding practices and traits of economic function for major parts of Ethiopia are deficient. Developing appropriate breeding program for village status needs characterization of production circumstances and identification of breeding practices and trait of economic performance of farmers Abdelqader *et al.* (2007). For conservation and utilization, local chicken characterization is the first step towards long-term genetic improvement as it provides the basis for any other livestock development interventions, and a pre-requisite information for designing appropriate breeding programs Johannes *et al.*(2009). Rural farmers keep, on average, about five or six birds Bushra, (2012). However, the contribution to the national economy to ensure food security both as a food item and as a means of cash income is large.

2.5. The Production Systems of Chicken in Ethiopia

Chicken production in Ethiopia for the most part, is a traditional operation that uses a few scavenging birds with low productivity. Women and children benefit from producing poultry, through income generation. Chicken production in Ethiopia can be classified into three major production systems. These include; traditional (backyard) chicken production, small scale intensive and commercialized chicken production system, based on some identified parameters such as breed, flock size, housing, feeding, healthcare, insecurity and other technologies Tadelle, (2003). Backyard chicken production is production system which practiced in most rural areas of the country with the aim of the households' consumption and as additional income for the households. Backyard chicken production covers 95-98% of the chicken production system of the country and it is not profitable since it is not market oriented. It contains a small flock size (5-20 chickens per household) which was local chicken types mostly depend on the scavenging feed sources and have focused on low level of management practices such as watering, feeding, housing, health management, and services of agricultural extension Afras, (2018).

Small-scale poultry production systems have been integrated with human livelihoods for thousands of years, increasing diet, income, food and nutrition security of the rural poor Alders and Pym, (2009). It holds a flock size of 50-200 improved breeds of chickens per household Afras, (2018). The commercial chicken production system is highly intensive management system which kept under indoor conditions with a medium - high bio-security level. This system mainly focused on imported exotic breeds that need intensive inputs such as housing, health, feed, and modern management system. It is categorized by higher level of productivity where chicken production is entirely market-oriented to meet the large chicken demand in major cities and also delivers employment opportunities for workers from chicken attendants to truck drivers and to professional managers Afras, (2018).

Chicken production and market system were studied in Southern Ethiopia by Mekonnen, (2007) and Bogale, (2008). Still these large populations of indigenous chickens are found in back-yard production systems. There is no suitable provision of additional feeds, they

are rearing by consuming table left over from the household, requiring small house at night and free ranging at day time, but they are well adapted to the harsh environment, resistant to poor management, feed shortages, tolerate to diseases and provide better test of meat and eggs than the exotic chickens Tadelles and Ogle, (2001).

2.6. Productive and Reproductive Performances of Native/Indigenous Chickens

Concerning the production potential of native chickens, studies carried out at in Western zone of Tigray Markos *et al.* (2015) which indicated that the average annual egg production of the native chicken was 52.68. Authors reported that about 48.98, 54.20 and 54.87 annual average egg production for lowland, highland and midland chicken ecotypes, respectively. Other study carried out by Halima, (2007), Ayalew & Adane, (2013), Addisu *et al.*(2013) and Meseret, (2010) at North West Ethiopia, Chagni town in Awi administrative Zone of Amhara, North Wollo zone of Amhara and Gomma wereda of Jimma zone, respectively, revealed that the average egg production of local chicken were 43.8, 18-57, 27-45 and 49.51 eggs/hen/year. As findings of Abera and Tegene, (2011) also reported that the production potential of scavenging hens is generally low, with only 40-60 small sized eggs produced per chicken per year by smallholder management conditions. Higher egg productions per year per hen were reported by Mekonnen, (2007), Fisseha *et al.* (2010) in Wonsho district (62.95 eggs) and Bure district (60 eggs).

In Ethiopia, a native scavenging hen on average lays about 36–40 eggs/year (FAO, 2004). The average number of eggs/clutch of native hens in Burkina Faso was estimated to be 12 eggs Kondombo, (2005). The average number of clutches/hen per year and the number of eggs/clutch of native chicken reported in Sudan were 3 and 12 eggs, respectively Khalafalla *et al.*(2001). By Halima, (2007) reported that an average productivity of 9–19 eggs/clutch with 2–3 clutch periods/hen per year and an average total egg production ranged from 18–57 eggs/year per hen for native hens in North-West Ethiopia. Local chickens are reared in many parts of the world irrespective of the traditions, life standard, climate, or religious prohibitions. The chickens are raised for eggs, meat, and also for recreation in many areas of the world.

The chickens in the developing countries are reared under suitable conditions and with negligible or no inputs hence they are better adapted to the prevailing agro climate but they are poor producers of both meat and eggs. The local hens still exhibit signs of broodiness and sit on their eggs for hatching of chick. The total mean age of cock at first mating was 4.9 months in Mezhenger and Sheka however, in Benchi-Maji zone extends to 5.2 months Yadessa *et al.*(2017). As findings Meseret, (2010) the mean sexual maturities of local chicken at Gomma district of Jimma zone was about 6.33 months. Local chickens are poor in productive and reproductive potential which are identified by late maturity, slow age at first mating, small sized eggs, slow growth rate, small clutch size, high mortality of chicks among the flock, and a natural learning to broodiness. There were large number of local chickens in Ethiopia but its productive and reproductive potential were low and differ in different locations. Findings of Solomon *et al.*(2013) found that 59.5 eggs per hen per year in Metekel zone, Northwest Ethiopia. As Fissaha *et al.* (2010) report, the total egg production/hen per year of native hens under farmer management situations is estimated to be 60, 53 and 55 in Bure, Fogéra and Dale woredas, respectively.

2.7. Sexual Maturity, Clutch Size and Incubation Practice

Village chicken, in Ethiopia attains sexual maturity at an average of 7 months. Halima, (2007) also reported that pullets and cocks reached sexual maturity at an age from 20 to 24 weeks; However, 31.92 % of the pullets and 20.07 % of the cocks reached maturity at 28 to 32 weeks, showing late maturity in North West Ethiopia. Uniformly Worku *et al.*(2012) and Markos *et al.* (2015) reported that age at first mating for cockerel in West Amhara region and western zone of Tigray was 6.49 month and 5.71 month, respectively. Mekonnen, (2007) also reported that the mean age at first egg laying of native pullets in three districts of SNNPR was 7.7 months and Addisu *et al.*(2013) also reported that the age at first egg laying of indigenous chickens in North Wollo zone of Amhara region was 6.6 months. The total mean age of cock at first mating was 4.9 months in Mezhenger and Sheka but in Benchi-Maji zone it requires 5.2 months Yadessa *et al.* (2017).

Meseret, (2010) reported that the mean sexual maturity of local chicken at Gomma district of Jimma zone were about 6.33 months. Aberra *et al.* (2013) report, age at first egg of local chickens in different agro-ecological zones of Amhara region was 6.6 months. Average age of local pullets and cockerels at first mating was 5.2 ± 1.16 and 5.44 ± 1.3 months at Metekel zone of Northwest Ethiopia, respectively Solomon *et al.*, (2013). Clutch numbers of Ethiopian indigenous chicken is different at different production and management systems. According to CSA (2016) report the national average clutch number of Ethiopia indigenous chicken was 4 per year. The number of clutch periods showed by local hens per year is 3.8, 2-6 and 3.7 in Bure, Fogéra and Dale, respectively Fissaha *et al.* (2010). Alem, (2014) reported in Central Tigray the average clutch number per year was 3.15 to 3.2 and 3.2 at lowland and midland agro- ecologies, respectively.

The number of clutch periods recorded per year was 4.29 ± 0.17 (range 3.38-6.11) in Metekel zone of Northwest Ethiopia, Solomon *et al.* (2013). The average number of clutches per year recorded from the Gomma Wereda was 3.43 by Meseret, (2010). The overall average clutch number of chicken in North Wollo of Amhara region was 3.62 per year by Addisu *et al.* (2013). Mekonnen, (2007) reported that the mean clutch number of indigenous chicken in three districts of SNNPRs was 3.8 per year. Standard incubation of temperature of 37.8°C is the thermal homeostasis in the chick embryo and gives conducive environment for embryo development and hatchability Kingori, (2011). According to the study conducted in Fogera district, 81.9 % and 26.4 % of the households showed favorable season of incubation was dry and rainy season, respectively Bogale, (2008).

2.8. Fertility, Hatchability, and Egg Quality of the Indigenous Chicken Strains

The natural incubation is the most popular method used for replacing and enhancing the size of flocks by the help of broody hens. The Producers adjust suitable place and prepare nest for broody hens from clay pot and straw bedding but in some season's uses clay without bedding. The farmers are very conscious and concerned for making of suitable place which give good feed resources and best environment for incubating by using broody hens.

Normally, farmers incubate at dry season and use eggs which were laid within the houses Bikila, (2013). Average number of eggs incubated per hen in various agro-ecological zones of Amhara region was 12.8 and out of the incubated eggs, only 10 chicks were hatched, giving an average hatchability of 79.1 % by Aberra *et al.*(2013). Solomon *et al.* (2013) the average number of eggs set per hen was 14.74 ± 0.25 (range 12.40 - 16.91) with hatchability of 84.7 percentages in Metekel zone of Northwest Ethiopia. As reported by Fissaha *et al.* (2010), 13 eggs (ranged 7 - 22) have hatchability percentage of 82.6 and 89.1 in Bure and Dale districts of Ethiopia, respectively. Number of eggs set per hen focused on size of eggs, availability of eggs, the maternal instinct of the broody hen and size of broody hen.

But, the total mean number of eggs incubated was 11.32 eggs with range of 6 - 20 eggs per hen and the percent hatchability was 82.74 % in Nole Kabba Woreda and Western Wollega, Ethiopia Habte *et al.* (2013). Average number of eggs set for incubation was 13 ranging from 10 - 20 per hen from which relatively reasonable number (83 %) chicks were hatched in East Gojam zone of Amhara regional state by Melese and Melkamu, (2014). The Artificial incubation system can reduce the problem of broodiness and also result in incubation of a large number of eggs at the same time. The mini-hatchery technology has proved to be successful under the socio- economic and the climatic conditions of the hatchability rate has largely been found to be influenced by handling, quality, and conservation of fertile eggs before incubation and also viability of day old chicks (DOC) after hatching Rota *et al.* (2010).

Hatchability and fertility are the most important parameters of reproductive potentials which are sensitive to environmental and genetic impacts Sapp *et al.* (2004). The total quality of an egg can be determined under two broad groups, namely, external and internal quality by Monira *et al.* (2003). External quality of egg is evaluated by characteristics such as the shape of the egg and egg weight, strength of the shell, and shell thickness by Bain, (2005). As the point of view of consumers, egg weight is the most crucial quality trait by Dudusola, (2010).

The consumers have come to expect strong shelled eggs, uniform, and for hatching purposes, eggs that have a strong shell will be more likely to produce a healthy chick Grignon, (2016). Internal quality is measured focused on quality of albumen as shown by Haugh units (HU), the relative size of the different internal components such as yolk color, weight of yolk, and the integrity of the shell membrane. Several studies have examined egg quality in chickens Zamans *et al.* (2005). The albumen quality has a major influence on the overall interior egg quality and decrease in albumen height is indicative of quality loss. Albumen of an egg is made up of jelly-like thick albumen and watery thin albumen which varies in their consistency by Ikgadimeng *et al.*(2013).

The albumen quality is measured in terms of Haugh units (HU) calculated from the height of the albumen and the weight of the egg Coutts and Wilson, (2006). A minimum measurement of HU for egg reaching the end users is 60 HU. Most of the eggs leaving the farm should be between 75-85 HU by Zamans *et al.* (2005). Egg with a good albumen quality should be free from internal blemishes such as blood spots and meat. Change in pH of egg will result in the loss of the thick albumen protein structure, and then the watery albumen will be observed Ikgadimeng *et al.* (2013).

A fresh egg has a cloudy color of the albumen due to the presence of CO₂, which diminishes as the egg ages causing the albumen to become transparent. Albumen quality is a quantitative genetic characteristic by Farhad *et al.*(2011). When the age of hen increases; albumen, yolk weights, and egg weight increase while there is little /no effect on shell weight by Silversides *et al.*(2007). The Haugh Unit (HU) is popularly calculated to evaluate the egg quality. The best qualified eggs shown 80 - 100 HU (lower levels as 65-79 HU (good), 55-64 HU (moderate) and <55 HU (bad). The Haugh unit were decreased from (farmer's management) 72.67 ± 1.53 to (Research station) $71.54 \% \pm 2.86$ in Bhutanese chicken breeds. Significance difference was observed for Haugh Unit between different management conditions in Bhutanese chicken breeds by Dorji, (2013). The Haugh unit of local chickens was lower (71.40 ± 1.48 than exotic in farm (74.42 ± 1.68 and market (73.23 ± 1.50) conditions. Haugh unit value has been reported depend mainly on storage condition and strain of eggs Hussain *et al.* (2013).

2.8.1. Egg weight

Egg weight has been explained as a primary egg production trait and numerous factors has influenced the weight eggs, among them were the age and genotype of laying hens by Rahimi, (2011). Among the crosses of local kei, Rhode Island Red and Fayoumi, RIR crosses had shown significantly higher egg weight (44.2 ± 2.94) than Fayoumi crosses (40 ± 1.83) and kei local (38 ± 1.98) under farmer management condition (Melesse et al, 2012). The egg weight of Vanaraja chickens was significantly higher (57.3 ± 0.12) than indigenous chickens (42.48 ± 0.39) at 40 weeks of age at north western Himalaya Varun *et al.*(2017). Similarly, the difference in egg weight could be due to different management, age of production, level of egg production and different agro-ecological conditions among different studies Islam *et al.* (2010).The amount and quality of egg yolk is associated to egg weight Lalev *et al.* (2010).

2.8.2. The egg shell weight

The variations in egg shell quality depend on the environmental conditions, the feed quality and strain of layers. Furthermore; findings have shown that the mean value of egg shell weight has been comparatively lower in indigenous eggs (4.89 ± 0.06) than commercial (5.08 ± 0.08) chickens by Hussain *et al.*(2013). According to Wang *et al.*(2009), Dongxiang blue-shelled layers had lower egg shell weight in outdoor than cage housing systems with (6.19 ± 0.05) and (6.30 ± 0.05) respectively, in China. According to Lalev (2013), two egg layer hybrids had significantly different egg shell weight with (6.49 ± 0.13) and (6.07 ± 0.10) respectively.

Plus, other two egg layer hybrids have also shown significantly different egg shell weight of (6.84 ± 0.11) and (6.23 ± 0.07). The four layer hybrids have shown statistically significant different in Bulgaria Lalev, (2013). The Rhode Island Red (RIR) had higher egg shell weight (5.20 ± 0.20) than the Bovans White (WB) chickens (5.03 ± 0.25) under intensive management in Mekelle but was not significantly different Niraj *et al.*(2014).

2.8.3. Egg shell thickness of chickens (mm)

The Eggshell thickness without inner and outer membranes was measured at the blunt, equatorial, and sharp regions to get the average value by Van Den Brand *et al.*(2004). According to Wang *et al.*(2009), Dongxiang blue-shelled layers had no significant difference in egg shell thickness both in outdoor and cage housing systems with (0.33 ± 0.01) and (0.33 ± 0.01) respectively, under cage and outdoor housing system in China. Furthermore; findings have shown that the mean value of shell thickness has been comparatively higher in indigenous eggs (0.53 ± 0.003) than commercial (0.24 ± 0.001) Shell thickness has negative correlation with egg production and has been confirmed at indigenous chickens have higher egg thickness but lower egg production than the commercial chickens Hussain *et al.*(2013). According to Lalev, (2010), there was no significant difference among chicken breeds ranging from 0.35 to 0.37 mm in egg shell thickness.

2.9. Carcass Characteristics of the Chicken Ecotypes

Previous studies have reported the differences in carcass and meat quality traits between slow- growing and fast-growing chicken lines Chodova *et al.*(2021). Dramatic changes in the market forms for poultry in recent years, from a predominantly whole bird commodity to modern highly diversified industry based on cut up, deboned meat and process-to-eat products have resulted in a change of quality expectation. Genotype plays a major role in chicken carcass fatness De Smet *et al.*(2004), Shahin and Elazeem,(2005). Understanding factors that affect improving the poultry productivity would improve protein nutrition and could increase the income levels of the rural population.

In addition, consumers prefer meat from indigenous chickens, because of its leanness. Chickens meat consumption has changed from whole bird to cut-up or further processing modes. Previously it was sufficient to measure performance using body weights. Experiments now often include commercial parts analyses or body chemical composition, or both. Commercial parts always include the portion of breast meat, often without skin.

This is because of the usually greater value of breast for cut-up or in further processing. Other commonly reported parts include thighs, drumsticks, and wings. Body chemical composition is based either on the whole bird including feathers or sometimes on the whole processed (oven ready) bird. The male chickens had significantly bigger carcasses than females at all ages. Enhancing acidity of the maturing carcass varies in its speed, depending on a number of factors such as type of animal, breed, rearing characteristics, and treatment of the animal prior to slaughter. Modern consumers seek meat that is low in fat, tender, and juicy, with good flavour and aroma Walley *et al.* (2015). Indigenous chickens are also have better meat quality, with higher protein content and less fat compared to imported broiler chicken Makchumpon *et al.* (2015).

2.10. The pH measurement and color of indigenous chicken meat

The pH value of the chicken meat is also regarded as paramount crucial to meat quality as it influences the structure of myofibrils and in turns the colour of the meat by Dyubele *et al.*(2010). The rate and extent that muscle pH declines post slaughter are both variable and have a great impact on the color of meat and meat products. It is an indirect measure of meat color and has an effect on enzymatic activity and rate of oxygenation. There is an enhancing preference for local chicken meat over commercial poultry due to their meat qualities by Sheng *et al.* (2013). The acidity of meat is important in relation to the meat's microbiological and keeping quality.

In the live animal the pH-value of the muscular tissue is about 7.0 to 7.1. Very soon after slaughter a drop in the pH-value is observed and after several hours (24 hours or less) the pH-value reaches its lowest level of about 5.6 to 5.8. Enhancing acidity is because of the post-mortem formation of lactic acid from glycogen, a sugar-like substance stored in the live animal's muscles for energy supply. The rate of pH decline or lack thereof also has an impact on the water holding capacity of the meat sample. Sharp declines in pH are generally associated with meats that have a lower water binding capacity in contrast to meats with a small decline in pH that tend to have a much higher water binding capacity Heinz & Hautzinger, (2007).

The effect of pH on water binding capacity is an important factor concerning meat quality as the presence of the moisture based defects PSE and DFD can have detrimental effects when concerning the cooking and eating quality of the meat Heinz & Hautzinger, (2007). As findings reported by Wideman *et al.* (2016), after slaughtering, postmortem glycolysis is activated and accumulation of lactic acid in the muscle is increased, which results in a pH decline). The dramatic pH decreases are related with protein denaturation, causing paleness, negatively affects the meat quality, low water-holding capacity, and soft texture Petracci and Cavani, (2012).

The darker color of leg/thigh meat is due to the larger amount of myoglobin and haem pigments, as well as relatively a higher pH when compared to breast meat Wideman *et al.* (2016). It was noted that the red fibers are (high in myoglobin) as compared to white fibers and hence contributed to the thigh meat color to have a lower lightness value Barbut, (2001). This was due to the leg and thigh meat has a higher proportion of red muscle fibers, while the breast meat is almost entirely composed of white fibers. Higher yellowness color content of the thigh muscle may be related to the higher intramuscular fat content of the meat cut from this muscle portion Fanatico *et al.*(2005).

2.10.1. Water-holding capacity (WHC) of chicken meat

As the consumption of chicken meat continues to grow more emphasis is placed on fresh meat quality traits. WHC defined as the ability of meat to retain inherent or added water through processing and storage. WHC of fresh chicken meat is crucial because it has influences product yields for sensory quality for consumers and processors. Many approaches have been developed for measuring WHC, however all categorized into 3 basic classes: measuring fluid weight loss with the application of no external force, with the application of a mechanical force, or with the application of a thermal force Honikel, (2009). Those approaches are both destructive to the product and time consuming. Investigation of WHC in fresh meat is further complicated by the fact that WHC changes with postmortem processing, storage, and preparation of meat.

Therefore, there is a need to develop a rapid, nondestructive approach for measuring WHC in fresh chicken meat that can be used as a basis for detecting poor WHC and segregating product in a commercial setting. The water released can be described as cooking loss, drip loss, which is inversely related to water holding capacity Warner, (2017).

2.10.2. Drip loss of chicken meat

Meat with higher drip loss proved to be more acid, less red, lighter and more yellow with higher level glucose potential. A relationship between natural drip loss and other meat quality traits has been provided by many research findings. Negative correlation between drip loss, and ultimate pH in chicken meat was presented by studies of Jlali *et al.* (2012) and Beauclercq *et al.* (2017). A numerous studies showed significant differences in drip loss, color parameters, and protein content between normal and defective chicken meat Mudalal *et al.* (2014). Consequently, Schilling *et al.* (2017) shown significant correlation between more intensive glycolytic changes and decreasing meat quality, for example drip loss. As reported by Nguyen *et al.* (2020) the sexes did not vary in the cooking loss and drip loss values ($P>0.05$), whereas it was significantly different due to cold-storage time ($P<0.05$). At 4°C condition, the increasing storage time negatively reduced the drip loss (2.70 % - 1.61%).

2.11. Meat of Indigenous Chicken Proximate Analysis

In recent years, with the fast economic growth and globalization of the food industry, enhancing attention has been paid to the consumption and production of chicken meat. Chicken meat is rich in amino acids, proteins, polyunsaturated fatty acids (PUFA), carbohydrates, fat, and low in minerals, which is considered as one of the most desirable meats all over the world Kamboh and Zhu, (2013). Because of the balanced nutritional components, regular dietary intake of chicken meat has been suggested to reduce the incidence of many diseases and exert a beneficial effect on human health Jayasena *et al.*(2013).

Furthermore, the price of chicken meat is much cheaper than red meat (such as beef, and lamb meat), which also widely advertise the production and consumption of chicken meat. As report of Liu *et al.* (2012) and Jayasena *et al.* (2013) found that per capita consumption of chicken meat has increased approximately five folds during the last four decades in Korea. Genetics has been considered as the major factor that influences meat quality of chickens in previous studies Zhao *et al.* (2011). The nutrition value and physicochemical properties have been noted as the most crucial aspects in consumer perception of meat and meat products.

Generally, the indigenous poultry are a slow growing type with a low carcass weight FAO, (2004) and are reared mainly for meat production and secondarily egg production. Modern consumers perceive the meat from animals that have been produced in alternative production systems (organic) as safer due to the presumed absence of chemical residues Amao *et al.* (2011). The demands and expectations of the modern consumer could be a result of their being more scientifically informed and this has put pressure on the various supply chains within the industry to supply this information by Munisi *et al.* (2015). A higher guarantee of the absence of residues within organic meats has been well reported. Around 75 % of muscle has been confirmed made up of water, and 20 % protein, with the remaining 5 % constituting fat, carbohydrates, and minerals by Kalita *et al.* (2011).

The meat from poultry tends to vary in composition between species by Abdullahi *et al.* (2010). Chickens have both light and dark meats (caused by different muscle fibers) which differ in nutrient profile, contributing to differences in nutrient profile within species by Varun *et al.* (2016). Factors that may affect within species differences include strain, diet feeding, environment, and processing by Misba *et al.* (2013). The protein content of chicken meat is variable, ranging from 16-24 % by Owens *et al.* (2010). The nutritional value of a meat product is closely linked to the content of high quality proteins, which are characterized by their content of essential amino acids. Fat occurs as both intra, and extra-muscular fat, and contributes largely to the flavor and juiciness of the meat. There is generally an inverse relationship between moisture and intramuscular fat content, as moisture increases so fat decreases, and vice versa by Owens *et al.* (2010).

Ash represents the mineral portion constituting roughly 1% of the muscle composition and is primarily represented by the elements potassium, phosphorus, sodium, chlorine, magnesium, calcium and iron Hui, (2012). Muscles will tend to contain roughly the same amount of carbohydrate (1%) which is represented primarily by glycogen ante-mortem and lactic acid postmortem, although the contribution of carbohydrate is generally assumed to be zero by Owens *et al.* (2010).

2.11.1. Nutritive Value of Indigenous chickens' Meat

One of the reasons for the popularity of chicken is that like other “lean” meats, it has been reported to be healthier than other animal protein sources Daniel *et al.* (2011). Meat quality is a function of the genotype, nutrition and rearing practices. Further, the genotype of birds is also known to play an important role in the nutrient composition (proximate composition and amino acid profile) of the meat. Chicken meat is considered a staple of the human diet, providing an important source of animal protein and other nutrients Delgado *et al.* (2021). It is more acceptable than red meat due to low cholesterol, fat and high protein contents, which are important human health considerations by Tunim *et al.* (2021). According to recent statistics, poultry are more widely raised and consumed as reports of Magdelaine *et al.* (2008). In particular, the market of indigenous chickens is rapidly growing by Tang *et al.* (2009).

The majority of people prefer indigenous chicken meat over broiler chicken meat because of its distinct taste and flavor and the lack of potentially dangerous substances such as drug residues, intoxicants, allergenic components, and microbial contamination, all of which can contribute to health issues Charoensin *et al.* (2021). Nutrient composition of meat did differ among different types of available chicken. The meat quality can be affected by the different degree of maturity of the strains at slaughter age by Castellini *et al.* (2002). A chemical composition of meat can be affected by genotype, production system, diet and other factors (Meluzzi *et al.* (2009). Tang *et al.* (2009) demonstrated that, meat from slow growing genotypes contain higher fat as compare to the fast-growing genotypes.

CHAPTER 3. MATERIALS AND METHODS

3.1. Description of the Study Site

The study was conducted in four districts of Gambella regional state of Ethiopia namely; Abobo, Gambella Ketema Zuria, Itang and Lare (Figure.1). The Gambella People's Regional State (GPRS) is located South West of Ethiopia between the geographical coordinates 6° 28'38" to 8° 34' North Latitude and 33° to 35°11'11" East Longitude, that covers an area of about 34,063 km². The Region is bounded to the North, North East and East by Oromia Regional State, to the South and South East by the South West Regional State and to the Southwest, West and Northwest by the Republic of South Sudan. The mean annual temperature of the Region varies from 17.3°C to 28.3°C and monthly temperature varies throughout the year from 27°C to 35°C. Absolute maximum temperature occurs in mid-March and is about 45°C. Annual rainfall of the Region in the lower altitudes (500 m.a.s.l.) varies from 900-1500 mm. At higher altitudes (1900 m.a.s.l.), it ranges from 1,900-2,100 mm. The annual evapo-transpiration in the Gambella reaches about 1,612 mm and the maximum occurs in March is about 212 mm. Livestock population of the region is 321,722 cattle, 27,789 sheep, 135,494 goats, 636 horses, 577 donkeys, 314,680 Chicken, 77,902 bee colonies (CSA, 2020/21). The major crops grown both for consumption and sale are maize and sorghum. Rain fed and recession area farming makes it possible to produce maize in two different seasons.

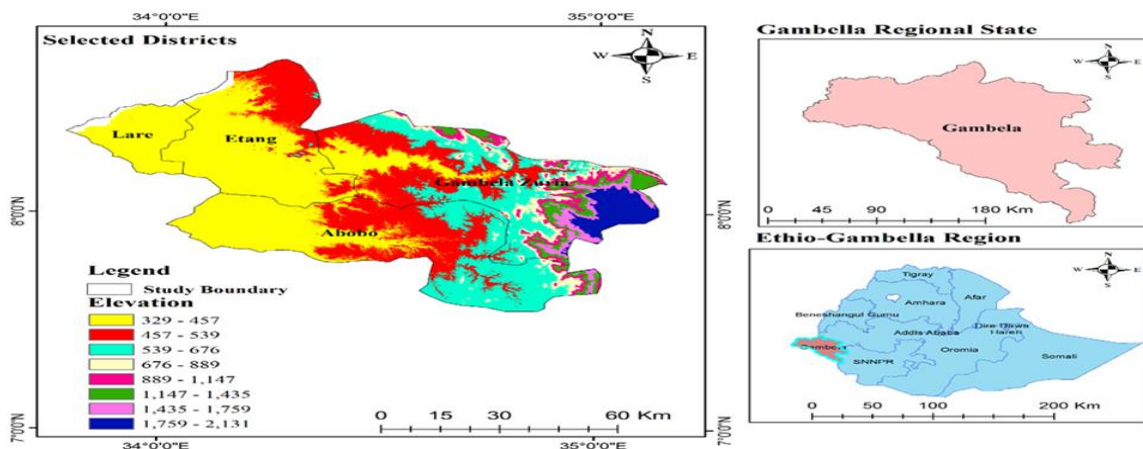


Figure 1. Map of the study areas

3.2. Study Population and Design

Chicken farmers and indigenous chickens kept by the households represented the study populations. Cross-sectional studies were conducted to collect data using the questionnaire. On-farm observations, on-station evaluation, and laboratory analysis were also conducted on relevant data.

3.3. Sampling Techniques and Data Collection Procedures

The field survey technique and data collection procedure were performed according to the FAO's exploratory characterization approach FAO, (2012). Four districts were purposively selected based on population density of chickens and accessibility of infrastructure from 13 districts of the regional state namely: Abobo (Ab), Gambella Ketema Zuria (GKz), Itang (It), and Lare (La). Therefore, 96 households who possess a minimum of five adult chickens of indigenous ecotypes per household were randomly chosen from each district. Accordingly, a total of 384 households (96 household's $\times$ 4 districts) were used in the interview and phenotypic characterization study. The households possessing exotic chicken or their crosses in the neighborhood were purposely excluded from the study.

3.4. Methods Used for Data Collection

The techniques used to collect data based on the objectives of the study were questionnaire survey, on farm observations, on-station evaluation, and laboratory analysis.

3.4.1. Questionnaire survey

The primary data were collected through interviews using a semi-structured questionnaire which was designed to collect data on flock characteristics, flock composition and production performances of the chickens (Figure 2). The interviews were conducted at farmers' houses. Moreover, phenotypic characterization of both qualitative and quantitative traits of local chicken populations was conducted on a total of 600 indigenous

chickens of both sexes: 150 chickens (50 males and 100 females) from Abobo, 150 chickens (50 males and 100 females) from Gambella Ketema Zuria, 150 chickens (50 males and 100 females) from Itang and 150 chickens (50 males and 100 females) from Lare on matured chickens with approximately six months and above. Qualitative phenotypic data were collected based on feather morphology, feather distribution, plumage colour, shank colour, earlobe colour, comb, and head types following the check list for phenotypic characterization of chickens FAO, (2012). Quantitative data on body weight, body length (the distance from the insertion of the neck to the tail), shank length (length of the shank from the top of the flexed hock joint to the bottom of the footpad), wattle length, neck length, comb length, comb height, keel bone length and, wingspan were collected from both sex groups following the FAO's descriptor check list for chicken genetic resources FAO, (2012). Shank length, comb length, comb height, wattle length, keel bone length, wingspan, body length and neck length were measured using a tailor's graduated tape and the live body weight was measured in gram to the nearest digit using a hanging scale.



Figure 2. Orientation for survey data collectors for interviewing households

3.4.2. Eggs quality parameters

A total of 120 eggs (30 eggs from each district) collected from households in the study districts were used to investigate the egg quality in terms of egg weight, egg length, egg width, albumen weight, yolk weight, shell thickness (from the narrow, middle and wide parts), shell weight, yolk color, Albumen height, yolk height, yolk width and Haugh Units Score (HU). All weight data were taken by sensitive balance. The shell thickness was the average of the thickness of blunt, middle and sharp points of the egg and was measured using a micrometer gauge. Yolk color fan consisting of a series of fifteen colored plastic strips was used as a reference to determine yolk color, with 1 rated as very pale yellow and 15 as deep intense reddish orange. Yolk height and albumen height were measured by tripod micrometer. Albumen of the broken eggs was carefully separated from the yolk. Albumen and yolk weights were measured by using sensitive balance. The average Haugh Unit values for each district were calculated by using the formula given by Stadelman and Cotterill, (1986).

The Haugh Unit (HU) calculated as followed:

$$Haugh\ Unit\ (HU) = 100\ Log[H - \sqrt{G}(\frac{30W^{0.37} - 100}{100} + 1.9)]$$

Where, HU = Haugh unit, G = Gravitational constant, 32.2, H = Albumen height (mm), and W= weight of egg.

3.4.3. Fertility, embryonic death and hatchability for on-station evaluation

Eggs laid during one week up to 10 days were collected from households these included during the phenotypic characterization from the selected districts and transported to Gambella University for fertility, embryonic death, and hatchability analysis. The collected eggs were labeled with the code given to the districts at the time of collection from the respective households of keeping only the indigenous chickens from each districts. A total of 1600 eggs (400 eggs from each districts) were collected and transported to the university. After arrival to the university, the eggs were again sorted for their appropriate size; cleanness and the debris were washed out by using water and alcohol mixed to save the air pores of the eggs shell.

And finally, a total of 880 eggs (220 eggs from each districts) were incubated using the incubator at Gambella University for hatching purpose. The incubation temperature, humidity and turning device were adjusted according to the recommendations of the manufacturer.

3.4.3.1. Candling process

Candling of incubated eggs was done on the 7th, 14th and 18th day of the incubation. A Candling was carried out on the 18th day of incubation for the identification of fertile eggs, and clear eggs. Candling process was carried out in a dark room using a Candler fixed with a neon fluorescent tube. Eggs were placed on the Candler for easy penetration of light through the eggs and the eggs were viewed against the source of light. Fertile eggs were seen to be densely clouded and opaque with network of veins indicating development of embryo within the eggs while the infertile eggs were translucent under the light. Number of embryonic mortality and infertile was recorded. After candling, the fertile eggs were transferred into the hatching tray according to the ecotypes into the hatchery unit and spent three days. After the chicks hatched, they were left in the hatchery until 90% were dried. At the 21st day, the numbers of hatched chicks including the normal, weak, abnormal chicks and dead chicks after hatch were recorded. Finally, fertility was calculated for the 220 eggs collected from each district's as:

$$Fertility(\%) = \frac{\text{total number of fertile eggs}}{\text{total number of eggs set}} \times 100$$

Mortality: Mortality (on hatching day) was recorded throughout the study period.

$$Mortality(\%) = \frac{\text{total number of dead chicks}}{\text{total number of chicks hatched}} \times 100$$

Embryonic death results were calculated based on developed chicks checked while candling as:

$$Embryonic\ death\ (\%) = \frac{\text{total number of died chicks in eggs before hatched}}{\text{total number of fertile eggs developed embryo}} \times 100$$

The hatchability values were calculated based on the formula of the following as:

$$\text{Hatchability}(\%) = \frac{\text{total number of chicks hatched}}{\text{total number of fertile eggs after candling}} \times 100$$

3.5. Experimental Design for On-Station Evaluation

A total of 649 indigenous chicken strains from four districts namely Abobo (181), Gambella Ketema Zuria (169), Itang (151), and Lare (148) artificially hatched were kept at the on-station for growth, egg production performance, egg nutritive value, and carcasses evaluation. Each strain was kept separately in a well ventilated house. Feed-trough, water-trough, and nests placed in the chicken pens houses and biosecurity was put in place. Chicken had been vaccinated towards Gumboro, Fowl Typhoid, and Newcastle and regular managerial practices had been followed. These included deworming after every three months and provision of compounded rations according to body requirements, with clean water throughout the day. Completely randomized design (CRD) was used. The watering troughs, feeding troughs, and laying nests were thoroughly cleaned, disinfected, and sprayed against external parasites before the commencement of the experiment. The ground of every pen was bedded with disinfected grass hay and changed when deemed appropriate. Birds were fed the same commercial starter (up to week 8), grower (week 9 to week 18) and layer rations (Table 1).

All layers during the laying period were subjected to similar management, and received a total of 16 hours of light daily (i.e. 12 hours of day light and 4 hours of electric light). Florescent lamps of 36 watt were used to deliver about 30 lux of light intensity at the feeder trough level in experimental house. The ethical clearance was provided by College of veterinary medicine and Agriculture committee with the ref. number of VM/ERC/01/12/020, 03/01/2020. The mortality was registered as it occurred and general health status was monitored throughout the experiment. Vitamins were given as supplement through drinking water.

Table 1. Nutrient composition of the diet fed to experimental chickens

Nutrients	Starter	Grower	Layer
ME (ME-Kcal/kg)	3000.0	2950.0	2800.0
CP (% DM)	20.5	18.8	16.0
CF (% DM)	5.5	5.8	7.0
Ca (% DM)	0.9	0.9	3.55
Fat (% DM)	6.5	5.0	5.0
Moisture (%)	10.0	10.0	10.0

The composition is as prepared by the manufacturer (Alema Koudjis Feed PLC, Debre Zeit, Ethiopia); DM = Dry matter, CP (crude protein), CF (crude fiber), Ca (calcium), ME (metabolized energy)

3.5.1. Growth, carcass components and egg production performance

Body weight of chicken hatched from a total of 649 indigenous chicken strains of four namely Abobo, Gambella Ketema Zuria, Itang, and Lare measured. Chicks hatched have been weighed, and tagged observed with the aid of using periodic measurements after each four weeks. Chicks have been monitored from day-old with parameters for body weight, weight gain, age at the start egg, and egg production per hen. The variation in body weight between two consecutive measurements was divided by the number of days in the interval to obtain daily body weight gain. For the carcass characteristics, a sample of 8 chickens of each strain with equal sex was slaughtered at the age of 24 weeks for the carcass evaluation. The live weight of the chickens was taken immediately before slaughtering them.

Each chicken was slaughtered by cutting of jugular vein for proper bleeding; then it immersed in moderately hot water for 2 to 4 minutes in order to facilitate the de-feathering process manually. Finally, the carcass components were separated from the offal and the following commercial carcass components were determined: Breast meat exclusive of bone, thighs, drumsticks, wings, keel bone meat, skin, neck and giblets (heart, gizzard and liver).

The carcass components were measured by using a digital balance and the egg production was calculated based on the hen day egg production (HDEP) and hen housed egg production (HHEP) by the formula of:

$$HDEP = \frac{\text{total number of eggs produced per hen}}{\text{total number of hens alive at the end of experiment}} \times 100$$

$$HHEP = \frac{\text{total number of eggs produced per hen}}{\text{total number of hens initially housed}} \times 100$$

3.6. Meat Nutritive Value Analysis

Thirty-two matured live chickens (4 males and 4 females) from each chicken strains evaluated on-station research were taken at random for nutritive value investigation. At the age of 24 weeks, the selected indigenous chicken strains were separated from the flock and fasted overnight but drinking water was provided *ad libitum*. The chicken strains were bled by section of the jugular vein manually and were allowed to bleed for a period of three minutes by holding the bird's head down. The samples of breast, thigh and drumstick were collected to determine the nutritive value of the meat. The meat samples were transported from Gambella regional state to Addis Ababa, and Bishoftu for the analysis at the laboratory of Bless Food- Agri. laboratory service PLC, (ISO/IEC 17025:2017 accredited), and National Veterinary Institute.

Nutritive value (moisture, crude protein, crude fat, and ash) of the samples (meat) were determined according to the AOAC, (2011) methods. Moisture content was determined by drying 6 g of meat samples at 105°C to constant weight. The crude protein content was determined by the Kjeldahl method and the crude fat content was determined by the Soxhlet method. Each analysis was repeated twice using petroleum ether at 40-60°C.

The ash content was determined by charring followed by ashing the samples at 550°C to a white ash with twice repeated to determine ash content.

3.6.1. The Meat color and pH measurements

The meat color and pH measurement parameters includes (CIE L*, a* and b* values determined with L* indicating lightness, a* the red-green range, and b* the blue-yellow range) using HunterLab MiniScan illumination/viewing system, D65 light source, and 10° observer angle) were obtained using a digital colorimeter (Hunter Lab MiniScan EZ, Washington, DC, USA calibrated with black and white standardized plates between each measurement AMSA, (2012). Three readings at different locations per sample were taken and averaged. The portable pH meter (Meat pH meter-HI99163, HANAN instruments) equipped with an InLaB Solids Pro Puncture-type sharp blade electrode was used to measure meat pH. The procedure was done according to the manufacturer's instructions.

A sampled meat pH was measured at 45 mins and 24 hrs post-mortem. The readings per sample were taken and averaged. For the color measurement, the internal face of the cranial position of the filleted breast meat samples was freshly exposed on the flat surface of white background in the measuring room and allowed to bloom for about 45 min at ambient temperature ($24^{\circ}\text{C} \pm 1.2^{\circ}\text{C}$). A total of 32 chicken strains, 8/ecotypes, and 16/sex samples/cut were considered in this study. The sample of breast meat cut was averaged to determine the meat pH and color measurements.

3.6.2. The meat water holding capacity (WHC %)

The water holding capacity of meat was determined at 24 hrs postmortem using the method suggested by R.C. Whiting, and R.K. Jenkins, (1981). The two what-man number-one filter papers were weighed and meat sample was placed between two filter papers, this in turn was placed between two glass sheets. Over it, a weight of 2.015 kg weight was placed while the glass sheet weighed of 0.8278 kg sheet, giving a total compression weight 2.8428 kg load for 5 minutes. Finally, the weight was removed, and the meat was separated from the filter papers and weighed.

Lastly, the filter paper was dried and the weight was recorded. Consequently, the actual weight of meat after pressure treatment was calculated. Awater holding capacity (WHC %) was calculated as:

WHC (%) = $\frac{ASWBPT - ASWAPT}{ASWBPT} \times 100$ Where; ASWBPT = actual sample weight before pressure treatment, ASWAPT = actual sample weight after pressure treatment, furthermore, a total of 32 chicken strains, 16/sex samples/cut were considered in this study. The sample of breast meat cut was averaged to determine the water holding capacity (%) of each ecotypes and sex of the current study.

3.6.3. Drip loss (%)

The drip loss of the breast meat sample from the reared chicken strains was measured using a plastic drip method according to the procedure Honikel, (2009). The meat sample was excised and cut perpendicular to the fiber direction in the widest part of the sampled muscle. Samples were hung in an inflated plastic bag and stored in the refrigerator at 4°C for 24 hrs and reweighed. The four chicken strains and each sex were measured and equally replicated for the breast considered in the present study. A total of 32 chicken strains, 8/strains, 16/sex were used, and the data collected were averaged to determine the drip loss percentage of each strains and sex of the present study.

The drip loss (DL %) was calculated as: $DL (\%) = \frac{ISWT - FSWT}{ISWT} \times 100$, Where: ISWT= initial sample weight treatment, FSWT=final sample weight treatment.

3.7. Statistical Method of Data Analysis

Preliminary data exploration method (homogeneity test, normality test and screening of outliers) was employed before conducting the main data analysis. All data collected from survey, on-station, and laboratory tests were coded and recorded in Microsoft Excel sheet. Discrete measurements on the qualitative morphological traits were analyzed using the frequency procedure and body weight and quantitative linear body measurements were analyzed using the Generalized Linear Model procedures. All data collected from on-farm characterization, internal and external egg quality parameters, fertility, embryonic death, and hatchability were analyzed. Data on body weight, started from day old chicks weight, 4th, 8th, 12th, 16th, 20th, 24th weeks, age at first egg, egg number produced and meat components were analyzed. A fixed effects linear model was adjusted to the data and

includes the fixed effects of chicken strains/districts, meat parts, and sex. Districts were fitted as fixed independent variables, whereas quantitative measurements were fitted as dependent variables. All data collected was subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of the statistical analysis system (SAS) version 9.3. When differences were significant, comparisons of means were done by using Tukey's studentized range test method. The results were expressed as (LSM $\pm$ SE) used means that are computed based on a linear model and (Mean $\pm$ SD) used Observed Means. All statements of statistical differences in quantitative data were based on $P < 0.05$.

The statistical models used in the present study included were:

Model 1: Phenotypic characterization, and egg parameters of districts

$Y_i = \mu + D_i + e_i$, Where,

Y_i = an observation for a given variables

μ = overall mean.

D_i = effect of the i^{th} district (i = Ab, GKz, It, and La)

e_i = residual random error

Model 2: The meat nutritive value statistics used was:

$Y_{ijk} = \mu + D_i + PT_j + S_k + e_{ijk}$, Where,

Y_{ijk} = an observation for a given variables response

μ = overall mean

D_i = effect of the i^{th} district (i = Ab, GKz, It and La)

PT_j = effect of the j^{th} product type (j = breast, thigh, drumstick)

S_k = effect of sex (k = male, female)

e_{ijk} = residual random error

CHAPTER 4. RESULTS

4.1. The Flock Composition of Indigenous Chickens in the Study Area

The flock composition per households is shown in Table 2. The current research results showed that the average flock size per household in Abobo, Gambella Ketema Zuria, Itang, and Lare districts was 15.76 ± 0.03 , 13.72 ± 0.94 , 13.44 ± 0.41 , and 11.42 ± 0.01 , respectively. The overall average flock size per households in the study area was 13.59 ± 0.16 , and the total number of hens, cocks, cockerels, pullets and chicks was 4.89 ± 0.06 , 1.72 ± 0.05 , 1.52 ± 0.01 , 2.01 ± 0.02 and 3.44 ± 0.09 , respectively. The chicken population per household in Abobo district is significantly higher than others. There was non-significant difference ($P > 0.05$) in the mean number of chicks in Gambella Ketema Zuria, and Itang areas.

Table 2. Flock compositions of households in Gambella regional state (LSM $\pm$ SE)

Composition of flock.	District				LSMeans $\pm$ SE
	Abobo (N=96)	Gambella Ketema Zuria (N=96)	Itang(N=96)	Lare(N=96)	
Hens	5.24 ± 0.82^a	5.06 ± 0.54^a	4.97 ± 0.97^a	4.32 ± 0.98^b	4.89 ± 0.06
Cocks	2.23 ± 0.02^a	1.59 ± 0.95^b	1.50 ± 0.99^b	1.57 ± 0.97^b	1.72 ± 0.05
Cockerels	1.72 ± 0.23	1.45 ± 0.17	1.46 ± 1.00	1.44 ± 0.99	1.52 ± 0.01
Pullets	2.39 ± 0.22^a	1.95 ± 0.20^{ab}	1.93 ± 0.03^{ab}	1.76 ± 0.84^b	2.01 ± 0.02
Chicks	4.18 ± 0.36^a	3.66 ± 0.24^b	3.57 ± 0.99^b	2.33 ± 0.01^c	3.44 ± 0.09
Avn/chicken/HH	15.76 ± 0.03^a	13.72 ± 0.94^b	13.44 ± 0.41^b	11.42 ± 0.01^c	13.59 ± 0.16

^{a, b, c} means across a row with different superscript letters are significantly ($P < 0.05$) different. SE, standard error of the Least square means (LSM).

4.2. Reproductive and Productive Performance

The average age at the time of laying the first egg, the number of eggs /clutches/hen/year and the number of eggs per hen per year are presented in Table 3. According to the present study, the average age at the time of the first egg was significantly different ($P < 0.05$) in the study areas. Abobo and Gambella Ketema Zuria hens started laying 6.08 and 6.13 months earlier than those in Itang (6.26 months) and Lare (6.35 months).

The present study showed that the mean age at first egg laying was 6.20 months. The average number of eggs /clutch in Abobo chickens was significantly ($P < 0.05$) higher than that of other sites, and the difference in the average number of eggs per hen per year was not significant ($P > 0.05$) between the study areas (Table 3). The average number of clutches per hen per year was 3.69, 3.68, 3.64 and 3.60 in Abobo, Gambella Ketema Zuria, Itang, and Lare districts, respectively. The average number of eggs per clutch found in the present study was 14.56, 13.01, 12.85 and 12.76 in Abobo, Gambella Ketema Zuria, Itang, and Lare areas, respectively. Similarly, average egg production per hen per year of Abobo, Gambella Ketema Zuria, Itang, and Lare chickens was estimated as 53.72, 47.88, 46.77 and 45.94, respectively.

The present study showed that the overall mean egg production per hen per year was 48.64. Table 3 shows the mean number of incubated eggs (9.64) and hatched percentage (70.37) for this study. The mean survival rate of chicks in the current study was 58.14 %. As indicated in Table 3, significant variations were also observed in some performance traits of indigenous chickens among the studied districts such as eggs hatched per incubated and chicks survived.

Table 3. Reproductive and productive performance of indigenous chickens in Gambella region (LSMeans $\pm$ SE)

Parameters	District				LSMeans $\pm$ SE
	Ab (N=96)	GKZ(N=96)	It (N=96)	La (N=96)	
Age at first egg (months)	6.08 $\pm$ 0.07 ^c	6.13 $\pm$ 0.36 ^{bc}	6.26 $\pm$ 0.13 ^{ab}	6.35 $\pm$ 0.12 ^a	6.20 $\pm$ 0.08
Number eggs per clutch	14.56 $\pm$ 0.25 ^a	13.01 $\pm$ 0.23 ^b	12.85 $\pm$ 0.63 ^b	12.76 $\pm$ 0.14 ^b	13.29 $\pm$ 0.25
Number of clutches/hen/years	3.69 $\pm$ 0.01	3.68 $\pm$ 0.47	3.64 $\pm$ 0.18	3.60 $\pm$ 0.17	3.66 $\pm$ 0.01
Number of eggs per hen per year	53.72 $\pm$ 0.05 ^a	47.88 $\pm$ 0.06 ^{ab}	46.77 $\pm$ 0.08 ^{bc}	45.94 $\pm$ 0.04 ^c	48.64 $\pm$ 0.07
Eggs incubated per hen	10.74 $\pm$ 0.13 ^a	9.66 $\pm$ 0.12 ^b	9.58 $\pm$ 0.11 ^b	8.56 $\pm$ 0.04 ^c	9.64 $\pm$ 0.19
Eggs hatched per incubated	8.03 $\pm$ 0.33 ^a	6.78 $\pm$ 0.32 ^b	6.54 $\pm$ 0.31 ^b	5.67 $\pm$ 0.35 ^c	6.76 $\pm$ 0.36
Hatchability (%)	75.27 $\pm$ 0.10 ^a	70.41 $\pm$ 0.09 ^b	69.11 $\pm$ 0.08 ^{bc}	66.69 $\pm$ 0.05 ^c	70.37 $\pm$ 0.11
Hatched chicks survived	4.95 $\pm$ 0.22 ^a	3.94 $\pm$ 0.21 ^b	3.69 $\pm$ 0.13 ^b	3.22 $\pm$ 0.17 ^c	3.95 $\pm$ 0.23
Survivability (%)	61.73 $\pm$ 0.01 ^a	57.76 $\pm$ 0.04 ^b	56.58 $\pm$ 0.03 ^b	56.48 $\pm$ 0.01 ^b	58.14 $\pm$ 0.02

^{a, b, c} indicated among rows for traits significantly differ at $P < 0.05$., standard error(SE), Least Square means (LSM), Ab (Abobo), GKZ (Gambella Ketema Zuria), It (Itang), and La (Lare)

4.3. Phenotypic and Morphological Variations in Qualitative Traits

4.3.1. Plumage color, feather morphology and distribution

Variations in qualitative traits such as plumage color, comb type, earlobe color, head shape, and shank color of 600 indigenous chickens were evaluated in the study areas. The results indicated that the predominant plumage color of the indigenous chicken found in the Abobo and Gambella Ketema Zuria districts are red (21.33 % and 20 %) followed by black (16 %) and white (18 %) respectively (Table 4). The results of the current study indicated that the predominant plumage color of the indigenous chicken found in the Itang and Lare districts were black (24.67 %) and red (18.67 %) followed by red (18.67 %) and black (17.33 %), respectively (Table 4). The predominant body feather color of the hens reared in the study districts of Abobo and Gambella Ketema Zuria was brown (26 % and 23 %) followed by black (17 %) and white (21 %) respectively and the body feather color of the hens reared in the districts of Itang and Lare was black (29 %) and red (19 %) observed predominantly. Netch teterma body feather were observed in all the study areas in few numbers. As shown in figure 3, the dominant body feather colour of the cocks was red followed by black with other colours. The indigenous chicken populations studied in the four districts showed a total of eleven distinct plumage colors (Table 4).

Table 4. Plumage color variation of indigenous chickens in Gambella regional state (frequency %)

Parameters	District											
	Ab			G KZ			It			La		
	M	F	Total	M	F	Total	M	F	Total	M	F	Total
	N=50	N=100	N=150	N=50	N=100	N=150	N=50	N=100	N=150	N=50	N=100	N=150
Gebsuma*	9(18)	5(5)	14(9.33)	7(14)	11(11)	18(12)	15(30)	8(8)	23(15.33)	17(34)	9(9)	26(17.33)
Red	21(42)	11(11)	32(21.33)	18(36)	12(12)	30(20)	13(26)	15(15)	28(18.67)	9(18)	19(19)	28(18.67)
White	5(10)	13(13)	18(12)	6(12)	21(21)	27(18)	4(8)	13(13)	17(11.33)	3(6)	15(15)	18(12)
Black	7(14)	17(17)	24(16)	9(18)	13(13)	22(14.66)	8(16)	29(29)	37(24.67)	9(18)	17(17)	26(17.33)
Grey	--	5(5)	5(3.33)	1(2)	3(3)	4(2.67)	3(6)	7(7)	10(6.67)	1(2)	5(5)	6(4)
Kokima*	2(4)	9(9)	11(7.33)	3(6)	7(7)	10(6.67)	1(2)	3(3)	4(2.67)	--	11(11)	11(7.33)
Key Teteruma*	--	3(3)	3(2)	--	2(2)	2(1.33)	-	1(1)	1(0.67)	1(2)	3(3)	4(2.67)
Lebework*	2(4)	7(7)	9(6)	1(2)	2(2)	3(2)	3(6)	5(5)	8(5.33)	5(10)	2(2)	7(4.66)
Tikur gebzat*	1(2)	4(4)	5(3.33)	3(6)	1(1)	4(2.67)	3(6)	--	3(2)	3(6)	1(1)	4(2.67)
Brown	1(2)	26(26)	27(18)	--	23(23)	23(15.33)	--	17(17)	17(11.33)	1(2)	18(18)	19(12.67)
Netch teteruma*	2(4)	--	2(1.33)	2(4)	5(5)	7(4.67)	--	2(2)	2(1.33)	1(2)	--	1(0.67)

Ab (Abobo), GKZ (Gambella Ketema Zuria), It (Itang), La (Lare), Gebsuma = Greyish with varying mixture; Lebework = White with golden breast color; Netch teteruma = white with black or red spots; Tikur gebzat = black with wheaten or red strips; Key teteruma = Red with white or blackspots; Kokima = grayish strips on brown background.*Names of plumage colors are in Amharic, Official Working Language of Ethiopia*



Figure 3. Plumage color distributions indigenous chickens in the study areas.

The results of this study showed that 33.33 % of the observed chickens were male and 66.67 % were female. In the investigated chicken populations, the distribution of feathers was normal and the rare naked-neck was observed (figure 4). In Abobo, Gambella Ketema Zuria, Itang, and Lare study areas, the normal distribution of plumage was dominant in the chicken populations at 88.67 %, 94 %, 90 %, and 92.67 %, respectively. While naked-neck feathers were dominant in Abobo and Itang study areas (Table 6). Most of the chicken populations in Abobo (98 %), Gambella Ketema Zuria (95.33 %), Itang (96.67 %) and Lare (96 %) were plain headed and those in Gambella Ketema Zuria (4.67 %) were relatively crested headed (Table 6). However, in the present study, feathered shank hens were rarely observed in Abobo (1.33 %), Gambella Ketema Zuria (0.67 %), Itang (2 %) and Lare (2.67%) (Table 6). Among the investigated chicken populations, four comb types were observed in single, double, strawberry, and rose comb types, respectively (Table 5).

The single combed chicken populations from Abobo, Gambella Ketema Zuria, Itang, and Lare were observed with frequency of 78.67 %, 83.33%, 84.67 % and 76.67 %, respectively, whereas double comb were 19.33 %, 12 %, 13.33 % and 20.66 % in the respective districts. Three shank colors were observed in both sexes of the studied indigenous chicken populations (Table 5). The color of the shank in chickens was predominantly yellow in all districts. The proportion of chickens having yellow shanks was dominant in Abobo, (88.67%), Gambella Ketema Zuria (86 %), Itang (84.67 %), and Lare (82 %). Grey colored shank (15.33 %) was predominant in chicken populations of Lare district. In the current study four earlobe colors were observed in the characterized chicken populations (Table 5). The yellow earlobe was the commonest color in Abobo (58 %), Gambella Ketema Zuria (55.55 %), Itang (60.67 %) and Lare (42.67 %) districts. The proportion of chickens with yellow earlobe was almost comparable among studied districts.

Table 5. Morphological characteristics of indigenous chickens in Gambella regional state

Traits	District				N, (%)
	Ab N (%)	GKZ N (%)	It N (%)	La N (%)	
Feather morphology	--	--	--	--	--
Normal	150(100)	150(100)	150(100)	150(100)	600(100%)
Feather distribution					
Normal	133(88.67)	141(94)	135(90)	139(92.67)	548(91.33%)
Naked-neck	17(11.33)	9(6)	15(10)	11(7.33)	52(8.67%)
Shank color					
Red	5(3.33)	7(4.67)	2(1.33)	4(2.67)	18(3%)
Yellow	133(88.67)	129(86)	127(84.67)	123(82)	512(85.33%)
Grey	12(8)	14(9.33)	21(14)	23(15.33)	70(11.67%)

Ear lobe color					
White	12(8)	17(11.33)	11(7.33)	9(6)	49(8.17%)
White and Red	23(15.33)	19(12.67)	15(10)	35(23.33)	92(15.33%)
Red	28(18.67)	31(20.67)	33(22)	42(28)	134(22.33%)
Yellow	87(58)	83(55.33)	91(60.67)	64(42.67)	325(54.17%)
Comb type					
Single	118(78.67)	125(83.33)	127(84.67)	115(76.67)	485(80.83%)
Rose	1(0.67)	3(2)	2(1.33)	1(0.67)	7(1.17%)
Strawberry	2(1.33)	4(2.67)	1(0.67)	3(2)	10(1.67%)
Double	29(19.33)	18(12)	20(13.33)	31(20.66)	98(16.33%)
Head shape					
Plain	147(98)	143(95.33)	145(96.67)	144(96)	579(96.5%)
Crest	3(2)	7(4.67)	5(3.33)	6(4)	21(3.5%)
Hen spur					
Present	57(38)	61(40.67)	59(39.33)	64(42.67)	241(40.17%)
Absent	93(62)	89(59.33)	91(60.67)	86(57.33)	359(59.83%)
Shank feathered					
Present	2(1.33)	1(0.67)	3(2)	4(2.67)	10(1.67%)
Absent	148(98.67)	149(99.33)	147(98)	146(97.33)	590(98.33%)

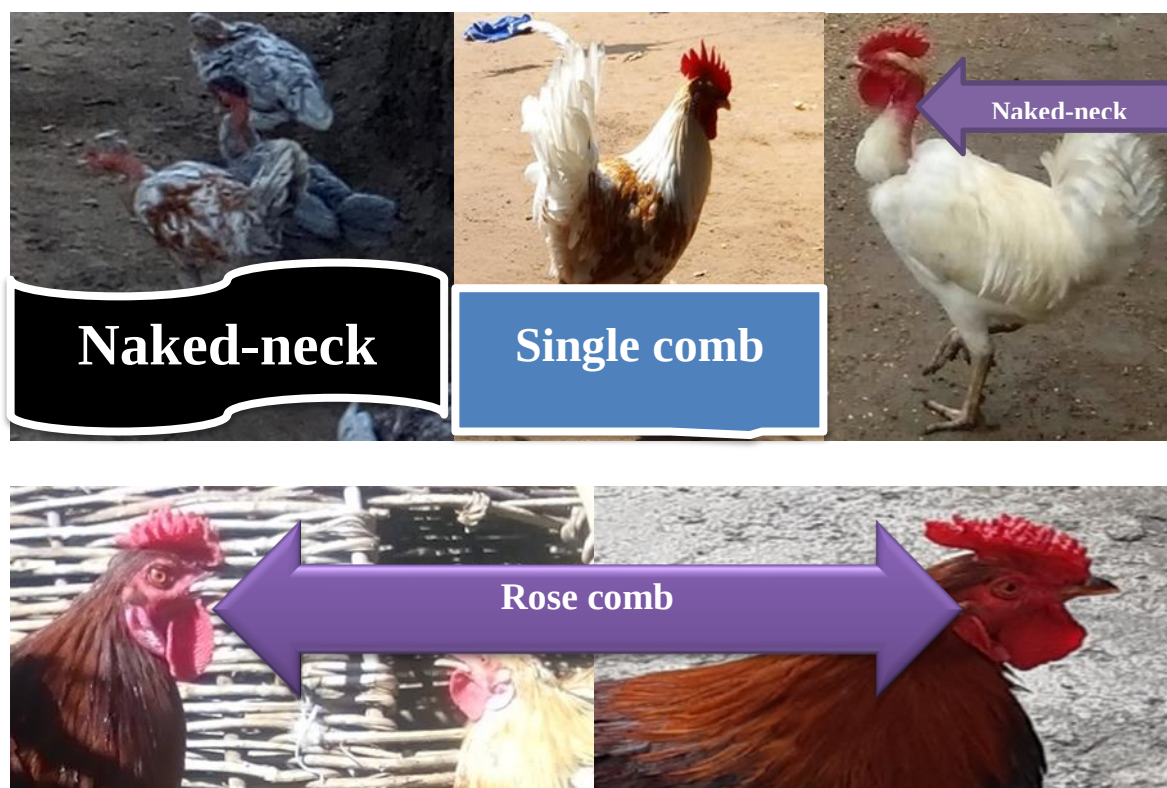


Figure 4. *Naked-neck, single and rose combs of indigenous chickens observed in the study areas*

4.4. Quantitative Traits and Their Variations in Both Sexes

The body weight and other measurements of male and female chicken populations in the four districts are presented in Table 6. The mean body weight of adult males and females were significantly ($P < 0.05$) different between the study districts. The adult male and female chickens in Abobo and Gambella Ketema Zuria were significantly heavier when compared to their counterparts in Itang and Lare districts. The body weight of adult males was 1.54 kg, 1.37 kg, 1.32 kg and 1.28 kg in Abobo, Gambella Ketema Zuria, Itang, and Lare district, respectively. While the body weight for adult females were 1.25 kg, 1.19 kg, 1.12 kg and 1.09 kg in Abobo, Gambella Ketema Zuria, Itang, and Lare districts, respectively. The overall mean body weight of adult male and female of studied chicken strains was 1.38 ± 0.02 and 1.16 ± 0.04 , respectively. The mean shank and keel length of adult males and females in Abobo and Gambella Ketema Zuria districts were significantly ($P < 0.05$) different from the other districts.

Table 6. Linear body measurements of indigenous chicken strains, (LSMeans $\pm$ SE)

Traits	Sex	Districts				LSMeans $\pm$ SE
		Ab(n = 150)	G KZ(n = 150)	It(n = 150)	La(n=150)	
Body weight (kg)	M	1.54 $\pm$ 0.04 ^a	1.37 $\pm$ 0.02 ^b	1.32 $\pm$ 0.02 ^b	1.28 $\pm$ 0.01 ^c	1.38 $\pm$ 0.02
	F	1.25 $\pm$ 0.01 ^a	1.19 $\pm$ 0.03 ^b	1.12 $\pm$ 0.02 ^b	1.09 $\pm$ 0.03 ^c	1.16 $\pm$ 0.04
Body length(cm)	M	38.92 $\pm$ 2.52 ^b	40.32 $\pm$ 3.48 ^a	40.22 $\pm$ 3.49 ^a	39.58 $\pm$ 3.91 ^b	39.76 $\pm$ 3.35
	F	37.35 $\pm$ 3.93 ^a	37.66 $\pm$ 1.96 ^a	37.24 $\pm$ 3.93 ^a	35.48 $\pm$ 2.07 ^b	36.93 $\pm$ 2.97
Neck length(cm)	M	18.04 $\pm$ 1.10	18.88 $\pm$ 1.16	18.87 $\pm$ 1.17	18.08 $\pm$ 2.35	18.47 $\pm$ 1.45
	F	17.29 $\pm$ 1.36	16.96 $\pm$ 1.25	17.19 $\pm$ 1.35	16.25 $\pm$ 0.94	16.92 $\pm$ 1.23
Shank length(cm)	M	10.46 $\pm$ 0.31 ^a	10.23 $\pm$ 0.76 ^a	10.11 $\pm$ 0.63 ^{ab}	9.95 $\pm$ 0.42 ^b	10.19 $\pm$ 0.53
	F	8.62 $\pm$ 0.31 ^a	8.59 $\pm$ 0.22 ^a	8.40 $\pm$ 0.25 ^a	7.81 $\pm$ 0.47 ^b	8.36 $\pm$ 0.31
Keel bone length(cm)	M	11.95 $\pm$ 0.50 ^a	11.72 $\pm$ 0.95 ^a	11.69 $\pm$ 0.96 ^a	11.29 $\pm$ 0.96 ^b	11.66 $\pm$ 0.84
	F	10.52 $\pm$ 0.49 ^a	10.22 $\pm$ 0.35 ^a	10.08 $\pm$ 0.89 ^{ab}	8.45 $\pm$ 0.26 ^b	9.82 $\pm$ 0.49
Wingspan(cm)	M	67.18 $\pm$ 5.41	65.42 $\pm$ 5.55	66.43 $\pm$ 5.54	64.06 $\pm$ 9.12	65.77 $\pm$ 6.41
	F	58.48 $\pm$ 6.01 ^a	56.55 $\pm$ 4.53 ^b	57.47 $\pm$ 6.01 ^b	54.82 $\pm$ 5.09 ^c	56.83 $\pm$ 5.41
Wattle length(cm)	M	3.67 $\pm$ 0.25	3.42 $\pm$ 0.62	3.43 $\pm$ 0.63	3.22 $\pm$ 0.32	3.44 $\pm$ 0.46
	F	1.00 $\pm$ 0.12	1.04 $\pm$ 0.10	1.01 $\pm$ 0.12	1.00 $\pm$ 0.08	1.01 $\pm$ 0.11
Comb height(cm)	M	2.23 $\pm$ 0.32 ^a	2.15 $\pm$ 0.4 ^{ab}	2.14 $\pm$ 0.43 ^b	2.06 $\pm$ 0.19 ^b	2.15 $\pm$ 0.35
	F	0.98 $\pm$ 0.06	1.02 $\pm$ 0.13	0.99 $\pm$ 0.05	0.97 $\pm$ 0.09	0.99 $\pm$ 0.08
Comb length(cm)	M	5.28 $\pm$ 0.57	5.35 $\pm$ 0.84	5.25 $\pm$ 0.85	5.23 $\pm$ 0.79	5.28 $\pm$ 0.76
	F	2.43 $\pm$ 0.19	2.57 $\pm$ 0.36	2.42 $\pm$ 0.18	2.39 $\pm$ 0.17	2.45 $\pm$ 0.23

Ab (Abobo), GKZ (Gambella Ketema Zuria), It (Itang), La (Lare), a, b, c Means within a row with different superscript letters are significantly different ($P < 0.05$)

4.5. Egg Quality Traits

The external egg quality traits such as, egg weight, egg length, egg width, shell weight, and shell thickness were presented in Table 7. The mean value of egg weight in the current findings was 39.15 g. The mean value of the egg length and egg width of the studied ecotypes was 48.98 mm and 37.55 mm, respectively. The mean value of the shell thickness in the current study was 0.28 mm. The mean value of the eggshell weight was 3.11 g. The internal egg quality traits such as albumen height (mm), albumen weight (g), yolk height (mm), yolk width (mm), yolk weight (g), yolk color (1-15), and Haugh unit were presented in (figure 5 and Table 7). The mean value of the albumen height of the current study was 4.17 mm. The mean value of the albumen weight of the current study was 20.53 g. The current study revealed that the mean value of the yolk height and yolk width were 13.59 mm and 37.98 mm, respectively. The mean value of the current study on haugh unit (HU) of the indigenous chickens reared in the studied areas was 68.48.



Figure 5. Yolk color identification

Table 7. The external and internal egg quality traits of indigenous chicken populations (LSMeans $\pm$ SE)

Parameters	District				LSMeans $\pm$ SE
	Ab (N=100)	GKZ (N=100)	It(N=100)	La (N=100)	
Egg weight (g)	38.97 $\pm$ 0.23 ^b	41.55 $\pm$ 0.29 ^a	38.02 $\pm$ 0.21 ^b	38.04 $\pm$ 0.22 ^b	39.15 $\pm$ 0.24
Egg length (mm)	48.49 $\pm$ 0.04 ^b	50.15 $\pm$ 0.09 ^a	48.37 $\pm$ 0.06 ^b	48.91 $\pm$ 0.08 ^b	48.98 $\pm$ 0.07
Egg width (mm)	37.11 $\pm$ 0.22 ^b	39.10 $\pm$ 0.29 ^a	36.96 $\pm$ 0.24 ^b	37.02 $\pm$ 0.26 ^b	37.55 $\pm$ 0.25
Shell weight (g)	3.06 $\pm$ 0.03 ^b	3.31 $\pm$ 0.08 ^a	3.02 $\pm$ 0.06 ^b	3.05 $\pm$ 0.04 ^b	3.11 $\pm$ 0.06
Shell thickness (mm)	0.28 $\pm$ 0.23 ^b	0.32 $\pm$ 0.27 ^a	0.24 $\pm$ 0.23 ^d	0.26 $\pm$ 0.25 ^c	0.28 $\pm$ 0.26
Albumen height (mm)	4.15 $\pm$ 0.01	4.29 $\pm$ 0.03	4.11 $\pm$ 0.01	4.13 $\pm$ 0.02	4.17 $\pm$ 0.01
Albumen weight (g)	20.27 $\pm$ 0.13 ^b	21.68 $\pm$ 0.17 ^a	19.97 $\pm$ 0.15 ^b	20.21 $\pm$ 0.16 ^b	20.53 $\pm$ 0.15
Yolk height (mm)	13.55 $\pm$ 0.07 ^b	14.16 $\pm$ 0.11 ^a	13.21 $\pm$ 0.09 ^b	13.43 $\pm$ 0.08 ^b	13.59 $\pm$ 0.09
Yolk width (mm)	37.73 $\pm$ 0.12 ^b	39.08 $\pm$ 0.15 ^a	37.42 $\pm$ 0.14 ^b	37.69 $\pm$ 0.11 ^b	37.98 $\pm$ 0.13
Yolk weight(g)	13.90 $\pm$ 0.07 ^{ab}	14.26 $\pm$ 0.09 ^a	13.41 $\pm$ 0.06 ^{bc}	13.71 $\pm$ 0.08 ^c	13.82 $\pm$ 0.08
Yolk color (1-15)	5.21 $\pm$ 0.01 ^{ab}	5.39 $\pm$ 0.05 ^a	5.13 $\pm$ 0.02 ^b	5.17 $\pm$ 0.04 ^b	5.23 $\pm$ 0.03
Haugh unit	68.28 $\pm$ 5.31	69.83 $\pm$ 6.23	67.46 $\pm$ 6.12	68.35 $\pm$ 5.72	68.48 $\pm$ 5.85

^{a, b, c} Means with different superscripts across districts are significantly different ($P < 0.05$). Ab: Abobo, GKZ: Gambella Ketema Zuria,

It: Itang, La: Lare,

4.6. Fertility, Embryonic Death and Hatchability of Eggs hatched using Artificial Incubator

Total values and percentages of egg set, fertility, embryo death and hatching for all ecotypes of chickens studied are given in Table 8. The total number of eggs set for Abobo, Gambella ketema Zuria, Itang and Lare ecotypes was 880 (220 from each ecotype), respectively. Fertility was 89.09 %, 85.45 %, 81.36 % and 78.18 % for Abobo, Gambella ketema Zuria, Itang, and Lare ecotypes, respectively. Abobo chickens had the highest fertility rate (89.09 %) followed by Gambella Ketema Zuria (85.45 %).

The percentages of the embryonic death in egg shells were 7.65 %, 10.11 %, 15.64 % and 13.95 % for Abobo, Gambella ketema Zuria, Itang, and Lare ecotypes, respectively. Hatchability values were given (Table 8 and Figure 6), which were 82.27 %, 76.82 %, 68.64 % and 67.27 % for ecotypes of Abobo, Gambella Ketema Zuria, Itang, and Lare, respectively. There was non-significant difference ($P>0.05$) in the hatchability of fertile eggs between chicken strains while some differences were noted in the hatchability of total number of eggs set. The percentage of infertility in ecotypes of Abobo, Gambella ketema Zuria, Itang, and Lare were 10.91 %, 14.55 %, 18.64 % and 21.82 %, respectively.

Table 8. Egg set, fertility, infertility, embryonic death, and hatchability N, (%)

Parameters	N	District				N, (%)
		Ab	GkZ	It	La	
Egg set	880	220	220	220	220	220
Fertile eggs	735	196(89.09 %)	188 (85.45%)	179(81.36%)	172 (78.18 %)	184(83.64 %)
Infertile eggs	145	24 (10. 91%)	32 (14.55 %)	41 (18.64 %)	48 (21.82 %)	36(16.36 %)
Embryo dead in shell	86	15 (7.65 %)	19 (10.11 %)	28 (15.64 %)	24 (13.95 %)	22(10 %)
Hatchability on eggs set basis	649	181(82.27 %)	169 (76.82%)	151(68.64%)	148 (67.27 %)	163(74.09 %)

Ab = Abobo ecotype, GKZ = Gambella ketema Zuria ecotype, It = Itang ecotype, La = Lare ecotype, N=number of eggs set, standard deviation (SD)



Figure 6. Part of collected eggs from households incubated and hatched

4.7. Growth, Carcass Components and Egg Production Performance of Chicken Strains

4.7.1. On-station evaluation of growth performances of chicken strains

The mean body weights of day-old-chicks for Ab, GKz, It, and La strains were 26.53 ± 0.22 , 27.01 ± 0.19 , 26.44 ± 0.24 , and 26.23 ± 0.31 g, respectively. The significant ($P < 0.05$) differences in day-old and final body weights at age were observed within the indigenous chicken strains, with the highest body weight being recorded in the Abobo, and Gambella ketema Zuria strains (Table 9). The mean body weights for matured Ab, GKz, It, and La strains were 1144 ± 0.13 , 1142 ± 0.27 , 1139 ± 0.29 , and 1137 ± 0.31 g, respectively. The Ab and GKz chicken strains were moderately the fast growing among the indigenous chicken strains studied.

Non-significant difference ($P > 0.05$) was observed between the indigenous chicken strains for daily feed intake per chicken per day (Table 9). The mean daily feed intake from day-old to 24 weeks of age for Ab, GKz, It, and La were 88.51 ± 0.77 , 88.27 ± 0.58 , 88.09 ± 0.66 , and 87.86 ± 0.73 g, respectively. There were no significant differences in total feed consumption amongst the evaluated chicken strains of Ab, GKz, It, and La with the value of 14.87 ± 0.23 , 14.83 ± 0.35 , 14.80 ± 0.37 , and 14.76 ± 0.28 kg, respectively.

There was non-significant differences ($p > 0.05$) in FCR between the indigenous chicken strains. FCR is a complex process and a highly aggregate trait which is the result of the interaction of behaviour, level of production, appetite and other factors. The feed conversion ratio (feed: gain) for all strains was, evaluated from 13.28 ± 0.11 , 13.24 ± 0.15 , 13.33 ± 0.23 , and 13.42 ± 0.14 of Ab, GKz, It, and La strains, respectively. The mortality rate from hatching to the end of the growing period, i.e. at maturity (24 weeks of age), of Ab, GKz, It, and La, was 12.71%, 11.24%, 16.56%, and 18.92 %, respectively.

Table 9. Day-old chicks and mature body weight pooled (gram) of chickens (LSMeans $\pm$ SE)

Parameters	District			
	Ab (N=181)	GKz (N=169)	It (N=151)	La (N=148)
Day-old body wt/chicks (g)	26.53 $\pm$ 0.22 ^b	27.01 $\pm$ 0.19 ^a	26.44 $\pm$ 0.24 ^b	26.23 $\pm$ 0.31 ^b
Final body wt/chicken (g)	1144 $\pm$ 0.13 ^a	1142 $\pm$ 0.27 ^a	1139 $\pm$ 0.29 ^b	1137 $\pm$ 0.31 ^c
Total body wt gain (kg)	1.12 $\pm$ 0.41	1.12 $\pm$ 0.33	1.11 $\pm$ 0.29	1.10 $\pm$ 0.22
Body wt gain/chicken/day (g)	6.67 $\pm$ 0.31	6.66 $\pm$ 0.17	6.61 $\pm$ 0.25	6.55 $\pm$ 0.19
Total Feed intake/chicken (kg)	14.87 $\pm$ 0.23	14.83 $\pm$ 0.35	14.80 $\pm$ 0.37	14.76 $\pm$ 0.28
Feed intake/chicken/day (g)	88.51 $\pm$ 0.77	88.27 $\pm$ 0.58	88.09 $\pm$ 0.66	87.86 $\pm$ 0.73
FCR (kg feed/ kg gain)	13.28 $\pm$ 0.11	13.24 $\pm$ 0.15	13.33 $\pm$ 0.23	13.42 $\pm$ 0.14
Overall mortality rate (%)	23 (12.71%)	19 (11.24%)	25 (16.56%)	28 (18.92%)

DOC (day-old chicks), N (number hatched chicks), SE (standard error), FCR (feed conversion ratio)



Figure 7. Day-old chicks' body weight (g) taken from chicken strains evaluated on-station

4.7.2. Body weight and growth performance of indigenous chicken's strains studied

The mean weekly body weight measurements and average daily gain of four indigenous chicken strains from day-old to 24 weeks was presented in Table 10. The day-old chicks mean body weight of Ab, GKz, It, and La; indigenous chicken strains pooled were 26.53 ± 0.22 , 27.01 ± 0.19 , 26.44 ± 0.24 , and 26.23 ± 0.31 g, respectively. The present result shown that, the matured body weight at the age of 24 weeks pooled (figure 8) of Ab, GKz, It, and La, was 1144 ± 0.13 , 1142 ± 0.27 , 1139 ± 0.29 , and 1137 ± 0.31 g, respectively.

Table 10. Growth performance of four indigenous chickens strains pooled (LSMeans $\pm$ SE)

Parameter/s	District			
	Ab	GKz	It	La
Day old chick weight in gm	26.53 ± 0.22^b	27.01 ± 0.19^a	26.44 ± 0.24^b	26.23 ± 0.31^b
Average weight of chicks at 4 weeks	120.34 ^a	119.55 ^a	117.82 ^b	117.44 ^b
Weight gain in gm per day (0-4weeks)	3.13	3.08	3.05	3.04
Average weight of chicks at 8 weeks	294.33 ^a	293.89 ^a	289.51 ^b	288.62 ^b
Weight gain in gm per day (4-8 weeks)	5.79	5.81	5.72	5.71
Average weight of chicks at 12 weeks	495.82	494.75	485.83	483.25
Weight gain in gm per day (8-12weeks)	6.72	6.69	6.54	6.49
Average weight of chicks at 16weeks	711.60	708.30	706.70	704.81
Weight gain in gm per day (12-16weeks)	7.19	7.12	7.36	7.39
Average weight of chicks at 20weeks	1044.87 ^a	1038.44 ^b	1039.22 ^b	1024.32 ^c
Weight gain in gm per day (16-20weeks)	11.11	11.01	11.08	10.65
Average weight of chicks at 24 weeks	1144 ± 0.13^a	1142 ± 0.27^a	1139 ± 0.29^b	1137 ± 0.31^b

Note: a, b, c, Means between districts with different superscript letters are significantly different ($P < 0.05$), Ab (Abobo), Gambella Ketema Zuria), It (Itang), La (Lare) strains,

The mean average growth for the Abobo, Gambella Ketema Zuria, Itang, and Lare indigenous chicken strains were 3.13, 3.08, 3.05, and 3.04 g, per day from day old to week 4 and 7.19 g, 7.12 g, 7.36 g, and 7.39 g, at week 12 to week 16 respectively. The mean average daily body weight gain of the Abobo, Gambella Ketema Zuria, Itang, and Lare indigenous chicken strains at week 16-20 were 11.11g, 11.01g, 11.08g, and 10.56g, respectively.



Figure 8. Matured body weight of chicken strains by sex (g)

4.8. Egg Production Performances of the Evaluated Indigenous Chicken Strains

The body weight at first egg production, age at first egg production, peak production age, HDEP, HHEP, and total egg production per hen of the laying period was shown in table 11. The mean body weight (g) and mean age (days) at first egg production of Ab, GKz, It, and La was (1084 ± 0.22 , 151), (1079 ± 0.41 , 152), (1077 ± 0.53 , 150), and (1073 ± 0.26 , 154), respectively. The overall mean body weight (g) and age (days) at first egg production was, 1078 ± 0.36 , and 152, respectively. From the current study, non-significant effect of strains on the age at first egg production was observed. The HDEP (%) for Abobo, Gambella Ketema Zuria, Itang, and Lare was, 58.14, 61.34, 68.69, and 74.44, respectively. The HHEP (%) of the present results of Abobo, Gambella Ketema Zuria, Itang, and Lare was 51.36, 56.15, 61.82, and 67.68, respectively. The average of egg production per hen of the Abobo, Gambella Ketema Zuria, Itang, and Lare was 75 ± 0.12 , 73 ± 0.43 , 68 ± 1.11 , and 67 ± 1.33 , respectively. From the present results shown that, the mortality rate of the Abobo, Gambella Ketema Zuria, Itang, and Lare of brooding phase was, 1.66 %, 1.18 %, 3.31 %), and 5.40 %, respectively. Consequently, the laying phase of mortality rate in Abobo, Gambella Ketema Zuria, Itang, and Lare was 11.64 %, 8.46 %, 10 %, and 9.09 %, respectively. Finally, the overall mortality during the study period of Ab, GKz, It, and La was 12.71 %, 11.24 %, 16.56 %, and 18.92 %, respectively.

Table 11. Egg production (Mean $\pm$ SD) performances of the indigenous chicken strains

Parameter/s	District				Mean $\pm$ SD
	Ab	GKz	It	La	
Body wt. at first egg production(g)	1084 $\pm$ 0.22	1079 $\pm$ 0.41	1077 $\pm$ 0.53	1073 $\pm$ 0.26	1078 $\pm$ 0.35
Age at first egg, (day)	151	152	150	154	151.75
Peak production age (weeks)	22.31	22.37	22.45	22.51	22.41
Hen-day egg production /HDEP (%)	(N=129) 58.14	(N=119) 61.34	(N=99) 68.69	(N=90) 74.44	64.75 %
HHEP(number) %	(N=146) 51.36	(N=130) 56.15	(N=110) 61.82	(N=99) 67.68	58.35 %
Total egg number/hen	75 $\pm$ 0.12 ^a	73 $\pm$ 0.43 ^a	68 $\pm$ 1.11 ^b	67 $\pm$ 1.33 ^b	70.75 $\pm$ 0.74
Mortality rate (%)					
Brooding, mortality %	3(1.66 %) N= 181	2(1.18 %) N=169	5 (3.31 %) N=151	8(5.40 %) N=148	18(2.77 %)
Growing, male mortality %	1(3.85 %)N=26	2(6.89 %)N=29	3 (11.53 %)N=26	6(18.75 %)N=32	12(10.62 %)
Growing, female mortality %	2(1.32 %)N=152	4(2.89 %)N=138	6 (5 %)N=120	5(4.63 %)N=108	17(3.28 %)
Laying, mortality %	17(11.64 %)N=146	11(8.46 %)N=130	11(10 %)N=110	9(9.09 %)N=99	48(9.89 %)

Ab (Abobo), GKz (Gambella Ketema Zuria), It (Itang), La (Lare) strains, HHEP (hen-housed egg production), HDEP (hen day egg production), Standard deviation (SD)

4.9. Indigenous Chicken Ecotypes Carcass Characteristics

The carcass characteristics of indigenous chicken strains were presented in the Table 12. The live body weight (g) of the Abobo, Gambella Ketema Zuria, Itang, and Lare indigenous chicken male strains was 1181 ± 0.12 , 1193 ± 0.22 , 1188 ± 0.42 , and 1185 ± 0.25 g, respectively. The dressing percentage (%) of the Ab, GKz, It, and La male chicken ecotypes, was 70.45 ± 3.22 , 68.32 ± 3.20 , 69.19 ± 3.19 , and 68.27 ± 3.17 , respectively. The overall dressed carcass of the all studied districts male chicken ecotypes was 819.5 ± 0.59 g. There were non-significant differences ($p>0.05$) in the weight of the breast, thighs, drumstick, neck, liver, keel bone, skin, heart, wings, and gizzard of all carcass component values of males indigenous chicken strains studied.

The live body weight (g) of the Abobo, Gambella Ketema Zuria, Itang, and Lare indigenous chicken female strains was 1107 ± 0.13 , 1091 ± 0.31 , 1090 ± 0.17 , and 1089 ± 0.36 g, respectively and the dressing percentage (%) of the Ab, GKz, It, and La, female chickens was 69.11 ± 0.73 , 69.48 ± 0.62 , 69.36 ± 0.21 , and 69.15 ± 0.33 , respectively. The overall dressed carcass of the all studied districts female chicken ecotypes was 758 ± 1.23 g. There were non-significant differences ($p>0.05$) in the weight of the breast, thighs, drumstick, neck, liver, keel bone, skin, heart, wings, and gizzard of all carcass component values of female indigenous chicken strains studied.

Table 12. LSMeans $\pm$ SE of indigenous chicken strains' carcass characteristics

parameters	Sex	District				LSMeans $\pm$ SE
		Ab	GKz	It	La	
Live weight (g)	M	1181 ± 0.12	1193 ± 0.22	1188 ± 0.42	1185 ± 0.25	1186.75 ± 0.25^a
	F	1107 ± 0.13^a	1091 ± 0.31^b	1090 ± 0.17^b	1089 ± 0.36^b	1094.25 ± 0.24^b
Dressed carcass(g)	M	832 ± 0.62	815 ± 0.61	822 ± 0.59	809 ± 0.57	819.5 ± 0.59^a
	F	765 ± 1.34	758 ± 1.22	756 ± 1.19	753 ± 1.14	758 ± 1.23^b
Dressing percentage (%)	M	70.45 ± 3.22	68.32 ± 3.20	69.19 ± 3.19	68.27 ± 3.17	69.06 ± 3.19
	F	69.11 ± 0.73	69.48 ± 0.62	69.36 ± 0.21	69.15 ± 0.33	69.27 ± 0.47

Breast(g)	M	136 ± 9.1	134 ± 8.2	133 ± 8.3	131 ± 7.2	133.5 ± 8.2 ^a
	F	129 ± 1.5	127 ± 1.2	128 ± 1.3	126.1 ± 1.1	127.5 ± 1.28 ^b
Thighs(g)	M	180 ± 11.1	178 ± 7.4	176 ± 8.3	175 ± 6.5	177.25 ± 8.3 ^a
	F	167 ± 5.2	166 ± 3.4	165 ± 4.2	164 ± 2.7	165.5 ± 3.9 ^b
Drumsticks(g)	M	152 ± 13.2	149 ± 11.4	151 ± 9.6	150 ± 10.3	150.5 ± 11.1 ^a
	F	143 ± 7.1	142 ± 8.1	141 ± 10.1	141.5 ± 6.5	141.88 ± 7.9 ^b
Wings(g)	M	88 ± 5.3	86 ± 8.1	89 ± 7.7	87 ± 6.2	87.5 ± 6.8 ^a
	F	76.5 ± 3.6	75.5 ± 3.5	76.0 ± 2.8	76.2 ± 2.5	76.05 ± 3.1 ^b
Neck(g)	M	49 ± 3.5	47 ± 4.2	48 ± 3.8	51 ± 4.5	48.75 ± 4 ^a
	F	43 ± 2.4	41 ± 3.1	42 ± 4.3	42.5 ± 3.6	42.13 ± 3.35 ^b
Skin(g)	M	84.7 ± 3.5	82.3 ± 2.9	83.4 ± 4.3	81.6 ± 3.7	83 ± 3.6 ^a
	F	77.3 ± 2.2	78.3 ± 3.3	77.5 ± 2.8	77 ± 3.7	77.53 ± 3 ^b
Keel bone(g)	M	107 ± 4.3	104 ± 4.6	105 ± 3.7	101 ± 4.1	104.25 ± 4.2 ^a
	F	99 ± 3.6	98 ± 2.3	97.6 ± 3.5	97.8 ± 2.9	98.1 ± 3.1 ^b
Heart(g)	M	7.8 ± 1.3	7.9 ± 1.5	7.5 ± 2.1	7.4 ± 1.7	7.65 ± 1.65 ^a
	F	6.2 ± 1.4	5.2 ± 1.8	5.5 ± 1.7	5.1 ± 2.0	5.5 ± 1.7 ^b
Liver (g)	M	11.3 ± 3.4	11.5 ± 4.1	12.5 ± 3.9	10.3 ± 3.1	11.4 ± 3.6 ^a
	F	9.4 ± 1.2	11.4 ± 2.4	10.6 ± 3.6	10.5 ± 3.3	10.48 ± 2.7 ^b
Gizzard (g)	M	16.2 ± 2.1	15.3 ± 2.5	16.6 ± 2.8	14.7 ± 1.9	15.7 ± 2.3 ^a
	F	14.6 ± 1.6	13.6 ± 1.9	12.8 ± 1.0	12.3 ± 2.7	13.3 ± 1.8 ^b

Note: a, b, Means between districts with different superscript letters are significantly different ($P < 0.05$), LSM ± SE (least square means, standard error), Ab (Abobo), Gambella Ketema Zuria), It (Itang), La (Lare) strains.

4.10. The Breast Meat Quality

The breast meat quality of pH and color of carcass for the different chicken strains investigated is shown in Table 13. The current investigated indigenous chickens breast meat lightness scores (L^*) of males of Ab, GKz, It, and La were, 49.51 ± 0.22 , 49.72 ± 0.16 , 48.87 ± 0.33 , and 48.91 ± 0.42 , respectively. The current investigated indigenous chicken breast meat lightness scores (L^*) of females of Ab, GKz, It, and La were, 48.89 ± 0.43 , 48.95 ± 0.18 , 48.29 ± 0.55 , and 48.47 ± 0.64 , respectively. The result showed that there were non-significant differences ($P > 0.05$) within the lightness scores (L^*) of different types of indigenous chicken strains' breast meat. However, the male (49.25 ± 0.28) breast meat had a significantly ($P < 0.05$) lighter score (L^*) than the female (48.65 ± 0.45).

The investigated indigenous chickens' breast meat redness (a^*) of males of Ab, GKz, It, and La were, 4.53 ± 0.12 , 4.48 ± 0.18 , 4.83 ± 0.22 , and 4.68 ± 0.25 , respectively. And also the current investigated indigenous chicken strains breast meat redness (a^*) scores of females of Ab, GKz, It, and La were, 5.71 ± 0.15 , 5.62 ± 0.31 , 5.92 ± 0.14 , and 5.87 ± 0.19 , respectively. The females (5.78 ± 0.18) breast meat was significantly different ($p \leq 0.05$) from that of the redness (a^*) scores within the males chicken strains (4.63 ± 0.19).

The investigated indigenous chickens breast meat yellowness (b^*) of males of Ab, GKz, It, and La were, 11.93 ± 0.55 , 11.89 ± 0.22 , 10.92 ± 0.51 , and 10.97 ± 0.61 , respectively. The current investigated indigenous chicken strains breast meat yellowness (b^*) scores of females of Ab, GKz, It, and La were, 10.16 ± 0.37 , 10.23 ± 0.41 , 10.02 ± 0.35 , and 10.06 ± 0.45 respectively. The male (11.43 ± 0.47) breast meat had significantly different yellowness ($p \leq 0.05$) than the yellowness (b^*) scores of the females chicken strains (10.12 ± 0.39). The current investigated chicken strains breast meat males' at pH_{45min} value of the Ab, GKz, It, and La were, 6.46 ± 0.07 , 6.45 ± 0.08 , 6.50 ± 0.03 , and 6.48 ± 0.06 , respectively.

And also the current investigate chicken strains breast meat females' at pH_{45min} value of the Ab, GKz, It, and La were, 6.49 ± 0.05 , 6.47 ± 0.04 , 6.53 ± 0.01 , and 6.51 ± 0.02 , respectively. The male (6.47 ± 0.06) breast meat was not significantly different ($p > 0.05$) within the pH_{45min} value with the females' chicken strains (6.50 ± 0.03). The current investigated chicken strains breast meat males' at pH_{24hr} value of the Ab, GKz, It, and La were, 5.84 ± 0.06 , 5.83 ± 0.02 , 5.89 ± 0.06 , and 5.87 ± 0.04 , respectively. And also the current investigated chicken strains breast meat females' at pH_{24hr} value of the Ab, GKz, It, and La were, 5.88 ± 0.05 , 5.86 ± 0.07 , 5.91 ± 0.01 , and 5.90 ± 0.03 , respectively. The male (5.86 ± 0.05) breast meat was not significantly different ($p > 0.05$) within the pH_{24hr} value with the females' chicken strains (5.88 ± 0.04).

The present investigated indigenous chicken strains breast meat water holding capacity (%) of males' of Ab, GKz, It, and La were 86.77 ± 2.15 , 86.71 ± 2.18 , 86.93 ± 2.05 , and 86.89 ± 2.11 , respectively. And also the current investigated chicken strains breast meat females' water holding capacity (%) of the Ab, GKz, It, and La were, 86.92 ± 2.07 , 86.85 ± 2.09 , 87.22 ± 1.95 , and 87.19 ± 1.72 , respectively. The female (87.05 ± 1.96) breast meat WHC had significantly ($p \leq 0.05$) higher than the water holding capacity (%) values with the breast meat of males' chicken strains (86.83 ± 2.12). The current investigated indigenous chicken strains breast meat drip loss (%), of males' of Ab, GKz, It, and La were, 2.51 ± 0.01 , 2.43 ± 0.04 , 2.76 ± 0.07 , and 2.89 ± 0.06 , respectively. And also the current investigated chicken strains breast meat females' drip loss (%) of the Ab, GKz, It, and La were, 2.08 ± 0.03 , 2.10 ± 0.09 , 2.05 ± 0.08 , and 2.07 ± 0.04 , respectively. The male (2.65 ± 0.05) breast meat DL had significantly ($p \leq 0.05$) higher than the breast meat DL (%) values of females' chicken strains (2.07 ± 0.06).

Table 13. The indigenous chicken strains breast meat quality (Mean $\pm$ SD)

Para	Ab		GKz		It		La		Mean ± SD	
meters	Sex (S)									
	M	F	M	F	M	F	M	F	M	F
L*	49.51 ± 0.22	48.89 ± 0.43	49.72 ± 0.16	48.95 ± 0.18	48.87 ± 0.33	48.29 ± 0.55	48.91 ± 0.42	48.47 ± 0.64	49.25 ±0.28 ^a	48.65 ± 0.45 ^b
a*	4.53 ± 0.12	5.71 ± 0.15	4.48 ± 0.18	5.62 ± 0.31	4.83 ± 0.22	5.92 ± 0.14	4.68 ± 0.25	5.87 ± 0.19	4.63 ± 0.19 ^b	5.78 ± 0.18 ^a
b*	11.93 ± 0.55	10.16 ± 0.37	11.89 ± 0.22	10.23± 0.41	10.92 ± 0.51	10.02 ± 0.35	10.97 ± 0.61	10.06 ± 0.45	11.43 ±0.47 ^a	10.12 ± 0.39 ^b
pH _{45min}	6.46 ± 0.07	6.49 ± 0.05	6.45 ± 0.08	6.47 ± 0.04	6.50 ± 0.03	6.53 ± 0.01	6.48 ± 0.06	6.51 ± 0.02	6.47 ± 0.06	6.50 ± 0.03
pH _{24hr}	5.84 ± 0.06	5.88 ± 0.05	5.83 ± 0.02	5.86 ± 0.07	5.89 ± 0.06	5.91 ± 0.01	5.87± 0.04	5.90 ± 0.03	5.86 ± 0.05	5.88 ± 0.04
WHC	86.77 ± 2.15	86.92 ± 2.07	86.71 ± 2.18	86.85 ± 2.09	86.93± 2.05	87.22 ± 1.95	86.89 ± 2.11	87.19 ± 1.72	86.83 ±2.12 ^b	87.05 ± 1.96 ^a
DL	2.51 ± 0.01	2.08 ± 0.03	2.43 ± 0.04	2.10 ± 0.09	2.76 ± 0.07	2.05 ± 0.08	2.89 ± 0.06	2.07 ± 0.04	2.65 ± 0.05 ^a	2.07 ± 0.06 ^b

^{ab} Mean under the same category bear different superscript letters are significantly different, L* = lightness, a* = redness, b* = yellowness, pH_{45min} = pH measure taken at 45 min after slaughter, pH_{24hr} = pH measure taken at 24 h after slaughter, DL = drip loss (%), WHC = water holding capacity (%), Ab (Abobo), GKz (Gambella Ketema Zuria), It (Itang), La (Lare) strains. Standard deviation (SD).

4.11. Nutritive Value of Indigenous Chicken Strains' Meat

The result of the nutritive value of meat evaluated on-station for Abobo, Gambella ketema Zuria, Itang, and Lare chickens were presented in Table 14. In the current study, there were non-significant differences at ($P>0.05$) in moisture contents in all of the chicken strains. The overall means were 75.51 ± 0.79 , 75.27 ± 0.38 , 75.34 ± 0.91 , and 75.32 ± 0.88 , respectively, for Ab, GKz, It, and La. From the current findings, the crude protein contents of the chicken between strains were showed non-significant differences at ($p > 0.05$) with the value of 19.15 ± 0.79 , 19.33 ± 0.32 , 19.05 ± 0.63 , and 19.08 ± 0.54 for Ab, GKz, It, and La, respectively (Table 14).

The crude protein contents of breast meat were significantly higher than those of the thigh and drumstick meat part at ($p<0.05$), whereas the contents in moisture, crude fat, and Ash of the thigh and drumstick meat were significantly higher ($p<0.05$) than those of the breast meat in all strains (table 14). The overall means of the ash contents in all the studied strains of (Abobo, Gambella Ketema Zuria, Itang, and Lare) meat were 0.39 ± 0.07 , 0.36 ± 0.05 , 0.48 ± 0.04 , and 0.52 ± 0.05 , respectively. The overall mean value of the indigenous chickens' meat moisture, crude protein, crude fat, and ash contents were 75.36 ± 0.74 , 19.15 ± 0.57 , 4.61 ± 0.36 , and 0.44 ± 0.05 , respectively.

Table 14. Nutritive value of indigenous chicken's meat pooled studied (Mean $\pm$ SD)

Chicken ecotype	Meat part	Moisture %	Crude-protein %	Crude-fat %	Ash %
Ab	Breast	75.35 $\pm$ 0.52	19.84 $\pm$ 0.56 ^a	4.36 $\pm$ 1.05 ^b	0.28 $\pm$ 0.06
	Thigh	75.48 $\pm$ 0.86	18.97 $\pm$ 0.94 ^b	4.60 $\pm$ 0.67 ^a	0.43 $\pm$ 0.09
	Drumstick	75.69 $\pm$ 0.99	18.65 $\pm$ 0.88 ^b	4.72 $\pm$ 0.71 ^a	0.47 $\pm$ 0.07
Mean $\pm$ SD		75.51 $\pm$ 0.79	19.15 $\pm$ 0.79	4.56 $\pm$ 0.81	0.39 $\pm$ 0.07
GKz	Breast	75.24 $\pm$ 0.54	20.04 $\pm$ 0.05 ^a	4.34 $\pm$ 0.36 ^b	0.20 $\pm$ 0.04
	Thigh	75.26 $\pm$ 0.55	18.98 $\pm$ 0.73 ^b	4.78 $\pm$ 0.43 ^a	0.41 $\pm$ 0.05
	Drumstick	75.31 $\pm$ 0.06	18.97 $\pm$ 0.17 ^b	4.62 $\pm$ 0.20 ^a	0.46 $\pm$ 0.07
Mean $\pm$ SD		75.27 $\pm$ 0.38	19.33 $\pm$ 0.32	4.58 $\pm$ 0.33	0.36 $\pm$ 0.05
It	Breast	75.25 $\pm$ 0.94	19.76 $\pm$ 0.49 ^a	4.31 $\pm$ 0.14 ^b	0.38 $\pm$ 0.04
	Thigh	75.27 $\pm$ 1.02	18.71 $\pm$ 0.77 ^b	4.92 $\pm$ 0.13 ^a	0.47 $\pm$ 0.01
	Drumstick	75.50 $\pm$ 0.78	18.69 $\pm$ 0.62 ^b	4.63 $\pm$ 0.12 ^a	0.61 $\pm$ 0.08
Mean $\pm$ SD		75.34 $\pm$ 0.91	19.05 $\pm$ 0.63	4.62 $\pm$ 0.13	0.48 $\pm$ 0.04
La	Breast	75.22 $\pm$ 0.86	19.78 $\pm$ 0.69 ^a	4.42 $\pm$ 0.17 ^b	0.40 $\pm$ 0.03
	Thigh	75.39 $\pm$ 0.99	18.74 $\pm$ 0.54 ^b	4.87 $\pm$ 0.15 ^a	0.52 $\pm$ 0.06
	Drumstick	75.36 $\pm$ 0.80	18.72 $\pm$ 0.39 ^b	4.75 $\pm$ 0.18 ^a	0.63 $\pm$ 0.07
Mean $\pm$ SD		75.32 $\pm$ 0.88	19.08 $\pm$ 0.54	4.68 $\pm$ 0.16	0.52 $\pm$ 0.05
Over all Means $\pm$ SD		75.36 $\pm$ 0.74	19.15 $\pm$ 0.57	4.61 $\pm$ 0.36	0.44 $\pm$ 0.05

Ab (Abobo), **Gkz** (Gambella ketema Zuria), **It** (Itang) and **La** (Lare), Standard deviation (**SD**), different superscripts in the same column indicate significant difference in nutritive value among chicken's meat at $P < 0.05$

CHAPTER 5. DISCUSSION

The natural conditions at the Gambella regional state farmers' condition and on-station evaluation were like those in other farmers and on-station environment in Ethiopia and a little bit hotter than some environmental conditions. Therefore, the phenotypic characteristics, production performance and mortality are comparable to those in the publications from high-level research and academics journals and organizations in developed countries. In this discussion part, results from the on-farm and on-station evaluation experiments are discussed in the order as presented in the result section. Consequently, results from the on-farm phenotypic characterization, and egg quality of indigenous chicken strains in Gambella regional state are discussed respectively in the first five subsections (5.1 - 5.5), and the results dealt with the evaluation of egg fertility, growth, and egg production performances of indigenous chicken strains on-station management conditions are discussed under the second sub-section of (5.6 -5.11). Similarly, results from evaluation of meat proximate composition and carcass characteristics produced under on-station management conditions with intensive some laboratory parameters were discussed in the sub-sections.

5.1. The Flock Composition of Indigenous Chickens in the Study Area

As the composition of the flock is shown in Table 2, the averages of chickens in different age groups and the proportion of households owning chickens are in line with Hailu *et al.*, (2019), who reported 13 chicken / households to Sheka zone, Southwest Ethiopia and Abera *et al.*, (2014) who reported 11.9 chickens per household in Southeast Oromia Regional State of Ethiopia. However, the result is higher than that of Tadelles and Ogle (1996) 7.10 chickens per household for the Central Highlands of Ethiopia and 8.8 chickens per household Assefa, (2007) for Hawassa Zuria. The present result is concurrent with Hailu *et al.* (2019) who reported 2.4 cockerels per household in the Sheka zone of south western Ethiopia and significantly more than Abera *et al.* (2014) who reported 0.74 cockerels per households in a south Eastern Oromia Regional State of Ethiopia.

The value of the mean pullets 1.31 per households in southeastern Oromia regional state of Ethiopia by Aberra *et al.* (2014) are lower than those observed in the current study result. The variation in flock size reported in different parts of Ethiopia may be due to disease, presence of predators, availability of feed resources, general management, and economic status of households that regularly sell chickens to meet their immediate economic needs.

5.2. Reproductive and Productive Performance

The overall mean age at first lay in months (6.20) recorded in this study was similar with Hailu, (2019), who reported 6.3 months of mean age at first lay and also the current finding agrees with Aberra *et al.* (2014) who reported 6.17 months of mean age at first lay. The overall mean age at first lay recorded in this study was longer than the finding by Mammo, (2006) and Halima, (2007), who reported 5.35 and 5.5 months of mean age at first lay, respectively for chickens. The reason for delayed age of sexual maturity of those chickens reared in the study areas could be attributed to lack of supplementary feeds and exposure of chickens to excessive high ambient temperatures, which are characteristics of all districts.

The mean number of clutches per year 3.66 recorded in this study was higher than Hailu, (2019), who reported the overall mean number of clutches per year 3.0 and lower than Fisseha *et al.*(2010) and Eskinder,(2013) who reported 3.83, and 3.94 per year respectively. This reason might be the variation of broodiness behavior among the Ethiopian indigenous chickens. The number of eggs per clutch found in this study area agrees with the reported of 11.2, 15.5 and 14.2 eggs in Yeki, Andracha, and Masha, respectively Hailu *et al.*, (2019) and the finding was similar with the reported of 15.0, 12.94, 15.7 and 14.9 eggs in Horro, Jarso, Bure and Dale Worde's, respectively Eskinder, (2013) and lower than the 17.7 average eggs per clutch per hen reported by Taddelle, (2003) for five regions in Ethiopia. The overall mean of the egg production per hen per year (48.64) in the study areas was higher than the reported 40.8 eggs production per hen per year for the Sheka zone, south western Ethiopia Hailu *et al.* (2019).

The value is less than the reported 66.5 eggs per hen per year of unimproved chickens Wondmeneh, (2015). The current finding for incubated eggs (9.64) and hatched percentage (70.37 %) was lower than the value by Aberra *et al.*(2014) 11.8 and 81.5 % which was reported in South eastern Oromia Regional State of Ethiopia and similar with the value by Hailu *et al.*(2019) on 8.7 and 74.1% which was reported in Sheka zone, south western Ethiopia. However, the current finding was more than, the hatchability (22%) which was reported in Gomma Woreda, southwestern Ethiopia Meseret, (2010) and lower than, the (98.6%) hatchability reported Matiwos *et al.* (2015).

The current results, was also comparable with that of Pedersen, (2002) who reported that the average number of eggs incubated per hen was 10.6 with average hatchability rate of 73 percent. The results observed in the present study are less than those of Ssewanyana *et al.*, (2008) who reported higher hatchability percentage (87 percent) among native chickens of Uganda. These variations might be related within culling practices, nutritional and incubation management in different locations. The mean survival rate of chicks (58.14 %) in the current study was concurrent with the value of survival rate of chicks (48.8 %) reported by Aberra *et al.* (2018) and 59.3 % value reported by Hailu *et al.* (2019) and higher than the value 45.32 % reported by Meseret, (2010).

5.3. Phenotypic and Morphological Variations in Qualitative Traits

5.3.1. Feather morphology, Plumage color and distribution

Variation in qualitative traits such as plumage color, comb type, earlobe color, head shape, and shank color was evaluated on 600 indigenous chickens of the study areas. The plumage colors found in the current study are in line with previous reports by Reta, (2006); Halima, (2007); Bogale, (2008); Eskinder, (2013), and Hailemichael, (2015) for the Ethiopian indigenous chickens. The present findings of feather morphology of the studied chicken populations was similar with the findings of Bogale, (2008), and Hailemichael, (2015), who reported normal feather morphology in all the local chicken populations in Fogera woreda, Ethiopia and chicken populations in southern zone of Tigray, Ethiopia.

The current finding was different from the result reported by Hailemichael, (2015) which was in Endamehoni (56.25%) and Ofla (57.92%) had plain head while chicken populations in Raya-azebo (53.33%) had crested head. The difference within and among each district in terms of head shape characteristics probably suggests that head shape could be considered as one of the most important morphological characteristics to discriminate between different populations of indigenous chickens. According to Aberra and Tegene, (2011), reported value 83.2 % of chickens in southern region of Ethiopia had normal feather distribution followed by naked-neck (7.9 %), and feathery shank (2.0 %) which was similar with the current findings.

From the investigated chicken populations four comb types were observed in single, double, strawberry and rose comb types were the most dominant ones, these frequencies are almost similar with the findings of Badubi *et al.* (2006) who reported about 90 % of the indigenous chickens in Botswana to be single combed, while very low proportion were rose (4.9 %) and pea (1%) combs. But, these frequencies are dis or in-agreement with the reported by Eskindir, (2013) who found 33.49 % and 48.65 % of chicken in Horro and Jarso, single comb type. The current finding was agrees with the result reported by Hailemichael, (2015) which was the proportion of chickens having yellow shanks was dominant in Ofla (68.33 %) and in Endamehoni (47.08 %) and the findings of Nigussie *et al.* (2010) and Halima *et al.* (2007) who reported yellow shank as the most prevalent trait in indigenous chicken populations found in other parts of Ethiopia.

The ratio of chickens with yellow earlobe was almost comparable among studied districts. The current result disagreed with the finding reported by Hailemichael, (2015) in Endamehoni (54.58 %) and Ofla (32.92 %) white and red. As the value reported by Nigussie *et al.*(2010), the proportion of indigenous chickens showing white, red and yellow earlobe was 40 %, 8 %, and 52 %, respectively, which have similarity by yellow frequencies with in the current study. The current findings disagree with the findings reported by Aberra and Tegene, (2011) white earlobe ranging from 30.4% to 34.9% and different with the red earlobe shows 49.5 % in Horro and Jarso ecotypes, Eskinder, (2013).

5.4. Quantitative Traits and Their Variations in Both Sexes

The body weight and other measurements of male and female chicken populations in the four districts measured were in agreement with the value reported by Hailemichael, (2015), for adult males were 1332 g, 1246 g and 1241 g in Raya-azebo, Endamehoni and Ofla district, respectively and the reported by Aberra, (2014) for indigenous chicken populations of adult males were 1.40kg, 1.37kg and 1.40 kg in the high-, mid- and lowland agro-ecological zones of Southeastern Ethiopia and which is lower than 2049g for males in northwest Ethiopia Halima, (2007). Similarly, for adult females were in line with the reported by Eskinder, (2013) for Horro (1289 g) and Jarso (1116 g) by respectively, but higher than the reported for north-west Ethiopia (847.77 g) by Halima, (2007) and lower than report of Choprakarn and Wongpichet, (2007) that male and female chickens enter maturity at 8–12 and 6–8 months of age, and with 1.8-2.3 and 1.4-1.8 kg body weight, respectively.

The mean shank length (10.19cm) of males found in this study is comparable with the reported average of 9.1cm for the five chicken ecotypes in Ethiopia Nigussie *et al.* (2010) and the reported 11.3 cm in Horro and 10 cm in Jarso ecotypes, by (Eskinder, 2013). But longer than the reported 8.69 cm in Southern Zone of Tigray, Ethiopia, by Hailemichael, (2015) and the reported 7.50 cm, 7.37cm, 7.41cm by Aberra, (2014) in the high-land, mid-land and lowland agro-ecological zones of Southeastern Ethiopia respectively.

Similarly, the average female shank length (8.36 cm) is in line with the range of shank length 9.2 cm in Horro and 8.5 cm in Jarso ecotypes Eskinder, (2013). But longer than (6.6-7.8 cm) in five ecotypes of Ethiopia Nigussie *et al.* (2010) and 7.07cm in Southern Zone of Tigray, Ethiopia, by Hailemichael, (2015). The body weight to shank length ratio is an indicator of degree of fleshing in relation to body size and the heavier the chicken the higher would be the ratio Renema *et al.* (2007). The Significant difference ($p < 0.05$) on long legs, large combs and wattles were observed in Abobo male chicken populations, which are important of morphological traits that allow better heat dissipation in the tropical hot environment.

5.5. Egg Quality Traits

The external egg quality traits was in line with the finding of local chicken reared in Hawassa and Yirgalem reported by Yonas *et al.* (2019) and similar with the finding of several researchers from Ethiopia Mesere, 2010; Aberra *et al.* (2012). The mean value of egg weight in the current findings (39.15 g) was in agreement with the value of mean egg weight in Bench Maji zone of Southern Nations, Nationalities and People Regional State, Ethiopia (43.9 g) reported by Welelaw *et.al.* (2018). As Getachew *et al.* (2016) also reported comparable egg weight value of 41.1 g for indigenous chicken western Shewa zone of Oromia region, Ethiopia. On the contrary, Halima, (2007) reported lower egg weight values (34.1 g to 41.7 g) for different chicken ecotypes in northwestern part of the country. This could be due to the type of chicken ecotype, feed availability, environmental temperature, and the agro-ecological location of the study sites.

The egg length and egg width of the studied ecotypes were similar with the finding reported by Welelaw *et al.* (2018) in Bench Maji zone of Southern Nations, Nationalities and People Regional State, Ethiopia were 52.1 mm 37.8 mm. The mean value of the shell thickness in the current study was similar with the value of Desalew *et al.* (2015), who reported 0.31 average shell thicknesses in East Shewa, Ethiopia. On the other hand, Fisseha *et al.* (2010) reported lower value of shell thickness (0.26 mm) in northwestern Ethiopia. Whereas, Melesse *et al.* (2010) observed a relatively higher shell thickness value (0.37 mm) in Ethiopian naked-neck chickens reared under improved production system. These variations in shell thickness among the indigenous chicken ecotypes reared in various parts of the country might be due to the availability of calcium in the feed material, type of management, and type of chicken breed.

According to Kingori, (2012) shell thickness is influenced by calcium availability in layer nutrition and ability of the hen to absorb calcium by the shell gland. The mean value of the egg shell weight (3.11 g) of the studied indigenous chickens' ecotypes were lower than the value (3.82g) reported by Yonas *et al.* (2019) in Yirgalem and Hawassa towns, Ethiopia and the values reported by Meseret, (2010) who recorded that the weight of the shell of

fresh and aged egg of the indigenous chickens was 4.61 and 4.35 g, respectively. The shell weight is also lower than the value reported by Markos *et al.* (2017) for chicken populations reared in the high-land, mid-land and low-land 5.05, 4.72 and 4.30 g, respectively. And also the current findings of shell weight was lower than the value 4.95 g reported by Ahmedin and Mangistu, (2016) from Eastern Hararghe, Ethiopia also revealed that higher value for shell weight. The variation on the shell weight could be due to availability of calcium in the diet and also the bioavailability of calcium and phosphorus Pelicia *et al.* (2009).

The mean value of the albumen height of the current study was similar with the value reported by Aberra *et al.* (2012) for eggs 4.51 mm, from indigenous chicken reared at Amhara region. The mean value of the albumen height (4.17 mm) of the current study was lower than the value of finding by, Yonas *et al.* (2019) who reported that the height of albumen among eggs of local chickens collected from Yirgalem and Hawassa towns, was 5.7 and 5.20 respectively.

The present results albumen height was lower than the value of findings of Markos *et al.* (2017) who reported that the height of albumen among eggs of indigenous chicken collected from highland, midland and lowland agro-ecologies of Western zone Tigray, was 5.66, 5.65 and 5.05, respectively. The current findings are also lower than that of the findings of Alewi *et al.*, (2012) and Mube *et al.* (2014) for local Kei chicken (5.79 mm) raised in Guraghe zone and also indigenous chickens (5.74 mm) in Cameroon, respectively.

The mean value of the albumen weight (20.53 g) of the current study was lower than that of the value (23.1g) reported by Welelaw *et al.* (2019) in Bench Maji zone of Southern Nations, Nationalities and People Regional State, Ethiopia. The low albumin height and the resulting HU in the current study might be due to the age of hen, duration of the egg storage after being collected, and environmental temperature. The mean value of the yolk height (13.59 mm) and yolk width (37.98 mm) were higher than the value reported by, Meseret, (2010) 11 mm yolk height for fresh eggs and 9.1mm for market purchased eggs.

However, Melesse *et al.* (2010) reported higher (16.9 mm) yolk height in eggs of naked - neck indigenous chicken. These differences might be due to the duration and storage temperature as well as the age of the hens. The mean value of the current study of the yolk color was comparable with the findings of Halima, (2007) who reported a yolk color ranging from 3.0 to 4.0 for different indigenous birds in northwestern Ethiopia. The variation of yolk color in the current study might be due to the quality and availability of greenish scavenges available feeds in the free-range production system. The mean value of the haugh unit (HU) of the indigenous chickens reared in the studied areas was higher than the values of the HU of the eggs from the native chickens those reported by Meseret, (2010) for fresh and aged eggs (54.50 and 46.74), respectively.

5.6. Fertility, Embryonic Death and Hatchability of Eggs Used by Artificial Incubator

As the general values and percentage of egg set, fertility, embryonic death, and hatchability estimated in all chicken ecotypes studied were investigated, the values and percentage of fertility (83.64 %) in this study was more than the value reported 76.14 % for normal feather bird's ecotype and 77.67 % for naked-neck ecotypes fertility of Nigerian locally adapted chickens, respectively Adedeji, *et al.* (2015). According to the results obtained, the current study showed higher value of fertility than the value reported 74.5 % of fertile eggs from eggs set by Ahmedin and Mangistu, (2016) and higher than the value reported by NureHasni and Bhuiyan, (2018), in artificial incubation system the average fertility of indigenous chicken eggs were 70.81 %.

The results were higher than Msoffe *et al.* (2004) who found 70 % fertility for artificially incubated indigenous chicken. The fertility of the study was also more than the value reported by Ahmad *et al.* (2013) where the fertility was 77 % and by-far higher than the value reported by Faruque *et al.* (2011) found 46.69 % fertility in Hilly chickens. The lower fertility of indigenous chicken in the current study might be due to the cock shortage in the area, egg storage time before incubation, transportation of collected eggs from households to hatchery room and the overall monitoring systems during incubation period.

The current value of the embryonic death in eggs shell findings were lower than the value reported by Adedeji *et al.*(2015), with the average mortality on hatching day of indigenous chicken egg was 19.63 % and also on the dead-in-shell was highest in naked-neck eggs chickens by (25%), while the present result was higher than the value which was observed in normal feather eggs (3.33%). The embryonic death before hatched in the eggs shell might be due to the lack of monitoring and the overall manipulation of the incubator such as temperature, moisture and electric power. However, such expanded information about embryonic death in the eggs shell before hatched of chicks was not available in other scenarios.

The hatchability values of the current finding was similar with the value reported by NureHasni and Bhuiyan,(2018) on the artificially incubated indigenous chickens' hatchability which was 77.52 and the value reported by Sonaya and Swan, (2004) that hatchability from 65-75% should be expected in case of mini hatchery which is almost similar with the present study. The hatchability results obtained in the present study were lower than the value reported by Rahman *et al.* (2013) who found 91.35% hatchability and similar with the value reported by Faruque *et al.*,(2013) where the hatchability for incubator hatched chickens were 79.81, 64.85, 86.38%, respectively for H, NN and ND genotypes. However, the hatchability was higher than Rota *et al.*, (2010) where the average of hatchability rate was 67% and Patrick *et al.* (2014) where hatchability rates were 51.58, 50.26 and 40.56% for normal, naked-neck and Dwarf strain.

The hatchability values in current study were in line with the reported value by Kalita *et al.* (2009) in Assam (70 - 81 %) and Portas *et al.*, (2010) in Kenya (45-100 %), with mean hatchability of (81.5 %). And also the current study findings were similar with the value reported by Ahmedin and Mangistu, (2016) on the percentage of hatchability on total egg set (67.78 %). From the current study values, the infertility percentages were lower than the value reported by Adedeji *et al.* (2015) that infertility was observed in Frizzle feather hens with 32.28 %.

5.7. Growth, feed intake and mortality under on-station condition

The Ab and GKz chicken strains were moderately faster growing among the indigenous chicken strains studied. These findings are similar to that reported by Halima *et al.* (2006), that the Mello-Hamusit, Guangua and Mecha native chickens were the fastest growing among the indigenous lines of the evaluation trial which was conducted at the Andassa Livestock Research Centre (ALRC), Ethiopia. The mean daily feed intake from day-old to 24 weeks of age for Ab, GKz, It, and La were in agreement with the report of value by Halima *et al.* (2006), that the mean daily feed intake from day-old to 22 weeks of age of indigenous chicken lines studied under intensive management showed no significant differences.

The feed conversion ratio (feed: gain) for all strains of Ab, GKz, It, and La strains, were in agreement with Solomon, (2003) who observed a FCR of 13.4 in indigenous chickens kept under intensive management conditions in Ethiopia. The mortality rate from hatching to the end of the growing period, i.e. at maturity (24 weeks of age), of Ab, GKz, It, and La, was in agreement with the value reported by Halima *et al.* (2006), for the mortality rate from hatching to the end of the growth period of maturity (22 weeks of age), varied substantially between chicken lines, from 18.9% (RIR) to 24% (Debre-Ellias).

The mean body weights of the day-old-chicks of the current results were similar with the value reported with weight of local chickens at hatch in Northwest Ethiopia by Belay *et al.* (2018) with 27.2 g for Tilili, 27.9 g for Gelila, 27.1 g for D/Elias, and 27.9 g for Mecha under intensive management. But, the day-old chicks mean body weight of Ab, GKz, It, and La; indigenous chicken strains were lower than the findings reported by Magonka *et al.* (2016) that the mean body weight of Kuchi, Horasi, Naked Neck, and Frizzled ecotypes at day old chick was 36.26, 34.26, 31.99, and 29.02g, respectively. The present result shown that, the matured body weight at the age of 24 weeks of Ab, GKz, It, and La were lower than that of findings reported by Magonka *et al.* (2016) at the age of 24 weeks from the four ecotypes namely, Kuchi (1738.70), Horasi (1572.8g), naked-neck (1427.58g), and Frizzled (1100.47g).

The mean average growth for the Abobo, Gambella Ketema Zuria, Itang, and Lare indigenous chicken strains were comparable with the findings reported by Magonka *et al.* (2016) that the average growth for Kuchi, Horasi, Naked neck, and Frizzled of 3.96 g, 3.67 g, 3.61 g and 2.94 g per day from day old chick to week 4 and 10.36 g, 8.81 g, 8.37 g, and 7.93 g at 16 weeks to 20 weeks, respectively.

5.8. Egg Production Performances of the Evaluated Indigenous Chicken Strains

The present findings of the mean age at first egg were late matured than the value reported by Bamidele *et al.* (2019) from the locally sourced breeds Fulani, FUNAAB Alpha, Noiler and Shika-Brown with the mean ages at first egg, was 125 days. The HDEP (%) for Abobo, Gambella Ketema Zuria, Itang, and Lare were similar with that of the value reported by Bamidele *et al.* (2019) on the HDEPs for Fulani (56.1%), Kuroiler (65.4%), Noiler (55.6%), Shika- Brown (68.1%), and FUNAAB Alpha (63.9%). The HHEP (%) of the present results of Abobo, Gambella Ketema Zuria, Itang, and Lare were comparable with that of the value reported by Dogara *et al.* (2021) on Black and Brown chickens of the HHEP values were recorded in 63.59 % and 63.13 %, respectively. The average of egg production per hen of the Abobo, Gambella Ketema Zuria, Itang, and Lare were comparable with the findings reported by Dogara *et al.* (2021) on the Spotted Noiler, Brown, and Black chicken was, 62.28 ± 1.66 , 55.71 ± 1.93 , and 55.90 ± 1.26 , respectively.

However the current results of egg production per hen were lower than the value reported by Reta, (2009) for the on-station evaluated for egg production value with 80 eggs laid/bird/year. The laying phase of mortality rate in Abobo, Gambella Ketema Zuria, Itang, and Lare were similar with the value reported by Bamidele *et al.* (2019) on the locally sourced breeds had lower mortality rates (brooding 7.3 %, growing 8.2 %, and laying 20.5 %) than the exotic breeds (Brooding 21.3 %, growing 8.7 %, and laying 24.2 %) which suggests that the locally sourced breeds were more adaptable to the environment than the foreign breeds.

5.9. Indigenous Chicken Strains Carcass Characteristics

The live weight (slaughter weight) of the indigenous chicken strains studied of males (1186.75 ± 0.25 g) and females (1094.25 ± 0.24 g) was lower than the findings reported by Iqbal *et al.*(2009) for males (1720 g) and females (1253 g) indigenous chicken raised in Kashmir. And also the present results were lower than the values reported by Addisu, (2012), from north-Wollo zone, for the value of live weight of female at 23.84 and male at 24.25 week's age were 1253.36 gm and 1500.97, respectively. The variation in live body weight (slaughter weight) of local chickens raised in different regions might be due the variations in genetic makeup of chickens, environmental and conditions management system Magala *et al.*(2012) and Yousif *et al.* (2014).

The mean dressed carcass weight for studied chicken strains is lower than the value reported by Walelegne *et al.* (2021) for dressed carcass for Yeki (1097 g), Anderacha (1153g), and Masha (1183g) quality characteristics of indigenous chickens in Sheka Zone, South Western Ethiopia. The mean dressing percentage of the current study was similar with the findings reported by Walelegne *et al.* (2021) the average dressing percentage (71.4%) of local chicken, and higher than the value reported by Halima, (2007), who reported an average value of 65.7 % for three chicken ecotypes reared in Northwestern Ethiopia. Additionally, the average dressing percentage of indigenous chicken strains in the present study is similar with the findings reported by Magala *et al.* (2012) for local Ugandan chickens. The differences in the current results from other findings might be due to the age of the chicken when slaughtered and carcass components that were included in the dressed carcass during the calculation of the dressing percentage.

5.10. Indigenous Chicken Strains pH and Meat Color Characteristics

The pH is one of the most important physicochemical characteristics in meat since it is related to water holding capacity and color Bosque *et al.* (2020). A high pH value shortens the meat shelf life since it creates a more favorable environment for bacteria Sarica *et al.*, (2019). The present study of pH measurement results indicated that the initial pH ($\text{pH}_{15\text{min}}$) of breast meat was higher compared to the ultimate pH ($\text{pH}_{24\text{h}}$) for all of the chicken

strains in the present study, which is in line with the studies on guinea fowl (*Numida meleagris*) and three chicken genotypes in Ethiopia by Getnet *et al.* (2022) and in Chinese indigenous chickens by Guan *et al.* (2013). The decline in postmortem pH can be related to the most important events in the conversion of muscle to meat due to its impact on meat texture, color, and water holding capacity and the rate of declining is dependent on the activity of glycolytic enzymes just after death and the initial glycogen reserves of the muscle Devatkal *et al.* (2018).

The current findings of the pH value at 24hrs after slaughtered (5.86 ± 0.05 to 5.88 ± 0.04) male to female of indigenous chicken strains were in line with the findings of pH values from breast meat of Chinese indigenous chicken breeds which were reported to range from 5.5 to 5.8 and 5.9 to 6.3, respectively Guan *et al.* (2013). The pH of meat may be influenced by other internal factors such as muscle type, chicken strain, and external factors including feed, fasting, stress, electrical stimulation and chilling Santos *et al.* (2005). The pH of the meat seems to have a strong influence on the color of the meat. As a result, the meat from all indigenous chicken strains studied in the current study was lighter.

In this regard, it was noted that higher pH values resulting in darker meat color, while lower muscle pH values are associated with lighter meat Wideman *et al.* (2016). For poultry fillets, the typical range of pH values 24 hrs after slaughter is between 5.6 and 6.2 Bruckner *et al.* (2012), which can be considered normal. Hence, the ultimate pH results of all indigenous chicken strains breast investigated (5.86 ± 0.05 to 5.88 ± 0.04) of male to female in the current study are concurrent with the above range indicating the meat from all poultry genotypes fall within the normal range.

In addition to the meat pH value, meat color is highly correlated to the amount of haem-containing compounds such as myoglobin, haemoglobin, and cytochrome-c Wideman *et al.* (2016). Meat color is one of the first traits noticed by consumers and thus an indicator of meat quality Guan *et al.* (2013).

Therefore, the characteristic differences in meat color of the chicken strains may influence consumer preference when they are used to make the same dish Jayasena *et al.* (2013). As reported by Qiao *et al.* (2001) determined the border values for color of chicken breast muscle: lighter than normal ($L^* > 53$), normal ($48 < L^* < 53$) and darker than normal ($L^* < 48$). According to this border value, the lightness (L^*) color values (49.25 ± 0.28) and 48.65 ± 0.45) males to females values in the present study for the breast meat without skin from chicken strains fall under the normal range. Chicken breast meat generally appears to have a pink color, which is considered a desirable characteristic by the consumers and has a normal color Choo *et al.* (2014).

The redness (a^*) values indigenous chicken strains breast meat after cold storage for 24 hr from the current study was similar to that of three chicken genotypes in Ethiopia by Getnet *et al.*(2022) and Laudadio *et al.*(2012). The female (5.78 ± 0.18) breast meat had significantly different ($p < 0.05$) than the redness (a^*) scores within the males chicken strains (4.63 ± 0.19). Consequently, the genetic differences might have contributed to the variation in breast and other meat color, the tendency for chicken meat to be darker or redder under an intensive production system might be due to slower growth and higher physical activity in the experimental pens.

There was difference among indigenous chicken strains of sexes in the yellowness (b^*) color of breast meat. The current findings of the values in yellowness color (b^*) 11.43 and 10.12 males and females respectively was in line with the values ranged from 8.2 to 13.8 reported for the breast meat of four different Chinese indigenous chicken genotypes Guan *et al.* (2013) and the values ranged from 11.9 to 10.5 reported for the breast meat of horro local chicken and Tilili local chicken Getnet *et al.* (2022). Contrary to the current yellowness (b^*) color result 11.43 to 10.12 males to females of the current study was lower than the values (17.4 – 19) for breast meat for Korean native chickens reported by Jayasena *et al.* (2013). The WHC value of the breast meat was significantly ($P < 0.05$) lower in males (86.83 ± 2.12) than in females (87.05 ± 1.96). Therefore, the WHC value of the breast was significantly ($P < 0.05$) affected by sex.

In the same line, the water holding capacity (WHC) of the breast was significantly ($P < 0.05$) affected by sex as reported by Debut *et al.* (2003). As noted by Uhlirova *et al.* (2018) the acceptable standard of WHC is 85.43 % to 87.61%, therefore, the present findings were within the acceptable range. Furthermore, differences in breast meat WHC values have been attributed to breed and gender differences in water retention in the meat, which can be explained by variations in composition and quality Kralik *et al.* (2018). The male (2.65 ± 0.05) breast meat DL (%) had significantly ($p < 0.05$) higher than the breast meat DL (%) values of females' chicken strains (2.07 ± 0.06), which was similar with the DL (%) value of breast which was significantly higher in male chicken of Arbor Acres than the females Baicheng (2.64 ± 0.28 vs. 1.89 ± 0.49) as the value reported by Sarsenbek *et al.* (2013). And the DL (%) meat varied across genotypes and between sexes was due to differences in interlocked connective tissues. The DL (%) of the breast meat was significantly varied by Genotype, sex, age, and diet Choe *et al.* (2010).

5.11. Nutritive Value of Indigenous Chickens' Meat

The result of the nutritive value of on-station evaluated of Abobo, Gambella ketema Zuria, Itang, and Lare chicken strains meat were in agreement with the findings reported by Salma *et al.* (2016) non-significant difference in moisture content of breast and thigh meat in breeds was recorded from Pakistan and also the current results were similar with the findings reported by Mbaga *et al.* (2014) on crude protein (CP) and ash content was similar in male and female local chicken meat in Tanzania.

The present findings of mean moisture(75.36) contents were comparable with the value reported by William and Jonathan (2017) for chickens slaughtered at 24 weeks of age had a mean moisture content of 73.06 and the mean moisture content of chickens slaughtered at 24 weeks old was not significantly different ($p < 0.05$). From the present findings the mean crude protein (19.15) contents of chicken slaughtered at 24 weeks of age old was similar with the value reported by William and Jonathan (2017) for chickens slaughtered at 24 weeks of age had a mean crude protein content of 20.05.

In all of the studied chicken strains, the crude protein contents of breast meat were significantly higher than those of the thigh and drumstick meat part which was similar with the value reported by Mbaga *et al.* (2014) for breast cut had higher CP content than thigh and drumstick cuts of Tanzanian local chickens. The findings of this study showing non-significant difference in crude protein contents in all chicken strains were in agreement with those of Salma *et al.* (2016) who reported non-significant difference between protein content of poultry breeds. The current results of the mean Ash (0.44) contents of chicken slaughtered at 24 weeks of age old was lower than the value reported by William and Jonathan (2017), for chickens slaughtered at 24 weeks of age had a mean ash content of 1.28. The current studied results of mean crude fat (4.61 %) contents of chicken slaughtered at 24 weeks of age was similar with the value (4.57 %) reported by William and Jonathan (2017).

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

The study was conducted in Gambella regional state, to characterize the phenotypic and on-station evaluation of indigenous chicken ecotypes. A total of 384 households (96 households from each district) keeping indigenous chicken strains were randomly sampled for interview. Data were collected using the questionnaires. On-farm observations, on-station evaluation, and laboratory analysis were conducted on relevant data.

The mean survival rate of chicks in the current study was lower. The results indicated that the predominant plumage color of the indigenous chicken found in the Abobo and Gambella Ketema Zuria districts are red followed by black and white. The normal feather distribution in the chicken populations had normal feather distribution. The mean body weight of adult males and females were significantly different among the study areas. As presented in the current study, the shank length, keel bone length and comb height are highly correlated with body weight ratio for all the study districts.

From the on-station evaluation, the lower fertility of indigenous chicken in the current study might be due to the cock shortage in the area, egg storage time before incubation, transportation of collected eggs from households to hatchery room and the overall monitoring systems during incubation period. The embryonic death before hatch in the eggs shell might be due to the lack of monitoring the overall manipulation of the incubator such as temperature, moisture and electric power. However, such expanded information about embryonic death in the eggs shell before hatched of chicks was not available in other scenarios. There were non-significant differences in FCR between the indigenous chicken strains. The body weight for males' chicken strains was significantly greater than those of the female chicken strains.

The variation in mean weights for day old chick and other stages of growth among the strains could be attributed to differences in strains. The overall mean of the HDEP (%) and HHEP (%) of the present results of chicken strains were, moderately good. From the present results shown that, the overall mean mortality rate of the evaluated strains of brooding phase was, at the normal condition.

There were non-significant differences in the weight of the breast, thighs, drumstick, neck, liver, keel bone, skin, heart, wings and gizzard, of all carcass component values of indigenous chicken strains studied. In the current study, there were non-significant differences in moisture contents in all of the chicken strains. In all of the studied chicken strains, the crude protein contents of breast meat were significantly higher than those of the thigh and drumstick meat part, whereas the contents in moisture, crude fat, and Ash of the thigh and drumstick meat were significantly higher than those of the breast meat.

6.2. Recommendations

According to the findings, the following recommendations could be forwarded.

- ✓ Phenotypic differences are observed among the chicken strains. Therefore, it is recommended that a further molecular characterization should be used to back up the present findings and determine genetic variation within and among the chicken strains. Finally, genetic differences should be considered to develop effective utilization and conservation strategies.
- ✓ The supplementary feed and overall management should be provided at farmers' level.
- ✓ There should be provision of good management, disease prevention and control of predators.
- ✓ The standard male to female breeding ratio of cock and hens, timing of egg storage before incubation and transportation facilities should be well-prepared and well-equipped in the study area.
- ✓ During hatching the certified international standard incubators should be used.

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APPENDICES/ ANNEXES

Annex 1. Questionnaires

Appendix 1. Phenotypic characterization of indigenous chicken in selected districts of, Gambella regional state, Ethiopia

A. For on-farm characterization Socio characteristics

1. District _____, Peasant Association/Kebeles _____

2. Enumerator's name _____ Date of interview _____

3. Numbers of animals kept

a. Cattle _____

e. Donkeys _____

b. Sheep _____

f. Mules _____

c. Chickens _____

g. Goats _____

d. Horses _____

h. Honey bee colony _____

B. Number of chicken the farmers have

B.1. types of poultry production systems: 1. extensive 2. Semi-intensive
3. intensive

1. State the number of chicken you have (Based on sex and age group)

Poultry by Age and sex group Number currently owned	Hens _____	Cocks _____	Pullets _____	Cockerels _____	Chicks _____

2. What are the major Challenges of poultry rearing in your area?

1.
2.
3.

3. Presence of any cultural or religious belief to rear a special type of chicken

1. Yes
2. No

If yes; specify the type of cultural/religious belief to rear a special type of chicken

.....
.....

4. Presence of any cultural or religious belief not to eat chicken meat and eggs

1. Yes
2. No

If yes; specify the type of cultural/religious belief not to eat chicken meat and eggs

.....
.....

5. Presence of any cultural or religious belief not to sell chicken and eggs

1. Yes
2. No

If yes; specify the type of cultural or religious belief not sell chicken and eggs

.....
.....

6. Do you have access to advisory/technical/ support from extension workers on poultry?

1. Yes
2. No

If yes, how often do they visit you per month.....

C. Housing

1. Where do birds sleep at night? 1. Separate shelter. 2. Perches in the main house. 3. Perches in the kitchen. 4. Perches on the veranda. 5. Perches in shoat house. 6. Separate shelter.

2. If you don't have a separate house for your chickens, why not?

1. Lack of knowledge (Awareness). 2. Less attention given to poultry. 3. Lack of construction materials. 4. Risk of predators. 5. Risk of theft. 6. Small flock size. 7. Other (please describe).....

3. Are there periods during the year when birds are confined within their housing e.g.

Planting, harvesting? 1. Yes 2.No If yes, which months? _____

D. Feeding

1. Do you ever provide any supplementary feed for your birds? 1. Yes 2. No

2. Do you provide separate supplementary feed just for chicks? 1. Yes 2. No

3. During the rainy season, do you provide: 1.More feed. 2. The same amount of feed. 3. Less feed. 4. No feed.

4. What type(s) of supplementary feed do you provide?

1. Wheat 2.Sorghum 3.Maize 4.Household scraps 5.Barley 6. Other (describe).....

E. Watering

5. Do you provide water to chicken?

a. yes b. No

6. If yes, fill in the following table

Source of water (tap, river, well)	Type of Material used for drinkers	How frequently do you provide water for chickens?	How faring the source of water from the home stead?

E. Culling

1. Do you practice culling of birds? 1. Yes 2.No

If yes, what is your reason for culling (multiple answers are possible)

1. Old age. 2. Poor productivity. 3. Unwanted plumage color/pattern

4. Illness 5. Bad temperament 6.Excess in number Other (Specify).....

F. Characteristics of your chickens

1. Have you observed any variation in disease resistance among your chickens?

1. Yes 2. No

2. How would you describe the temperament of your chickens?

1. Docile 3.Moderately 3.tractable Wild

3. Do your birds take dust bath regularly? Yes No

G. Breed and breeding

1. Do you practice selection with in your chicken flocks?
 - a. yes
 - b. No
2. For which character do you use selection for cockerels (rank)
 - a. color
 - b. comb type
 - c. body size
 - d. body weight
 - e. other
3. For which character do you use selection for pullets (rank)
 - a. color
 - b. egg production
 - c. weight
 - d. other
4. For which character do you use selection for male breeding stock (rank1-3)
 - a. Body plumage Color
 - b. Double/rose comb
 - c. large body size
 - d. Qumena (body conformation)
 - e. Early maturing
 - f. body weight
5. For which character do you use selection for female breeding stock (rank1-3)
 - a. Egg production
 - b. mothering ability
 - c. Hatchability
 - d. Large body size
 - e. Color
 - f. large egg size
6. Do you have your own cock or male for breeding? 1. yes 2.No
7. Do you use breeding/brooding/ practices? 1. Yes 2.No, if yes
 1. Natural hen
 2. Incubator

H. production and reproduction performance

Reproductive traits	Hen	Cock
Age at first mating (month)		
Age at first lay (month)		

1. Average number of clutches per hen per year (circle) 1 2 3 4 5
2. Average number of eggs per clutch (N).....
3. How many times a year does you incubate eggs for hatching.....
4. When is the season you prefer to set eggs for hatching?
 1. Dry season.
 2. Wet season.
 3. Any time.
5. When is the season you will **not** set eggs for hatching?
 1. Dry season.
 2. Wet season.
 3. Any time.
6. For how long (days) do you store eggs before incubation? _____
- 7. Hatching of eggs**
 1. Average hatch rate (%)
 2. Percentage of hatchability.
 3. Survival rate of chicks to 8 weeks

4. Percentage Survival rate of chicks to 8 weeks

6.1. Reproductive and Productive performance of local chicken ecotypes in the study area.

a. Average age of cockerels at first mating (month)_____

b. estimated egg production hen/year-----.

7. How would you describe broodiness in your hens (circle?)

a. Common b. Sometimes c. Rare

8. How do you deal with unwanted broodiness behavior? (Multiple answers are possible)

1. Hanging hen upside-down.

2. Disturbing.

3. Inserting feathers through nostrils.

4. Taking to another place.

5. Taking away brooding nest. 6. Immersing in cold water. 7. Tie their legs.8.Put other materials on brooding nest. 9. Other (specify).....

9. Which characteristics/traits of hens are you prefer /most important?

.....

10. Do you have your own cock? 1. Yes 2.No

Which characteristics/traits of cocks are you prefer /most important?

.....

I. Preferences for appearance of chickens

1. Plumage color of your preference (rank, 1=most important)

1.1. Hen

1..... 2. 3.

1.2. Cock

1..... 2. 3.

2. Which plumage colors do you dislike?

1..... 2. 3.

3. Reason for plumage color preference

1. Aesthetic value. 2. High market value. 3. Cultural and religious value.

4. Other (Specify).....

4. Which comb type do you prefer?

1. Single

2. Double

3.strawberry

4. Others

(Specify).....

5. Reason for comb type preference

1. Aesthetic value 2. High market value. 3. Cultural and religious value

4. Other (Specify).....

6. Which shank color do you prefer?

1. Yellow

2.White

3. Black/grey

7. Do you prefer?

1. Normal feathered chicken 2. Naked neck

2. For on-station evaluation check list

Data collection recording sheet for feed intake of the local chicken ecotypes

age in week	Gambella District					
	Female			Male		
	Feed offered (g/day)	feed refusal (g/day)	feed intake(g/day)	Feed offered(g/day)	feed refusal (g/day)	feed intake(g/day)
1						

Age in week	Abobo District					
	Female			Male		
	Feed offered (g/day)	feed refusal (g/day)	feed intake(g/day)	Feed offered(g/day)	feed refusal (g/day)	feed intake(g/day)
1						

Age in week	Itang District					
	Female			Male		
	Feed offered (g/day)	feed refusal (g/day)	feed intake(g/day)	Feed offered(g/day)	feed refusal (g/day)	feed intake(g/day)
1						

Age in week	Lare District					
	Female			Male		
	Feed offered (g/day)	feed refusal (g/day)	feed intake(g/day)	Feed offered(g/day)	feed refusal (g/day)	feed intake(g/day)

1						
2						

 Body weight gain weekly for both sex(M&F) @2019

S.N	Gambella District							
	Female (body weight in gram)/week				Male(body weight in gram)/week			
	Week1	Week2	Week3	Week4	Week1	Week2	Week3	Week4
1								
2								

 Body weight gain weekly for both sex(M&F) @2019

S.N	Abobo District							
	Female (body weight in gram)/week				Male(body weight in gram)/week			
	Week1	Week2	Week3	Week4	Week1	Week2	Week3	Week4
1								

 Body weight gain weekly for both sex(M&F) @2019

S.N	Lare District							
	Female (body weight in gram)/week				Male(body weight in gram)/week			
	Week1	Week2	Week3	Week4	Week1	Week2	Week3	Week4
1								
2								

+ Body weight gain weekly for both sex(M&F) @2019

S.N	Itang District							
	Female (body weight in gram)/week				Male(body weight in gram)/week			
	Week1	Week2	Week3	Week4	Week1	Week2	Week3	Week4
1								
2								

Caracas characteristics of local chicken ecotypes

ID of chicken	live weight	slaughter wt	wt of other parts	

Internal and external egg quality

ID egg	breed	egg wt	Egg length	Egg width	Shell thickness	Shell weight	Albumin wt	Yolk wt	Yolk color

Egg production of each hen

Sire Id	Dam ID	bird ID	date											
			1	2	3	4	5	6	7	8	9	10	11	12
Selection of birds to be parent for the next generation will be based on the egg production layed until 45 weeks of age														

Annex 2. Figure of the studied chickens on-farm characterized



Annex 3. Figure of the studied chickens' on-station characterized



PUBLICATIONS

In this study five (5) Articles were published with one article was accepted

1. On-farm Phenotypic and Morphological Characterization of Indigenous Chicken Populations in Gambella Region, Ethiopia, (*International Journal of Poultry Science (ijps)* ISSN: 1682-8356, Vol.20 (1), pp.27-38: DOI: 10.3923/.2021.27.38), December, 2020

2. Analysis of Fertility, Embryonic Death, Hatchability of Artificial Incubator Used and Egg Quality of Indigenous Chickens' Ecotypes in Gambella Regional State Ethiopia, (*International Journal of Animal Science, Husbandry and Livestock Production* ISSN: 2141-5191, Vol. 7(3), pp. 389-397, March, 2021)

3. The Nutritive Value of Meat and Egg of Indigenous Chicken Strains in Ethiopia, (*International Journal of Animal Science, Husbandry and Livestock Production (IJASHLP)* ISSN: 2141-5191, Vol. 9(1), pp. 463-468, March, 2023),

4. Blood Serum Contents and Fatty Acid Profiles of Meat from Different Chicken Strains in Ethiopia, (*International Journal of Animal Science, Husbandry and Livestock Production (IJASHLP)* ISSN: 2141-5191, Vol. 9(2), pp. 469-477, May, 2023)

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