Original Research Article||

Production and reproductive performance, and egg quality of indigenous chicken in Siltie Zone, Ethiopia

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Abstract

Limited attention has been given to the performance evaluation and classification of indigenous chickens. The performance of chicken production can be influenced by genetic and non-genetic factors. Thus, the purpose of this study was to assess the production and reproductive performance as well as egg quality of indigenous chickens in highland and midland agro-ecologies in Silte Zone of Central Ethiopia. From each agro-ecology four districts were purposively selected. Three hundred twenty farm households were randomly selected for household survey representing highland and midland agro-ecologies. Data on Production and reproduction performances were collected. Additionally, 160 chicken were used for measuring the body weight and other traits. Three hundred eggs were collected and transported to Hawassa University, poultry farm laboratory, for quality analysis. The collected data were analyzed using Generalized Linear Model (GLM) procedure of SAS. Body weight of cockerels were 1271.3±89.29 and 1220±87.27 grams while body weights of laying hens were 1023.8±80.47 and 1027.5±75.19 grams in midland and highland agro-ecologies, respectively. Matured age of cockerels, pullets' age at first egg and survival of chicks in wet season were significantly better in the midland agro ecology. Pullet's ages at first egg were 28.30±1.72 weeks. Egg weight, egg length, albumen weight and yolk diameter were significantly higher in midland. In conclusion, there was variation on production and reproductive performance and egg quality of indigenous chicken under farmers' management conditions between the two agro ecologies. In some production performances, and some egg quality parameters, indigenous chickens were better in the midland agro ecology. Hence, it can be recommended that agro-ecological-based improvements in breeding and management practice (feeding, housing and health) of indigenous chickens are vital in the study area.

Key words: Hawassa University; Egg quality parameters; poultry growth parameters; highland and midland agro-ecologies

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INTRODUCTION

Chicken production is a suitable enterprise for poor and landless households, as it requires small/no land and investment to establish and manage the farm (FAO, 2019). In Ethiopia, there are approximately 57 million chicken, with 78.85% (44,940,924) indigenous, 12.02% (6,857,718) hybrid and 9.11% (5,194,345) exotic–chicken (CSA, 2021). Poultry have added importance to various socio-economic, food security, and religious contributions (Gulilat *et al*., 2021).

Local chicken productivity is very low, as compared to exotic and commercial breeds with only 40-60 eggs annual egg production, 70% hatchability rate and excessive mortality rates (Getachew, 2016; Emebet, 2015). In the traditional poultry production system, more than 90% of the national egg and meat output is from indigenous chicken (Chaimiso, 2018). Non- genetic factors such as feeding, housing, healthcare, and other management practices have a much greater impact on production than genetics under a scavenging system of production (Berhanu *et al*., 2022). Native chickens are normally kept according to an extensive or scavenging system with few or no inputs for housing, feeding and health care **(**Mtileni *et al*., 2012)**.** Indigenous chickens are properly tailored to the local climatic conditions, feed and management stresses, with better resistance to diseases **(**Iqbal and Pampori, 2008). **A**lthough efforts have been ongoing for several years to introduce more efficient, exotic and crossbred types of poultry, village chickens remain predominant throughout many African villages. This is because local farmers have been unable to deliver the high input requirements such as housing/shelter, proper balanced diets, and disease control/vaccination programs associated with more genetically efficient breeds (Tabler *et al*., 2018).

The per-capital annual poultry meat, and egg consumption in Ethiopia is only 0.12 and 0.14 kg, respectively (Tshovhote, 2015). On the other hand, Yosefe *et al*., (2016) reported a higher value with 2.85 kg of meat and 57 eggs per year, which might attribute to the production of chicken in that specific study area in Ethiopia. Still, in low earning households, both chicken meat and eggs are preferred sources of cash income.

The traditional and improved family poultry production systems target smallholder farmers who can utilize potential feed resources locally. Generally, limited attention has been given to the performance evaluation and classification of indigenous and non-descriptive chicken types in Ethiopia. Future research needs to focus on the identification, description, and evaluation of these genetic resources and their production and reproduction performance under smallholder conditions as well as quality of products. The internal and external egg quality traits were influenced by factors such as agro-ecology, breeding, and their interaction (Serkalem et al., 2023). Aberra and Tegene (2009) reported that identification and characterization of the chicken genetic resources generally require information on their adaptation to a specific environment, possession of unique traits of current or future economic value and socio-cultural importance, which are crucial inputs to decisions on conservation and utilization.

In Silte zone, little research has been conducted on characterization of the production system of indigenous chicken. Even though there were little studies performed on production and reproductive performance, husbandry practices and egg quality of indigenous chicken, there was no adequate documented information on indigenous chicken in the study area.

Egg quality is a factor that contributes to the better economic price of fertile and table eggs. In general, the characteristics of eggs have a genetic basis (Silversides and Scott, 2001). Egg production is believed to be a complex qualitative trait that is influenced by several factors such as breed, nutrition, age, the weight of birds, level of production, management practices, and environmental factors (Oluyemi and Roberts, 2000). Therefore, the study was conducted to assess production and reproductive performance and egg quality traits of indigenous chicken in the mid and high land agro-ecologies.

MATERIALS AND METHODS

Description of the Study Area

The study was carried out in mid and highland agro-ecologies of Siltie Zone of Central Ethiopia Region, Ethiopia (figure 1).

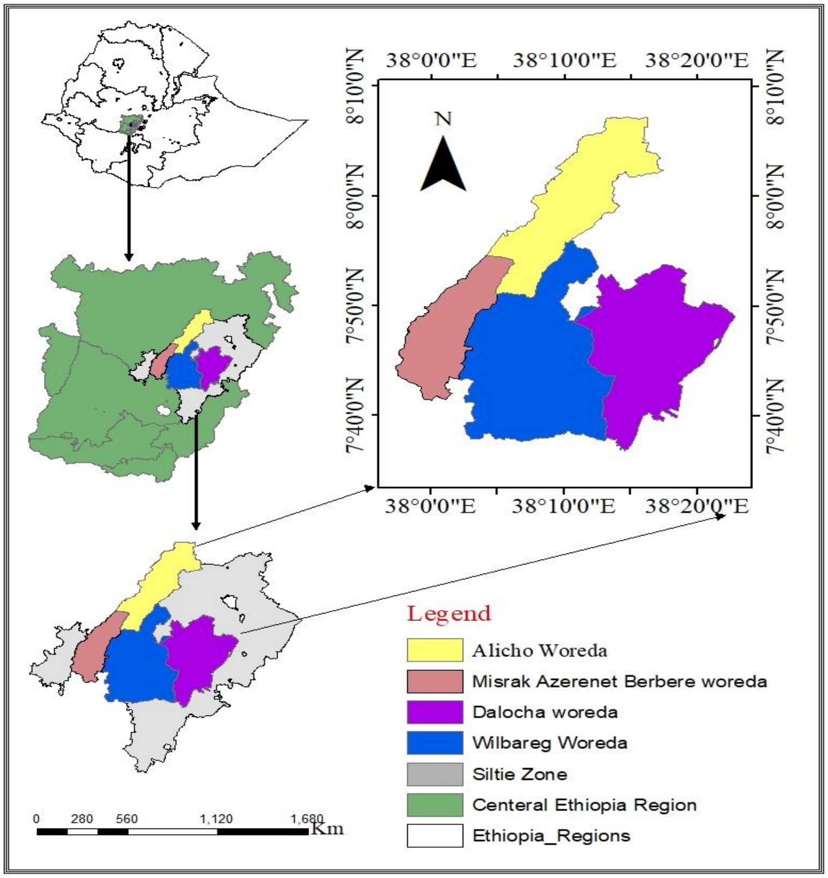

Figure 1. Map of the study area (Source: shape files from CSA, Ethiopia, 2013)

Siltie Zone is bordered by Hadiya Zone to the south, Gurage Zone to the north and north-west, Oromia to the east and Halaba Zone to the south east. Worabe is the capital town and found 172km South of Addis Ababa. Siltie Zone coordinates a Latitude of ranges 7°4'0"- 8°1'0" north and a longitude of 38°00'0" - 38°20'0" east and it is located at an elevation of 1,500-3,700 meters above sea level. There are 10 (ten) districts and 4 (four) administrative towns having two different agro-climatic zones, (Highland or Dega, 20.5%) and (Mid-land or Weyna-Dega 79.5%). The average temperature ranges from 12-26^{o}C and the average annual rainfall ranges from 780-1818mm (Tagese *et al*., 2021). In Siltie zone, there are approximately 646,525 chicken heads, with 71.43% (461,833) indigenous chicken population, 26.20% (169,452) are hybrid chicken population, and 2.36% (15,240) are exotic (CSA, 2021).

Sampling Design and Data Collection Procedures

The study had both household survey and laboratory studies. Four districts were purposively selected based on the potential of local chicken population and presence of both agro-ecologies. Two districts from each of highland and midland were selected. A total of eight (8) Kebeles, two Kebeles from each district were selected purposively based on potentiality of indigenous chicken population and accessibility for data collection. Before selecting the household for the survey, the total households having indigenous chicken in the Kebele were identified and listed.

Then from each Kebele, using simple random sampling technique, 40 households who have greater than five adult local chickens were selected. Prior to the selection of households for the survey, farmers who own exotic and their crosses have been identified with the help of extension workers in the district. Then those having exotic chicken or their crosses in the neighborhood were purposely excluded. Closely adjoining households also skipped to avoid the risk of sampling chickens sharing the same cock. Hence, a total of 320 poultry keeping smallholder households were selected from the study area.

Data Collection Procedures

The survey part was accomplished through interview using pre-tested and semi-structured questionnaires. Before the survey was started, the prepared questionnaires were provided to four households in four different districts to check whether or not it was understandable. Pre-testing the questionnaire before the actual survey had enriched the main structured questionnaire which otherwise could have been missed. The interviews were conducted at farmers' house. Data sets included chicken productivity and flock performance (number of times the hen brood in a year, number of eggs per clutch per hen, number of days per clutch, number of eggs per set of incubation, hatchability percentage of the eggs and survivability percentage of chicks).

Quantitative data such as body weight from both adult sex groups (age of chicken more than 6 months) were measured using a hanging spring balance to the nearest 0.01gram before the chickens leave for scavenging in the morning by holding the chicken systematically (without disturbing) and tie their legs. From each of the agro-ecologies, 160 chicken were used for measuring the body weight to see the effect of agro-ecology on their growth performance.

Data Collection for Egg Quality Measurements

Three hundred (300) fresh eggs that have not been stored for more than a week after being laid were directly collected (purchased), 150 eggs from each agro-ecologies.

The storage time of eggs ranged from 1-5 days since the eggs were collected from different household and it was not possible to get the same storage duration. The collected eggs were properly collected with straw bedded carton with several small holes on it for aeration and to avoid egg breaking. The eggs were labeled according to their agro-ecologies and transported to Hawassa University, college of Agriculture, poultry farm. On the next day, egg quality traits were evaluated.

External egg quality parameters include egg weight, egg length, egg width, eggshell weight, and eggshell thickness. Egg length and width were measured using stainless hardened digital caliper to the nearest of 0.01 mm. Egg shape index was calculated using the formula of Van den Brand *et al*. (2004).

$$\text{Eggshell wt. (\%)} = \frac{\text{Dry shell wt.}}{\text{Egg wt.}} * 100$$

$$\text{Egg shape index (\%)} = \frac{\text{Egg width}}{\text{Egg length}} * 100$$

The internal egg quality parameters including yolk height, yolk diameter, yolk weight, yolk color, albumen weight and albumen height were determined. Egg weight was measured using a digital sensitive balance (SF-400) to the nearest 0.1 gram precision. Each egg was broken on to a glass covered table and the albumen and yolk heights were measured using PAT.460176 Tripod micrometer to nearest 0.01mm. Yolk was carefully separated from the albumen and weighed separately. The eggshells were cleaned with tissue paper and the shell membrane was removed by hand and then dried in the open air for 24 hours and the eggshells were weighed without the shell membrane. Then, the eggshell thicknesses were measured using stainless steel hardened digital caliper to the nearest 0.01 mm. from three parts and average of the three was taken. Based on the collected data, egg shell ratio, Haugh Unit, yolk ratio, albumen ratio, and yolk index were calculated using the given formulas below .

Haugh units of the eggs were estimated based on the albumen height and egg weight according to the formula of Haugh (1937). Yolk height and diameter values were used to compute yolk index of the eggs. Yolk color was measured using Roche color fan consisting of a series of fifteen colored plastic trips which were used as a reference to determine yolk color.

$$HU = 100\log(AH - 1.7EW^{0.37} + 7.6)$$

Where: HU= Hough unit, AH= Albumen height in millimeters, and EW= Egg weight in gram

Yolk Ratio and Albumen Ratio were estimated by the following formula:

$$Yolk\ Ratio = \frac{Yolk\ weight}{Egg\ weight} * 100$$

$$\text{Albumen Ratio} = \frac{Albumen\ weight}{\text{Egg weight}} * 100$$

$$\text{Yolk index} = \frac{\text{Yolk height in (mm)}}{\text{Yolk diameter in (mm)}} * 100$$

Statistical Analysis

The data collected on production and reproductive performance, egg weight, egg quality parameters were subjected to analysis of variance (ANOVA) ($p < 0.05$). All data were analyzed using Generalized Linear Model (GLM) procedure of SAS (Version 9.0) statistical package (SAS, 2002). The statistical model used for quantitative data measurements of indigenous chicken was:

$$Y_{ijk} = \mu + Ai + eijk$$

Where: Y_{ijk}: the corresponding quantitative trait of indigenous chicken in i^{th} agro-ecology

μ: overall population mean for the corresponding quantitative trait

A_i: effect of i^{th} agro-ecology (i=2, midland and highland)

e_{ijk}: random error and

The statistical model used for Egg quality parameters was

$$Yik = \mu + Ai + eik$$

Where: Yik = response to the observed variable of egg quality

μ = overall mean

Ai = the effect of i^{th} Agro-Ecology (i = 2, Highland and Midland) and eik = random error

RESULTS AND DISCUSSION

Production and Reproductive Performance of Indigenous Chicken

Age at First Mating

Production and reproductive performance of indigenous chickens are presented in Table 1. The mean cockerels' age at first mating was 22.71±1.35 and 22.4±1.29 weeks in highland and midland agro-ecologies, respectively. The current result on cockerel age at first mating was earlier than the findings of Fisseha *et al.* (2010), who reported that average age at first mating was 24.6 ± 2.0 and 24.5 ±1.6 weeks in highland and midland respectively in Bure district, north west Ethiopia.. On the other hand earlier age at first mating 5.22±0.03 months (20.88±0.12 weeks) for local cockerels than the current study was reported by Andualem (2020) in Awei zone, Amhara region, Ethiopia. Similarly, Yadessa *et al.* (2017), also reported earlier sexual maturity of local cockerels with 20, 19.6 and 21.2 weeks of age in Mezhenger, Sheka and Benchi-Maji areas. The variations in sexual maturity or age at first mating in different areas might be due to agro-ecological factors such as environmental temperature; husbandry practices of the chickens, local breed eco-type, and the type of feed resources in and around the study areas. The sexual maturity in animals is a highly energy-consuming process, thus it is strictly regulated by the body's nutritional status and energy metabolism. Previous studies have found a correlation between the sexual maturity of animals and body weight and body composition on different animal species. Studies conducted on quails revealed that there is correlation between body weight and body composition with sexual maturity (Reddish et al., 2003; Abou Khadiga et al., 2016).

Matured Body Weight

Matured body weight of cockerels in the study area were 1271.3±89.29 grams in midland and 1220±87.27 gram in the highland agro ecology, with overall mean matured body weight of 1245.6±91.81grams. Matured body weight of laying hens was 1027.5±75.19 grams in highland and 1023.8±80.47grams in midland agro-ecologies with the overall mean matured body weight of 1025.6±77.78 grams. The matured body weight observed for both sexes in the current study area are lower than the value by Hailu and Aberra, (2018) who reported that 1.68 kg for cocks and 1.42 kg for hens with overall mean value of 1.55 kg in Sheka zone. Matured body weight of cockerels in the midland was significantly ($P<0.05$) higher than the highland agro ecology. The variation might be due to the agro-ecological effect in relation to the environmental temperature on local chicken and the husbandry practices (feed supplementation and watering management) of the chicken owners in the study area.

Non-genetic factors like feeding practices, flock management, housing, season, chick rearing, brooding and vaccination etc. have great influence on production performance (Ochieng et al., 2011; Hossen, 2010). Management intervention contributes to increase production potential of indigenous chicken and helps to support effectively the livelihood of poor rural households (Sarkar, 2012; Hossen, 2010) thus recognizing small-scale poultry production as an economically viable and sustainable enterprise for rural households in Bangladesh (Sarkar and Mustafa, 2009).

Age at First Egg Laying (AFE)

Mean age at first egg of local pullets were 28.96±1.46 and 27.63±1.69 weeks for highland and Midland agro-ecologies with overall mean of 28.30±1.715 weeks respectively. The overall mean of AFE in the current study was higher than the average values of 27.5±2.4 weeks by Fisseha *et al.* (2010), in Bure district, North West Ethiopia. In the current study AFE was significantly ($P<0.05$) earlier in Midland than Highland agro ecology. Similarly Getachew *et al*. (2021) conducted a study in Gambella region and the results revealed mean age of 24.8 weeks age at first egg which is much earlier than in the current study. The variation between the different studies might be attributed to differences in geographical location which could be related to availability of feeds and feed resources. The sexual maturity of animals is regulated by various factors, such as genetics, non-genetics (nutrition, and environment). The relationship between sexual maturity and nutritional status has been a subject of study in the field of reproductive biology. Some of the research findings were also confirmed in subsequent studies. Jambui et al. (2017) and Heijmans et al. (2023), suggested that poultry need to reach a critical threshold of body weight or fat storage to enter the egg-laying stage. Nutritional status also has an effect on the development of body frame, which was reported to be related to sexual maturity in mammals and poultry (Vargas et al., 1999; Setoguchi et al., 2011; Afrouziyeh et al., 2021).

The late maturity of pullets in the current study needs serious intervention measure to improve the situation. A different report on the age of chickens at first egg might be due to lack of proper supplementary feeds, availability of scavengable feed resources, disease outbreak, environmental temperature and provision of clean water by the households.

Egg Production Performance

Mean egg production per hen per clutch were (12.3±1.61 and 12.6±1.03 eggs) in the highland and midland with overall average egg per clutch per hen of 12.45±1.36. The result in this study for eggs per clutch per hen was lower than the result of Getachew *et al*. (2021) who reported that average egg per hen per clutch was (13.29±0.25 eggs) in Gambella region of Ethiopia. Similarly Assefa *et al.*

(2019), reported higher average egg production per hen per clutch of 13.3±2.5 eggs in two agro-ecologies (lowland and highland) than the current study. The current result egg production per hen per clutch was slightly higher than the finding by Habte *et al*. (2013), who reported 11.23 eggs per hen per clutch in Nole Kabba Woreda of western Wollega.

The current result showed that, the mean egg production of indigenous chicken per hen per year was 47.43±6.48 eggs in Highland and 48.42±6.94 eggs in the Midland agro-ecology with the overall mean egg production of 47.92±6.71 eggs in the study area. The mean egg production of indigenous chicken per hen per year (47.92 in the current study) is lower than the national average (65) of egg production per hen per year, which indicates low production performance (CSA, 2021).

Getachew et al. (2021) reported that comparable mean egg production per hen per year of indigenous hens with values (47.24, 46.0, 44.7 and 43.85 eggs) in Abobo, Gambella Ketema Zuria, Itang and Lare, areas, respectively with the overall mean egg production per hen per year of (45.48 eggs) in Gambella Region. The reason for low productive performance of indigenous chicken in the current study might be due to difference in management practices, environmental temperature, altitude, humidity and feed resource availability. The result of the current study revealed that there is a need for serious intervention in management practice, feeds and feeding situation so as to improve production and reproductive performance.

Table 1. Production and reproductive performance of indigenous chicken in the study area

Indigenous chicken performances	Agro-ecology			
	HL	ML	Overall	P-value
	N=160 Mean ±SD	N=160 Mean ±SD	N=320 Mean ±SD	
Pullets age at first egg lay in weeks	28.96±1.46	27.63±1.69	28.30±1.715	<0.0001
Cockerels age at first mating in weeks	22.71±1.35	22.4±1.288	22.56±1.324	0.0346
Matured age of cockerels(weeks)	29.63±1.114	28.96±1.732	29.2±1.493	<0.0001
cockerels matured body weight in grams	1220±87.271	1271.3±89.29	1245.6±91.81	<0.0001
Laying hen mature body weight in grams	1027.5±75.194	1023.8±80.47	1025.6±77.78	0.667
Clutch lengths in days	25.97±0.531	26.03±0.387	25.99±0.465	0.280
Number of clutches in a year	3.96±0.190	3.98±0.371	3.97±0.465	0.4899
Number of eggs/clutch/hen	12.3±1.614	12.6±1.029	12.45±1.359	0.0531
Average number of eggs lay per hen/year	47.43±6.480	48.42±6.94	47.92±6.712	0.1491

Means within row are significantly different at when (p≤0.05),
HL, refers to Highland, ML, refers to midland and N, Refers to sample size

Number of Clutch and Clutch Length

The mean number of clutch per year for local chicken was 3.96±0.19 in the highland and 3.98±0.37 in the midland agro ecology with the overall mean of number of clutch per year of 3.97±0.465. The result shows a non-significant (P>0.05) difference between two agro ecologies in the number of clutch per hen per year. The result was in agreement with the mean clutch numbers reported by Tsegaw et al. (2013) who reported 4.3 clutches per year in North Gonder, Ethiopia. The overall mean clutch length of indigenous chicken in the study area was 25.99±0.465 days and there was no significant difference (P>0.05) between the two agro ecologies The result was consistence with the report of Nebiyu et al. (2013) who reported that the average of clutch length of 26.0 days per clutch in Halaba zone of southern Ethiopia.

Brooding and Hatching Performance

The brooding and hatchability performance is presented in Table 2. The mean number of eggs set per incubation and hatching period per broody hen were 8.69±0.78 and 9.38±0.78 eggs in highland and midland agro-ecologies, respectively with overall average of 9.03±0.84 eggs. The number of eggs incubated per hen in this study was comparable with the finding of Getachew et al. (2021) who reported that, the overall mean number of eggs incubated was 9.64 eggs in Gambella Region of Ethiopia. The number of eggs set for hatching was significantly higher ($p<0.05$) in the midland than highland agro ecology in the study area The current report was inconsistent with the report of Andualem (2020) who reported greater numbers of eggs set to broody hen (12.50±0.3) in Awi Zone, Amhara Region. The mean number of chicks hatched per number of eggs set per hen per hatching was significantly higher ($p<0.05$) in the midland than highland agro ecology. The variation on the number of eggs set in the two agro-ecologies might be related to the number of egg produced per clutch in the respective agro-ecologies.

The variation on the number of hatching chicks might be due to the performance of broody hen, egg storage condition, the agro-ecological environmental temperature (seasons) and to the total number of eggs set during incubation period. The hatchability of chicks varied in dry and wet season in highland and midland agro-ecologies in the study area. In wet season higher rate of hatchability was observed in midland than highland. Highest hatchability rate was observed in dry season with values of 85.19±6.42% and 84.83±6.78% in highland and midland agro-ecologies, respectively, with overall average of 85.01±6.60%. The higher hatchability during dry season in the present study could be attributed to favorable environment for the hen to incubate her eggs for hatching than wet seasons.

Seasonal fluctuations could be one of the possible reasons for the wide variability in hatchability. In this regard, higher hatchability of chicken eggs was reported in other areas in spring than in summer (Farooq et al., 2003). On the other hand, poor hatchability was reported by North (1984) and Farooq et al. (2000) in summer hatches. Chowdhury et al. (2004) also reported highest hatchability of duck eggs in winter and lowest in summer.

Donald et al. (2002), Rashid et al. (2005) and King'ori et al. (2007) reported that performance in chickens in terms of hatchability and chick hatch-weight may be closely related to the weight of the eggs because the main effect of egg size lies in the mass of the residual yolk sac that the chick retains at hatching.

King'ori (2011) suggested that chick weight, fertility and hatchability are interrelated heritable traits that vary among breeds, variety or individuals in a breed. Asuquo and Okon (1993) studied the effects of age in lay and egg size on fertility and hatchability of eggs. The authors noticed that egg size within the intermediate range of 45–56 g would hatch better than small eggs.

Survival Rate of Local Chicks

Survival rate of chicks in dry and wet seasons are presented in Table 2. The survival rate to eight weeks of age at wet season was significantly higher ($p<0.05$) in the midland than highland agro ecology whereas in dry season, higher survival rate was obtained in highland agro-ecology. The overall mean survival rate of chicks in dry and wet seasons were 42.96±1.82 and 33.08±4.42 % respectively. The variation might be due to the environmental temperature condition, husbandry practices, season of the year and the prevalence of diseases and predators at that season in the study area. The current study was comparable with the report of Matawork et al. (2019) who reported that survival rate of local chicken ecotype in highland, midland and lowland were 38.06±2.13, 39.14±1.09 and 39.35±0.95 %, respectively. The difference in mortality or survival rate of chickens in different parts of the country might be due to the difference in environmental temperature, body weight at hatching time, chicken's health management practices, prevalence of predators in different localities, density of chicken kept and season of the year chicks' hatch. In a study conducted in other countries, significantly ($P<0.05$) higher chicks survival was recorded in summer, spring and autumn season as compared to winter season. This may be attributed to extremely harsh environmental condition during the winter season. Sankhyan et al. (2015) also recorded the higher survival of chicks during summer season.

Reproductive Life Span of Local Chicken

There was significantly higher (P<0.05) reproductive life span of hens in the midland than the highland agro ecology in the study area.

Reproductive life span of cocks shows a non-significant (P>0.05) difference between the two agro ecologies in the study area. The mean reproductive life span of cocks (1.87±0.43 years) in the current study was less than the study conducted by Zewdu et al. (2013) who reported higher reproductive life span of cocks (3.79 years) in Metekel zone. On the other hand, the same author had reported a lower mean reproductive life span of hen of 3.56±0.14 years than the mean reproductive life span in the current study. Andualem et al. (2024) reported overall average reproductive lifespans of male and female Local chickens were 4.07 ± 0.07 and 3.75 ± 0.07 years, respectively which is higher than the observed lifespan in the current study. Several factors play a role in determining how long chickens live. Genetics and breed characteristi**cs** influence their natural longevity, while the quality of care they receive and the conditions in which they live can make a substantial impact on their lifespan.

Table 2. Hatchability and survivability of indigenous chicks in the study area

Indigenous chicken performances	Agro-ecology			
	HL	ML	Overall	P-value
	N=160 Mean ±SD	N=160 Mean ±SD	N=320 Mean ±SD	
Average number of egg set/hatch/hen	8.69±0.779	9.38±0.784	9.03±0.847	<0.0001
Chicks hatched/Settled eggs/hen/hatching	7.3±0.612	8.5±1.133	7.9±1.089	<0.0001
Percentage of hatch rate in the dry season	85.19±6.418	84.83±6.799	85.01±6.603	0.6186
Percentage of hatch rate in the wet season	73.19±6.418	76.08±6.799	74.64±6.757	0.0001
Chick survival to 8 weeks (dry season %)	43.25±1.166	42.66±2.257	42.96±1.816	0.0039
Chick survival to 8 weeks (wet season %)	30.35±4.471	35.8±2.061	33.08±4.419	<0.0001
Reproductive life span of hens in (year)	4.06±0.231	4.2±0.409	4.13±0.339	0.0002
Reproductive life span of cocks in (year)	1.89±0.449	1.85±0.407	1.87±0.428	0.4343

Means within row are significantly different at when (p≤0.05), HL, refers to Highland, ML, refers to midland and N, Refers to sample size

External and Internal Egg Quality Traits

External Egg Quality Parameters

External egg quality traits, particularly egg weight, shell weight, width and length are important parameters to consider during selection for improvement in live weight of the local chicken (Parmar et al., 2006).

The different external egg quality parameters are presented in Table 3. The mean value of egg weight and egg length in the midland was significantly (p<0.05) higher than the highland agro-ecology. The average egg weight (38. 44 gram) in the current study were lower than values (39.4 gram in lowland, 40.2 gram in midland and 39.3 gram in highland) reported by Aberra et al. (2013) across different agro-ecologies of Ethiopia. Similarly, the values of egg weight in the current finding was lower than the report of Kgwatalala et al. (2016) who reported average egg weight of 49.79 gram and 48.21gram reported on necked neck and normal indigenous chicken.

The variation might be due to the environmental factors related to the agro ecology in terms of diet, water intake, temperature, humidity and management practices. Isidahomen et al. (2013) reported, environmental influences in terms of the age of chicken, body size, and type of feed, water intake, temperature, and humidity and management practices may contribute to the variability observed in their egg quality results. Alex (2001) further reported that an egg weight is proportional to body weight. Big body birds eat more feed to maintain their body size. Higher egg weight, egg volume and surface area for the egg influences its egg quality and reproductive fitness of the chicken. Thus, it plays a significant role in the process of embryo development and successful hatching while the size of the hatching egg influences body weight of chicks up to maturity as suggested by (Islam et al., 2001; Farooq et al., 2001).

Egg width had shown significant difference between the two agro-ecologies in the study area in which the midland egg width were significantly ($p<0.05$) higher than the highland agro ecology, with the overall mean egg width of (37.39±1.41mm). The width of the eggs from the indigenous chickens in the study area were in agreement with the finding of Legesse and Kefyalew (2022) who reported that the egg width of indigenous chicken of 37.37, 38.65 and 38.62 mm respectively for in highland, midland and lowland agro-ecologies of Sidama Region, Ethiopia.

Egg shell weight in the midland was significantly higher than the highland agro-ecologies at ($p<0.05$). The result of mean egg shell weight (3.42±0.567gram) in the current study was lower than the report of Matawork and Meseret (2022) who reported shell weight of 5.25 ± 0.73, 5.12 ± 0.73 and 4.76±0.73 gram respectively at highland, midland and lowland agro-ecologies in Gena Bossa district of Dawro zone.

The egg shell thickness of indigenous chicken eggs in the study area was recorded with the overall mean of 0.27±0.034 mm showing a non-significant difference between the two agro ecologies. The current finding was comparable with the report of Fisseha *et al*. (2010), who reported 0.26 mm in Northwestern Ethiopia. The result was also in line with the report of Legesse and Kefyalew (2022) who reported the egg shell thickness of 0.286, 0.234 and 0.298 mm respectively for indigenous chicken in highland, midland and lowland agro-ecologies in Sidama Region of Ethiopia. However, the result in the current study was lower than the finding of Serkalem et al., (2019), who reported 0.279±0.03 and 0.281±0.02 mm respectively for shell thickness in lowland and midland agro-ecologies in different areas of Ethiopia. The variations in egg shell thickness among indigenous chicken ecotypes reared in various parts of the country might be due to the availability of calcium mineral in the feed, type of management, type of chicken population, and environmental influence as reported by Welelaw et al. (2018). From external egg quality traits, egg shell thickness is one of the vital portion of egg quality as it measures the strength of egg shell to minimize egg shell breakages which is important for breeder flock as studied by Bekele et al. (2009).

Egg shape index of indigenous chicken in the highland was significantly ($p<0.05$) higher than the midland agro-ecologies which had the overall mean of 75.21±4.28%. The variation might be due to the agro ecological effect, the husbandry practices and age of the hens. The finding was in agreement with the study of Veena et al. (2015), who reported egg shape index values of 72.10 during winter and 71.99 during summer on indigenous chickens of Andhra Pradesh. Egg shape is an important parameter in commercial production systems. Sharp eggs and round eggs do not fit well in egg cartons; therefore, they are much more likely to be broken during transportation than eggs of normal shape (Jacob, Milles, & Mather, 2000).

Table 3. External Egg quality parameters in the study area

Egg quality parameters	Agro-ecology			
	HL	ML		
	(Mean ±SD)	(Mean ±SD)	Overall mean	P-value
Egg weight (gm.)	37.72±3.544	39.16±3.777	38.44±3.726	0.0012
Egg length (mm)	49.21±2.825	50.46±2.154	49.84±2.584	< 0.0001
Egg width (mm)	37.18±1.512	37.62±1.267	37.39±1.409	0.0088
Shell weight (gm.)	3.32±0.62	3.53±0.496	3.42±0.567	0.0025
Shell thickness (mm)	0.27±0.035	0.27±0.034	0.27±0.034	0.0977
Shell Weight (%)	8.79±1.348	8.93±1.392	8.86±1.369	0.1196
Egg shape index (%)	75.77±5.067	74.64±3.221	75.21±4.276	0.0266

Means within row are significantly different when (p≤0.05), HL, Refers to Highland, ML, Refers to midland and SD, Refers to standard deviation

Internal Egg Quality Parameters

Internal egg quality depends upon the albumen quality, yolk quality, existence of blood or meat spot and air cell size (Ketelaere et al., 2004). Internal egg quality parameters of indigenous chicken in the study area are presented in Table 4. Albumen weight was significantly (p<0.05) higher in midland agro-ecology than the highland agro-ecology. The value of the albumen weight in the current study was comparable with the study of Legesse and Kefyalew (2022) who reported albumen weight of indigenous chicken of (21.78±3.16, 25.47±3.39 and 23.49±4.25gram) respectively, in highland, midland and lowland agro-ecologies of Sidama Region, Ethiopia.
Albumen height was significantly (p<0.05) higher in highland than midland agro-ecology in the study area. There was a non-significant (p>0.05) difference in Yolk weight between the two agro-ecologies but numerically there was some difference in yolk weight of indigenous chicken (14.84±1.92 gram) in highland and (14.76±1.335 gram) in midland agro-ecology (table 3). The current study was slightly similar with the report of Matawork and Meseret (2022) who reported yolk weight of 15.21±0.27gram in Gena Bossa district of Dawro zone. The variation in different localities might be due to difference in age of the hen and difference in the feed resource (type and availability). The effects of storage period were remarkable in nearly all internal egg quality traits (Khatun et al., 2016). Among non- genetic factors affecting internal egg quality; age of hens has the most important role in determining albumen quality in fresh laid eggs. Younger hens lay eggs with good albumen quality than aged hens although an induced pause can also lead to better quality albumen in aged hens (Supral and Surya, 2022). Yolk height of indigenous chicken in the highland (15.19±0.934 mm) was significantly (p≤0.05) higher than the midland agro-ecology (14.76±1.335mm) in the study area. The variation might be due to difference in the environmental temperature difference and type of scavenging feed sources in the study area. The result was consistent with the finding of Matawork and Meseret (2022) who reported yolk height of (14.83± 0.31 millimeter) in Gena Bossa district of Dawro zone.

The yolk diameter of indigenous chicken in the current study was (36.81±2.37) millimeter in highland and (38.37±1.95 millimeter) in the midland agro-ecology which was significantly higher in midland than that of highland agro-ecology (p≤0.05). The study was in agreement with the report of Demissu (2020) who stated yolk diameter of unimproved Horro chicken of (36.6, 41.1 and 39.7 millimeter) in highland, midland and lowland agro ecologies, respectively.

The result of yolk color shows statistically a non-significant (p>0.05) difference. Albumen ratio also shows a non-significant difference between the two agro ecologies in the study area. The value of the yolk color (9.22±0.83) in the current study was comparable with the reports of Legesse and

Kefyalew (2022) who reported that the value of 9.35±1.49, 9.46±1.78 and 8.96±1.80 respectively in highland, midland and lowland agro-ecologies of Sidama Region, Ethiopia. Slightly lower yolk color was reported by Matawork and Meseret (2022) who reported average yolk color of eggs to be 8.37 ± 0.15. The variation might be due to difference in the feeds type which had an effect on the yolk color of eggs from indigenous chickens in different localities. The color of the egg yolk is mainly dependent on the type of feed and the management systems of chicken. The eggs collected from scavenging birds have a higher yolk color count because scavenging birds have free access to green plants and other feed sources rich in xanthophyll (Zaman *et al*., 2004).

Mean yolk ratio of 38.96±3.754% and Albumen ratio of 50.06±4.838% was recorded in the current study. Yolk ratio in the highland was significantly (p<≤0.05) higher than the midland agro ecology in the study area. Demissu (2020) reported average yolk ratio of 34.99% which was lower than the current study and nearly comparable average albumin ratio of 54.71% was reported and the current finding was consistent with the report of Legesse and Kefyalew (2022) who reported yolk ratio of (37.68±6.72, 36.17±3.92 and 37.30±6.28) and Albumen ratio of (51.35±9.75, 51.48±6.19 and 52.94±10.66) respectively in indigenous chicken in highland, midland and lowland agro-ecologies in Sidama Region of Ethiopia.

Both the Haugh unit and yolk index were significantly ($p \leq 0.05$) higher in highland agro ecology than the midland agro ecology in the study area. However, Nuhu *et al*. (2018) reported higher Haugh Unit (100.533) in Nigerian savanna indigenous chicken.

Table 4. Internal egg quality parameters in the study area

Egg quality parameters	Agro-ecology			
	HL	ML		
	(Mean ±SD)	(Mean ±SD)	Overall Mean	P-value
Albumen weight (gm.)	18.87±2.425	19.59±2.556	19.23±2.514	0.0172
Albumen height (mm)	4.7±0.678	4.49±0.804	4.59±0.749	0.0184
Yolk weight (gm.)	14.84±1.92	15.06±1.695	14.95±0.323	0.3231
Yolk height (mm)	15.19±0.934	14.76±1.335	14.97±1.169	0.0020
Yolk diameter (mm)	36.81±2.371	38.37±1.951	37.59±2.302	<0.0001
Yolk Roche fun color	9.2±0.712	9.24±0.935	9.22±0.83	0.6666
Yolk ratio	39.43±4.470	38.49±2.805	38.96±3.754	0.0364
Albumen ratio	50.19±6.052	49.93±3.214	50.06±4.838	0.6560
Haugh unit	76.01±5.012	73.64±5.461	74.82±5.365	0.0002
Yolk index	41.41±3.542	38.59±4.199	39.99±4.127	<0.0001

Means within row are significantly different when ($p \leq 0.05$), HL, Refers to Highland, ML, Refers to midland, SD refers to standard deviation

Correlation among Internal and External Egg Quality Parameters

Correlation among External Egg Quality Parameters

The result presented in Table 5 indicated that there was a strong positive correlation between egg weights and other external egg qualities such as egg width and egg length, and moderate positive correlation with shell weight and shell thickness. The current study is in good agreement with the finding of Berhanu *et al*. (2022) who reported that egg weight had a positive correlation with the external egg quality traits of egg width, egg length, and shell weight in southern Ethiopia.

There was a positive correlation between egg length with the egg width and shell weight. The finding was in line with the report of Bobbo *et al*. (2013) which found a strong positive correlation between egg length and egg width on frizzle and necked neck indigenous chickens in Yola.

There was a statistically significant positive correlation between egg shape index and egg weight ($P \leq 0.05$). This could be explained as a result of the denser part of the egg (albumen) occupying the width area, which translates to heavier weight for the egg. The result agrees with finding of Duman *et al*. (2016), but disagrees with the findings of Yilmaz *et al*. (2011). Egg length was negatively correlated with the egg shape index, but correlated positively with the egg width and egg shell weight. This indicated that when the egg becomes wider, its shape index will be larger, and it will possess a round shape that it makes it challenging to handle and pack. Similarly, a strong negative correlation between egg length and shape index but positive correlation between egg width and shape index were reported in dwarf, normal and necked neck indigenous chicken of Tswana as reported by Kgwatalala *et al*. (2016).

Shell weight indicated that a strong positive correlation with that of shell weight percentage and a positive correlation with the shell thickness (Table 5). The result was in good agreement with the Markos *et al*. (2017). Egg shell weight percentage with shell weight and shell thickness has a positive correlation but negatively correlated with egg weight.

Table 5. Pearson correlation of external egg quality parameters in the study area

	Egg weight	Egg length	Egg width	Shell weight	Shell thickness	Egg shape index (%)	Shell Wt. (%)
Egg weight	1						
Egg length	0.547	1					
Egg width	0.701	0.352	1				
Shell weight	0.435	0.285	0.342	1			
Shell thickness	0.304	0.123	0.17	0.257	1		
Egg shape index (%)	-0.05	-0.76	0.33	-0.05	-0.016	1	
Shell Weight (%)	-0.16	-0.03	-0.07	0.815	0.08	-0.02	1

Note: Wt., Refers to Weight, %, Refers to percentage

Correlation between Internal Egg Quality Parameters

There was a strong positive correlation between albumen weight with the albumen height and albumen ratio. Albumen weight was positively correlated with yolk height, yolk weight and Haugh Unit of indigenous chicken (table 6). The result was in line with the report of Markos *et al*. (2017) who reported a strong positive correlation between albumen weight and yolk weight in highland, midland and lowland agro ecology ecotypes of chicken in Tigray region. A strong positive correlation between albumen weight and yolk weight was reported in dwarf, normal and necked neck indigenous chickens of Tswana (Kgwatalala *et al*., 2016). The current result disagrees with the finding of Bertha (2013) reporting that there was a negative correlation between albumen weight and yolk weight and yolk diameter. Albumen height had a strong positive correlation with the Haugh Units (0.948) and positively correlated with the egg yolk height, albumen ratio and yolk index but negatively correlated with the yolk diameter and yolk ratio. The study was in line with the study of Bobbo *et al*. (2013) who reported positive correlation between albumen height and Haugh Units of 0.98, 0.91 and 0.90 for frizzle, necked neck and smooth feathered indigenous chickens, respectively, in Adamawa state of Yola. Albumen height is higher for fresh eggs and deteriorates with increasing storage period and storage temperature and at the same time, the Haugh Unit of eggs decreased.

There was a positive correlation between yolk weight with yolk height, yolk diameter and yolk ratio. The result was consistent with the report of Markos *et al*. (2017). Yolk height was strongly correlated with yolk index and Haugh Units of indigenous chicken eggs in the current study. The current study was in line with the study of Markos *et al*. (2017) and Bertha (2013) who reported strong correlation of yolk height with yolk index and Haugh Unit.

Correlation of yolk diameter with yolk index, Haugh units and albumen ratio were negative. It might occur when yolk height decreases due to different factors, the yolk expands, and its diameter increase. In the current study, Huagh unit showed a strong positive correlation with the albumen height and negatively correlated with egg yolk diameter and yolk ratio. The result was consistent with the report of Sinha *et al*. (2018).

Table 6. Pearson correlation of internal egg quality parameters of indigenous chicken

	Albumen Weight	Albumen Height	Yolk Weight	Yolk height	Yolk Diameter	Yolk ratio	Albumen ratio	Yolk index	Haugh unit
A/weight	1								
A/height	0.523	1							
Y/weight	0.292	0.1	1						
Y/height	0.386	0.512	0.454	1					
Y/Diameter	0.1	-0.25	0.376	-0.1	1				
Yolk ratio	-0.32	-0.25	0.62	0.11	0.208	1			
Albumen ratio	0.653	0.356	-0.25	0.074	-0.153	-0.21	1		
Yolk index	0.232	0.535	0.105	0.798	-0.674	-0.05	0.155	1	
Haugh Unit	0.321	0.948	-0.1	0.397	-0.353	-0.19	0.398	0.513	1

Correlation between Internal and External Egg Quality Parameters

Correlation between internal and external egg quality parameters of indigenous chicken is shown in Table 7. Albumen weight has a positive correlation with the egg weight, egg length and egg shape index. This result was in line with the study of Markos *et al*. (2017).

Albumen height has a positive correlation with the egg weight but negatively correlated with egg shell weight. The result was in good agreement with the study of Bertha (2013) who reported a significant negative correlation of albumen height with the egg length; egg width and shell weight but disagree with the egg weight which correlated negatively.

Yolk weight had a positive correlation with the egg weight of indigenous chicken in the current finding. The result is in agreement with the report of Markos *et al*. (2017). According to the current study, yolk weight increases with increasing of egg weight and egg length. The weight of eggs and egg length are related with different factors, such as the age of the hen, breed, nutrition and other environmental factors.

Yolk height had a positive correlation with the egg weight, egg width and egg shell thickness but had a negative correlation with the egg length, shell weight and egg shape index. The current finding is in line with the finding of Godson *et al*. (2020) who reported that a positive correlation of yolk height with egg weight, egg length and egg width. The same author reported a negative correlation of yolk height with shell weight, shell thickness and shape index.

Yolk diameter of indigenous chicken showed a positive correlation with the egg weight, egg length, shell weight and egg shape index but had a negative correlation with the egg width and egg shell thickness. Haugh Unit of the indigenous chicken eggs in the study area shows a positive correlation with the egg weight but negatively correlated with the egg length, egg width, egg shell weight, shell thickness and egg shape index. In general the egg quality of indigenous chicken at different localities might be different due to a number of factors, such as storage duration of eggs, storage temperature, age of laying hen, the chicken ecotype, the agro ecological condition, season of the year and difference in the feed type.

Table 7. Correlation between some internal and external egg quality parameters in the study area

Parameters	Egg weight	Egg length	Egg width	Shell weight	Shell thickness	Egg shape index
Albumen weight	0.551	0.176	-0.205	-0.029	-0.061	0.192
Albumen height	0.387	-0.03	-0.03	-0.159	-0.02	-0.013
Yolk weight	0.418	0.052	-0.028	-0.08	0.075	0.056
Yolk height	0.445	-0.07	0.011	-0.156	0.026	-0.045
Yolk diameter	0.033	0.078	-0.013	0.027	-0.052	0.062
Haugh units	0.215	-0.03	-0.029	-0.161	-0.016	-0.015

CONCLUSIONS

In this study, a better productive performance in terms of the number of eggs per clutch, number of chicks hatched and the number of eggs per year was observed in midland agro-ecology. Eggs from the midland agro-ecology had significantly greater weight, width and shell weight. Eggs from the midland agro-ecology had higher albumin weights and yolk diameter but lower albumen height. Eggs from highland were higher in HU and yolk index than midland. Based on the above conclusion, it can be recommended that agro-ecological-based improvements in breeding, management practice (feeding, housing and health) of indigenous chickens are vital in the study area

CONFLICTS OF INTEREST

Authors declare that they have no conflicts of interest regarding the publication of this paper with the Journal of Science and Development.

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