EVALUATION OF CHICKEN PRODUCTION PRACTICE, PERFORMANCE AND EGG QUALITY OF BOVANS BROWN AND SASSO CHICKENS IN DOBA DISTRICT, WEST HARARGHE ZONE, ETHIOPIA

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DEDICATION

This thesis work is dedicated to beloved families, especially my father, Ato Beker Umere, next to Allah, who has nursed me with love and affection and committed to my success with strong prayer for the betterment and, in general, the success of my life. I am also grateful for whatever he had for my education, and he also encouraged me to start this study.

STATEMENT OF THE AUTHOR

By my signature below, I declare that this thesis is my own original work and that all sources of materials used for this thesis have been appropriately acknowledged. This thesis is submitted in partial fulfillment of the requirements for a Master of Science degree at Haramaya University. The thesis is deposited in the Haramaya University Library and is made available to borrowers under the rules of the library. I seriously declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate. Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgement of the source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the School of Graduate Studies when, in his or her judgment, the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

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BIOGRAPHICAL SKETCH

Mr. Ahmed Beker (the author) was born in December 1996 in Ifabes Kebele, Mesela Woreda, West Hararghe Zone of Oromia Region, Ethiopia, to his mother, Momina Ahmed, and his father, Beker Umere. He attended his elementary school education (1–8) at Kore elementary school, secondary school (9–10) at Herawacha senior secondary school, and preparatory school (11–12) at Mesela preparatory school until 2012. He then joined Bule Hora University College of Agriculture in 2013 and graduated with a B.Sc. degree in animal and range science in 2015. Then, after being employed by the livestock development office in Mesela Woreda of West Hararghe zone, he was assigned as an expert at different positions for four years under the Mesela Woreda Livestock Development Office, starting from December 2015 to July 2019 and Starting in August 2019, he was also assigned as the livestock extension team leader for two years until he joined Haramaya University for his MSc study. He joined the school of graduate studies at Haramaya University, College of Agriculture, in 2021 to pursue a M.Sc. degree in animal production.

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LIST OF ACRONYMS AND ABBREVIATIONS

AH	Albumin Height
ANOVA	Analysis of Variance
BB	Bovans Brown
DWAO	Doba Woreda Agricultural Office
ESI	Egg Shape Index
EST	Eggshell Thickness
EW	Egg Weight
FAO	Food and Agriculture Organization
FGD	Focus Group Discussions
HU	Haugh Unit
Masl	Meter above sea level
NCD	Newcastle Disease
NGO	Non-Governmental Organizations
Sa	Sasso
SAS	Statistical Analysis System
SE	Standard Error
SPSS	Statistical Package for Social Sciences
YC	Yolk Color

TABLE OF CONTENTS

DEDICATION	**iv**
STATEMENT OF THE AUTHOR	**v**
BIOGRAPHICAL SKETCH	**vi**
ACKNOWLEDGEMENTS	**vii**
LIST OF ACRONYMS ANDABBREVIATIONS	**viii**
TABLE OF CONTENTS	**ix**
LIST OF TABLES	**xi**
LIST OF FIGURES	**xii**
LIST OF TABLES IN THE APPENDIX	**xiii**
LIST OF FIGURES IN THE APPENDIX	**xiv**
ABSTRACT	**xv**
1. INTRODUCTION	**1**
2. LITERATURE REVIEW	**4**
2.1. Chicken production Systems in Ethiopia	**4**
2.2. Introduction of Exotic Chickens to Ethiopia	**5**
2.3. Purpose of Keeping Chicken	**6**
2.4. Husbandry Practices of Chicken	**6**
2.4.1. Housing system	6
2.4.2. Feed resources and feeding practices	7
2.4.3. Source of water and watering	8
2.4.4. Chickens' health care	8
2.5. Performance of Bovans Brown and Sasso Chicken	**9**
2.5.1. Egg production	9
2.5.2. Egg weight	10
2.5.3. Chicken body weight	11
2.5.4. Age at first egg	12
2.6. Quality of Chicken Eggs	**12**
2.6.1. External quality of chicken eggs	13
2.6.2. Internal quality of chicken eggs	14
2.7. Constraints of Chickens Production in Ethiopia	**17**
3. MATERIALS AND METHODS	**18**

TABLE OF CONTENTS (Continued)

3.1. Description of the Study Woreda 18
3.2. Study Design and Population 19
3.3. Selection of the Study Woreda 20
3.4. Selection of the Study Households and Sampling Technique 20
3.5. Data Collection 22
3.6. Chicken Performance Evaluation 23
3.6.1. Chicken body weight 23
3.6.2. Age at first egg laying and egg production 23
3.6.3. Egg quality 24
3.7. Data Management and Statistical Analyses 25
4. RESULTS AND DISCUSSION 28
4.1. Household Characteristics of Respondents 28
4.2. Sources of Exotic Chicken 30
4.3. Purpose of Keeping Chicken 31
4.4. Chicken Production System 32
4.5. Chicken Husbandry Practices 33
4.5.1. Feed resources and feeding practices 33
4.5.2. Water sources and watering systems 36
4.5.3. Chicken housing system 38
4.5.4. Chicken diseases and health care 39
4.6. Major Constraints of Bovans Brown and Sasso Chicken Production 43
4.7. Performance of Sasso and Bovans Brown Chickens 45
4.7.1. Age at first egg, egg production, and mature body weights of Sasso and Bovans Brown chicken 45
4.8. Egg Quality Evaluation of Bovans Brown and Sasso Chicken 50
4.8.1. External egg quality 50
4.8.2. Internal egg quality 55
5. SUMMARY, CONCLUSION AND RECOMMENDATIONS 62
5.1. Summary and Conclusions 62
5.2. Recommendations 64
6. REFERENCES 65
7. APPENDICES 73
7.1. Appendix A. Sample Questionnaires 73
7.2. Appendix B. List of ANOVA Tables 79
7.3. Appendix C. List of Sample Figures 82

LIST OF TABLES

Table	Page
1. Sample size distribution and number of HHs per selected kebele and District	22
2. Household characteristics of the respondents in Doba District	28
3. Types and Source of Sasso and Bovans brown chicken in study areas	30
4. Purposes of keeping Bovans brown and Sasso chicken in the study area	31
5. Chicken production System in Doba District	32
6. Type of feeds, sources and feeding systems of chickens in the Doba District	33
7. Mode of provision and frequency of feeding chickens in the study area	35
8. Water sources and watering practices of chicken in Doba District	37
9. Chicken housing system in the study area	38
10. Chicken diseases and health care practices in Doba District	40
11. Ranking of the major constraints of chicken production in Doba District	43
12. Age at first egg, egg production, and female body weights of chicken in the district	46
15. The external egg quality traits of Sasso and Bovans brown chicken in Doba District	51
16. Effects of chicken breed, agroecology, and interaction on external egg quality traits	55
17. The internal egg quality of Sasso and Bovans brown chicken in Doba District	56
18. Effects of agro-ecology, chicken breed and their interaction on internal egg quality	60
19. Effect of agro-ecology and breed on yolk color by logistic regression (Mean±SE)	61

LIST OF FIGURES

Figure	Page
1. Map of the study area	19

LIST OF TABLES IN THE APPENDIX

Appendix Table **Page**

1. Effect of agro ecology, chicken breed and their interaction on average age at first egg of Sasso and Bovan brown in Doba district 79
2. Effect of agro ecology, chicken breed and their interaction on egg production per hen/year of Sasso and Bovan brown chicken in Doba district 79
3. The mature body weight of laying hens (>20 weeks) kg of Sasso and Bovans brown chickens in Doba District 79
4. Effect of agro ecology, breed and their interaction on egg weight of Sasso and Bovans brown chickens in Doba District 79
5. Effect of agro ecology, breed and their interaction on shell weight of Sasso and Bovans brown chickens in Doba District 80
6. Effect of agro ecology, breed and their interaction on shell thickness of Sasso and Bovans brown chickens in Doba District 80
7. Effect of agro ecology, breed and their interaction on egg shape index of Sasso and Bovans brown chickens in Doba District 80
8. Effect of agro ecology, breed and their interaction on albumin height of Sasso and Bovans brown chickens in Doba District 80
9. Effect of agro ecology, breed and their interaction on albumin weight of Sasso and Bovans brown chickens in Doba District 81
10. Effect of agro ecology, breed and their interaction on egg yolk height of Sasso and Bovans brown chickens in Doba District 81
11. Effect of agro ecology, breed and their interaction on egg yolk weight of Sasso and Bovans brown chickens in Doba District 81
12. Effect of agro ecology, breed and their interaction on Haugh unit of Sasso and Bovans brown chickens in Doba District 81
13. Effect of agro ecology, breed and their interaction on yolk diameter of Sasso and Bovans brown chickens in Doba District 82

LIST OF FIGURES IN THE APPENDIX

Appendix Figure	Pages
1. Spreading way of chicken supplementation with cereal grains in study area	82
2. Chicken feeding and watering practices with feeder and waterer in the Doba District	83
3. Mature body weight of Sasso and Bovan brown chicken measurement in study area	84
4. Measurement of egg weight and egg shell weight by using digital balance	84
5. Measurement of egg albumin and yolk height in the egg quality laboratory	85
6. Measurement of egg yolk length, yolk width, albumin length, and albumin width	85
7. Measurement of egg albumin and yolk weight in the egg quality laboratory	86
8. Measurement of egg shell thickness in the egg quality laboratory	86

ABSTRACT

The study was conducted with the objective of evaluating the chicken husbandry practices, productive performance, and egg quality of Bovans brown and Sasso chickens in Doba District. A total of 160 households were purposively selected and interviewed using semi-structured questionnaires. For the evaluation of egg qualities, a total of 160 freshly laid eggs were used. SPSS and JMP® pro version 17 (SAS Institute, 2023) were employed to analyze the data. The age at first egg for the Sasso chicken was 5.77 months, and for the Bovans brown chicken, it was 5.38 months. The average number of eggs per hen per year for the Bovans brown chicken was 248.86, which was higher as compared to the Sasso chicken, which was 227.32. A significant difference (P< 0.05) was observed between chicken breeds and agroecologies in terms of the pullet's age at first egg and the total number of eggs produced per year, with higher results in midland than in the highland agroecology of the study area. The female body weights of Sasso and Bovans brown chickens greater than 20 weeks of age was higher in the midlands, and the Sasso breed performed higher than Bovans brown chickens. The results indicated that egg quality traits with a significant difference (P<0.05) between the two agro-ecologies in terms of egg weight, egg length, shell weight, shell thickness, yolk weight, yolk color, yolk height, yolk diameter, and albumen weight of eggs collected from midland were higher than those of eggs from highland. However, the highest values for albumen height and Haugh unit were observed on eggs collected from highland. There was a significant difference (P<0.05) between eggs collected from the Sasso chicken with higher values than Bovans brown eggs in terms of egg weight, egg width, shell weight, egg length, albumin weight, yolk color, and yolk weight. In general, the Sasso and Bovans brown chickens perform relatively better in midland for egg production, growth performance, and most of the egg quality traits than highland agro-ecology. The prevalence of disease, predators, inadequate veterinary services, a lack of housing, and a shortage of supplementary feeds were the major constraints on chicken production. Therefore, we recommend that there should be appropriate intervention in disease and predator control activities, an improved housing system, a feeding system, and a vaccination of chicken to be promoted in the study areas.

Key words: Agro-ecology, Bovans Brown chicken, egg quality, Sasso chicken

1. INTRODUCTION

Chicken production has important socio-economic roles for food securities, generating additional cash incomes, and plays a significant role in family nutrition in developing countries (Mohamed *et al*., 2023). Similarly, in Ethiopia, chicken production plays an important role in improving family nutrition in rural and urban areas, creating employment opportunities, and as a source of income, especially for smallholder farmers. This is an appropriate enterprise for poor households because of the small amount of land needed and the low investment costs involved in starting and managing the chicken (FAO, 2019).

Ethiopia has a large chicken population, estimated to be about 56.9 million, of which 44.94 million indigenous (78.86%), 6.85 million hybrid (12.02%), and 5.19 million exotic breeds (9.12%) (CSA, 2021). However, as the performance of indigenous chickens is low, the demand for chicken products, which is much more projected by the rapid increase in human population, is not met (Mammo, 2012). This could be attributed to the limited production potential owing to poor management practices and low emphasis given to genetic improvement of the indigenous chicken ecotypes. As a result, various exotic chicken breeds have been introduced to Ethiopia to improve the existing low performance of indigenous chickens and increase the income of farmers involved in the poultry production (Alemneh and Getabalew, 2019).

Higher learning institutions, research organizations, the Ministry of Agriculture, and non-governmental organizations were the major institutions involved in the importation and dissemination of exotic chicken to rural farmers and urban-based small-scale poultry producers (Solomon, 2008). Despite this huge distribution of exotic chickens, the contribution of exotic chicken to the current production system in the country is very low. This can be the result of limited adoption of poultry technology, affected by a set of factors such as lack of knowledge on chicken husbandry practices (feeding, watering, housing, health care, etc.…), lack of production inputs, environmental challenges, lack of strong extension follow up, predators, and the high prevalence of chicken diseases (Fessiha *et al*., 2015; Habtamu *et al*., 2023).

The performance of local chicken breeds in Ethiopia is low because of their low egg and meat production potential and longer reproductive cycle (Demissu, 2020). The contribution of exotic chicken to the Ethiopian economy is also low compared to that of other African countries (Haftu, 2016). Most of the exotic breeds studied under the smallholder production system in Ethiopia were not high-yielding hybrids type used in the international poultry industry (FAO, 2010).

It is imperative to use exotic chickens with better productivity, adaptability, and disease resistance, of which Sasso and Bovans brown are examples. The Sasso chicken is a tropically adapted dual-purpose chicken that was intended for smallholder farmers and is suitable for a semi-scavenging system that is high-producing with low input (Yakubuu and Ari, 2018). Bovans brown also has excellent genetic potential in free-range environments (Duressa and Betelhem, 2022). It is a hybrid of Rhode Island Red (cock) and light Sussex (a hen), which is a brown-feathered chicken with a white tail feather, laying brown eggs that can meet the expectations of a variety of egg producers with different objectives (FAO, 2009).

The egg production performance of Sasso and Bovans Brown chicken is better than that of local chicken. The mean egg production potential of local chicken is reported to be 51.04 eggs per year per hen with an average of 39.43g egg weight while Sasso chicken produces around 230.56 eggs per year with an average egg weight of 54.91g in Daro Lebu District of West Hararghe Zone, Ethiopia (Jaleta, 2021). The mean number of eggs laid per hen per year for Bovans Brown chicken was 229.70 and 227.71 in the midland and highland agroecologies of Southern Tigray, Ethiopia (Brehanu *et al*., 2017). The weight of laying hens (>20 weeks of age) of Sasso and Bovans Brown chickens was reported as 2.91 and 2.65 kg, respectively, under farmers' management conditions in southern Ethiopia (Yonas, 2020). In another study conducted in the North Western Zone of Tigray, farmers perceived that producing improved hybrid layer chickens was advantageous in terms of egg production, growth potential, and selling price of exotic chicken eggs as compared to the local chickens (Teklemariam, 2017).

With the aim of improving chicken productivity, the performance of high-yielding layers such as Bovans Brown and dual-purpose hybrid Sasso (widely distributed by Ethio-chicken private farms) chickens has been distributed to smallholder farmers in Doba District by the government agriculture office and NGOs. However, there is limited information on husbandry practices, major constraints, biosecurity, and the health of the chickens in the district. There is also a lack of recorded data on the production performances of distributed Bovans Brown and Sasso chickens in Doba District and their egg quality traits.

Consequently, there is a need to generate information on the husbandry practices and production performances of Bovans Brown and Sasso chickens in Doba District. The quality of eggs laid could also be an indication of productivity and the overall care given to exotic chickens. As a result, this study was intended to assess husbandry practices on productive performances and evaluate the egg quality of Bovans Brown and Sasso chickens in Doba District of West Hararghe Zone, Oromia Region, Ethiopia, with the following objectives:

General Objectives

- ❖ To assess husbandry practices and to evaluate the productive performance and egg quality of Bovans Brown and Sasso chickens in Doba District, West Hararghe Zone, Oromia Region, Ethiopia

Specific Objectives

- ❖ To assess the husbandry practices of Bovans Brown and Sasso chickens in Doba District,
- ❖ To evaluate the productive performance of Bovans Brown and Sasso chickens in Doba District,
- ❖ To evaluate the quality of eggs produced by Bovans Brown and Sasso layers in Doba District.

2. LITERATURE REVIEW

2.1. Chicken production Systems in Ethiopia

Chicken can be reared in different management and production system. The chicken production systems in Ethiopia are classified into four categories based on production objectives, breed, flock size, housing, feeding, health, biosecurity level, and technology used in large-scale commercial, small-scale intensive, semi-intensive, and extensive or scavenging chicken production systems (Wondmeneh *et al.,* 2017; FAO, 2019).

The large-scale commercial chicken production system contained over 10,000 chickens with a high level of biosecurity, modern housing with concrete walls and a regulated internal environment, commercially compounded feeds, and a standard and regular animal health program (Fikadu, 2021; Abera, 2022). This system is characterized by a higher level of productivity where chicken production is entirely market-oriented to meet the large chicken demand in major cities.

Small-scale intensive chicken production system involves use of specialized, commercial day-old chicks or pullet, commercial balanced rations, and good quality chicken houses. Producers in this system have full access to veterinary services. It is rapidly growing in the urban and peri-urban areas of the country and mostly run as family businesses and considered as important sources of income for many families (FAO, 2019).

The semi-intensive chicken production system is characterized by flocks ranging from 50 to 200 chickens, using commercial, crossbred, or indigenous breeds reared under scavenging management conditions with regular supplementation. Unlike in scavenging systems, chickens are provided with housing is constructed from local materials, a low to minimal level of biosecurity, scavenging with regular feeding, and improved health care (FAO, 2019).

The extensive or scavenging chicken production system is the most common production system practiced in most rural areas of the country and objectives of production are for household consumption and as source of additional income for the household. The production system in extensive or scavenging chicken has kept few chickens, specific chicken houses are rare, scavenging and occasional feeding with home grains, and there is no regular health program with no biosecurity, and there is no formal marketing channel. Chickens kept in this system are usually indigenous and dual-purpose breeds that are adapted to the scavenging production environment (Fikadu, 2021). In terms of bio-security, extensive chicken producers use inputs with little or minimum external inputs, which include poor quality feed, mixed cereals, local breeds some time combined with improved exotic breeds obtained from extension services or other farmers, minimal veterinary services from the Bureau of Agriculture, and traditional housing systems (Aila *et al*., 2012).

2.2. Introduction of Exotic Chickens to Ethiopia

To boost poultry productivity, several exotic chicken breeds, including Rhode Island Red, Australorp, New Hampshire, and White Leghorns, have been introduced to Ethiopia since the 1950s. Consequently, non-governmental organizations, research organizations, higher learning institutions, and the Ministry of Agriculture have all introduced higher breeds of chicken to small-scale chicken producers in urban areas as well as rural areas (Solomon, 2008). In addition, the Ministry of Agriculture expanded the national poultry extension efforts by establishing several exotic chicken breeding and multiplication centers at different parts of the country. Among the exotic breeds, Sasso chickens are dual-purpose a commercial breed originated from France and it has been distributed to different regions of Ethiopia by Ethio-Chicken through better productivity, adaptation and disease resistance (Fasil *et al*., 2016). The other exotic chicken introduced is Bovans Brown-a temperate egg layer breed which has excellent genetic potential in free-range environments and it is a hybrid of Rhode Island Red (cock) and light Sussex (hen) which is a brown feathered chicken, brown egg layer with a white tail feather (FAO, 2009).

2.3. Purpose of Keeping Chicken

Chicken production is an important sector in Ethiopia where chickens and their products are important sources of food and income. Chicken production is widely practiced and used as a source of income for immediate household expenses (Samson and Endalew, 2010). The main objective of keeping chicken were for production of eggs, sales and home consumption. The major purposes of keeping chicken in Daro Lebu District, West Hararghe Zone were used for source of income generation (51.1%) and followed by for egg production (28.5%) in two agro ecologies (Jaleta, 2021). According to Duressa and Betelhem (2022), who showed that the majority of respondents (67.01%) utilize their exotic chicken to generate income by selling live chicken and eggs in Assosa Town of Benishangul Gumuz Region, Ethiopia.

The other important purposes of chicken production are household consumption, use of chicken for cultural/religious ceremonies, job opportunity and egg production. Earnings from the sale of chicken and eggs were used to purchase food for home consumption, to cover educational expenses for children (books, pen, pencils, school uniforms and immediate cash requirements at school) and to purchase clothes and agricultural inputs. This indicates the important role village chicken production in Bure district, North west, Ethiopia stated that sale of live chickens for income generation (51%) was the primary goal of keeping chicken (Moges *et al*., 2010).

2.4. Husbandry Practices of Chicken

The term chicken husbandry practice usually refers to production methods or management practices that help to increase the productivity of production either meat, eggs, or both. Good health care, regular access to clean drinking water, appropriate housing, and the use of sufficient amounts of high-quality feed are all part of chicken management practices (FAO, 2013).

2.4.1. Housing system

The housing system is one of the important chicken management practices to increase their productivity. According to Moges *et al*. (2010) reported that 77.9% of the village chicken owners provide only night shelter, and only 22.1% provided separate chicken house in Bure district, North West Ethiopia. This might be due to lack of knowledge and awareness, and poor attention to chicken producers were some of the reasons for not constructing separate chicken house. The other study Tilahun *et al*. (2017) who reported that from the total respondents, 16.11% of them kept their chicken at night at a separate shelter, 43.89% of the respondents shelter the chickens in the family house and the remaining (25%) in a separate house with other animals and in bamboo cage in both highland and midland agro ecologies of North Western Amhara, Ethiopia.

2.4.2. Feed resources and feeding practices

Feed sources and feeding management of chicken in smallholder production systems offered supplementary feeds for their chickens due to its contribution to egg production and meat yield. According to the study of Addisu *et al*. (2013) who reported that the chicken owners providing supplementary feed was for healthiness and maintenance of their chickens, to increase egg production and meat yield in Northern Wollo. The finding of Ermias *et al*. (2015) who indicates that the amount and type of supplementation were dependent on the type and size of crop production is different in the highland and midland agro-ecological zones, maize and wheat were the major grown crops that used supplementary feeds for chicken feeding in the Central Oromia Region, Ethiopia. Similarly, Jaleta (2021) also reported that the majority of the farmers used maize, wheat, sorghum, and household waste products as the main supplementary feeds given to chickens in both agro ecologies of Daro Lebu District, West Hararghe Zone, Ethiopia.

The study conducted by Tilahun *et al*. (2017) who indicated that the frequency of feeding practiced by chicken owners was 66.67% and 68.89% of the respondents feeding in the evening and morning, morning, evening, and afternoon feed only 13.33% and 11.11%, and morning only 12.22% and 18.89% feed in highland and midland agro ecologies in North Western Amhara, Ethiopia, respectively. This could be due to the difference in awareness, and availability of grain feeds between the respondents of highland and midland agro ecologies.

2.4.3. Source of water and watering

Water plays a vital role in the transport of nutrients, metabolic reactions and elimination of wastes. According to the finding of Tilahun *et al*. (2017) who showed that about 85.56% from high land and 88.89% from midland agro-ecologies of the respondents were provide water once/day at any time, and 14.44 % from highland and 11.11% from midland agro-ecologies provided water twice/day in North Western Amhara, Ethiopia.

According to the findings of Hailemichael *et al*. (2015), the major sources of water for chickens were 97.14% tap water and 2.86% river water in the southern zone of Tigray. Another study was also reported by Jaleta (2021), who showed that the major sources of water for chicken in Daro Lebu District, West Hararghe Zone, Ethiopia, were tap water (35.9%), spring water (33%), pond water (30.7%), and river water (0.4%). This was highly significant difference between the two agroecologies; this might be due to the differences in their locations as well as the differences in their water sources, which include spring and pond water.

2.4.4. Chickens health care

Health care is another factor that influences the productivity of chicken (CSA, 2017). Poor housing, climatic condition, poor nutritional status and low level of management contributed to a high incidence of chicken diseases in the Ethiopia. Tagesse (2016) who indicated that about 95.8% of the chicken owners interviewed could identify the presence of chicken diseases in all agro-ecologies of Kersa District, East Hararghe Zone, Ethiopia.

According to Halima (2007) who reported that the seasonal outbreaks of diseases, especially Newcastle disease are the major causes of death for chickens in North West Ethiopia. Newcastle disease is one of the most significant diseases of chickens worldwide and a major constraint to small holder chicken production. Most Ethiopian farmers did not vaccinate their chickens. In this context, it was stated that the majority of smallholders in the Ada'a district did not provide health management services and did not vaccinate their chickens (Desalew, 2012). Tareke

(2016) also stated that 12.22% of chicken owners had vaccinated their chickens, while 86.78% had not vaccinated their chickens in Wogdi, Borena and Legambo Districts.

2.5. Performance of Bovans Brown and Sasso Chickens

2.5.1. Egg production

The egg production is one of the important traits of chicken production. Low inputs for housing, feeding, and managing health care are the main reasons Ethiopian chicken production performance is considered poor (Mohammed, 2018). Poor management practices are used by rural smallholder farmers to raise chickens, and the result of this outdated production sector is lower to that of exotic and hybrid chicken populations (Hinsemu *et al*., 2018). According to Elias and Tegegn (2023), who showed that the average number of eggs per hen per year for Bovan Brown breed was 200 eggs, and for Sasso chicken breed was 150 eggs in the Malle district and Jinka town, Ethiopia. This indicates that Bovans Brown is better performing breed for egg production than Sasso breed, this might be due to breed variation and management difference. The other study also conducted in Southern, Ethiopia, were the average eggs laid per year per hen as 229 eggs for Sasso chickens (Aman *et al*., 2017a).

According to Alem (2014) reports that the management practices of farmers in two agro-ecological zones of Central Tigray, Northern Ethiopia, including inadequate water intake, lack of supplementary feed, diseases, and poor health care, may create difference in the production potential of the chicken. In Ethiopia's northwestern Amhara region, the mean number of eggs production per hen per year for Bovans Brown chickens was 135 in midland and 133 in highland agro ecologies (Tilahun *et al*., 2017).

The mean number of annual eggs production per hen per year for Bovans brown chicken was (127.11, 133.49) and Sasso chicken was (118.61, 112.87) in highland and midland agro ecologies of Northwest Ethiopia, respectively (Habtamu *et al*., 2023). This indicates that mean number of annual eggs production for Bovans brown breed in the midland agro ecologies was higher than highland agro ecologies, this might be due to the difference in environmental variation and management difference. Hence, Bovans Brown breeds had better annual egg production performance than Sasso breeds, which could be attributed to breed variation. Additionally, Birtukan (2019) also reported that the average egg production performance of Bovans Brown 119 per hen per 6 months was higher as compared to Sasso chicken 105 per hen per 6 months in selected towns of South Gondar Administrative Zone, Amhara region; this might be breed variation and husbandry practice of the producers and the average egg production of Bovans Brown and Sasso chicken per hen per 6 months in highland has higher than in midland agro-ecologies.

2.5.2. Egg weight

Egg weight is a very simple measurement to collect and therefore is frequently analyzed simply by placing an unbroken egg on a scale and recording the value. The study of Serkalem *et al*. (2019) mentioned that the average egg weight for Sasso chicken was 51.0±4.3 grams and for Bovans Brown chicken was 52.0±3.8 grams in midland agro-ecologies of Boricha District, Sidama Zone, Southern Ethiopia. The result of Melkamu *et al*. (2019) who reported the overall mean of 57.4, and 65.6g egg weight for Sasso T44 chicken in midland and highland agro ecologies, respectively in North Showa Zone, Ethiopia. This differences in egg weight of sasso chicken breeds could be due to different management practices, and agro-ecological factors.

The average weight of the eggs laid by Sasso hens varied across the study agro ecologies with higher values recorded in the midland 56.84±0.79g than the eggs recorded in the lowlands 52.97±0.60g, this might be breed variation due to the difference in environmental variation and management difference (Jaleta, 2021). Similarly, the finding of Desalew *et al*. (2013) who reported that the average egg weight of 60.27g for Bovans Brown respectively in East Shewa, Ethiopia. Duressa and Betelhem (2022) also reported that the mean egg weight of sasso T44 chicken was (60.90 ± 0.13grams), and Bovans brown chicken was (59.20 ± 0.13grams) in traditional production system in Assosa Town, Western Ethiopia. Additionally, the study of Serkalem *et al*. (2023) who conducted in Silte zone, Southern Ethiopia, showed that the egg weights of Sasso chickens in midland (50.7 ± 3.9 g,) and highland (51.9 ± 2.9 g). This difference of egg weights could be attributed to differences in management practices or environmental conditions.

2.5.3. Chicken body weight

Sexual maturity and body weight determine the acceptance of service for the first time. Sexual maturity at an appropriate body weight is important as it determine the future productive performance of hen. The body weight of mature Sasso chickens raised in Southern Ethiopian under village production systems was found to be 2.73 kg for female Sasso chicken at the age of greater than 20 weeks (Aman *et al*., 2017a). According to Birtukan *et al*. (2023), the body weight of mature hens of Bovans Brown (1.6±0.01, 1.57±0.05kg) and Sasso T44 (1.6±0.01, 1.6±0.01kg) in midland and highland agro ecologies of South Gondar zone, Ethiopia, respectively. This shows that the average mature body weight of Sasso and Bovans Brown hen among in midland has higher mature body weight than in highland, this higher body weight of matured hen might be due to the increase in feed intake in midland than in highland agroecology.

The finding of Elias and Tegegn (2023) who reported the mature body weight of Sasso chicken at age first egg laying was 2.5 kg which was higher than the body weights of Bovans Brown chicken at age first egg laying of 1.82 kg in the Malle district and Jinka town, Ethiopia. Hence, Bovans Brown breeds showed the lower body weight than sasso breeds, due to the breed difference; the Sasso is dual-purpose breeds, whereas, the Bovans Brown is a commercial egg layer. The adult female the body weight of Bovans Brown chicken at sexual maturity was 1.55 kg which was lower than the adult female body weights of Sasso chicken studied in Southern Ethiopia (Desalew, 2012). The another study also reported by Litigebew *et al*. (2021) showed that Bovans Brown chicken breed reached 1.58 kg at the age of 5.5 months but Sasso chicken breed reached 1.57 kg at age of 4 months, this indicates that Sasso has higher mature body weight than seems to reach slaughter age earlier than Bovans brown in Northern Ethiopia.

2.5.4. Age at first egg

The interval between the date of hatch and the first egg laid is known as the age at first egg. The average age at first laying of Bovans Brown (132.8±14.4) had shorter age of the first egg lay than that of Sasso T44 (164.8±11.3) in South Gondar zone, Ethiopia (Birtukan *et al*., 2023). These observed differences in age at the first egg of the two breed might be due to the genotype differences. The other finding was also reported by Tunsisa and Fiseha (2024), who stated that in the Sidama Zone and Halaba Special Woreda, Ethiopia, the average age of the first egg lay for the Bovans brown breed was 24.31 weeks, while that of the Sasso was 25.93 weeks. This indicates that there is a significant difference among breeds in average age at first egg laying that the Bovans brown start to lay eggs earlier than that of Sasso chicken.

According to the result of Birtukan (2019), the average age at first laying for Bovans Brown 132.8 day was earlier than Sasso 164.8 day in selected towns of South Gondar Administrative Zone, Amhara Region. This might be due to breed variation (Bovans Brown reach early age at first laying than Sasso) and the age at first egg laying of Sasso and Bovans Brown hen in midland has shorter than in highland agro-ecologies. The other study also reported by Aman *et al*. (2017b) who reported that the average age at first egg lay of the Sasso hens was (5.9, 5.7) months while the age at first egg lay for Bovans Brown chickens was (5.6, 5.6) months in highland and midland agro-ecologies of Southern Ethiopia, respectively. Additionally, Brehanu *et al*. (2017) who reported age at first egg laying for Bovans Brown chicken was 6.34 months and 6.41months in midland and highland agro ecologies of Southern Tigray, North Ethiopia, respectively.

2.6. Quality of Chicken Eggs

Eggs are one of the most nutritious foods available to man. It provides a balanced protein that contains all the amino acids considered essential in sufficient amounts and proportions to maintain life and support growth when used as a sole source of protein food (Raji *et al*., 2009). Egg quality parameters expresses that the characteristics of an egg which influence its acceptability by consuming community. The quality of egg could be categories internal and external quality of egg.

2.6.1. External quality of chicken eggs

The external quality of the egg is determined by features such as the size and shape of the egg as well as the structure, thickness and strength of the shell (Bain, 2005). The external egg quality traits in different agro-ecologies are indicated that values for egg weight and egg length in midland were significantly higher than highland agro-ecologies of Sidama Region, Ethiopia (Tunsisa and Berihun, 2022). This is due to grain feed availability in the midland than highland. The other study reported by Serkalem *et al*. (2019) in Boricha District, Sidama Zone, Southern Ethiopia, reported that the external egg quality traits of different breeds were influenced by agro ecologies, which could be attributed to the quality and quantity of feed available.

Egg Shape Index (ESI) is a measurement of the overall shape of an egg. The shapes most often encountered are sharp, normal (standard) and round eggs which are enumerated on the shape index as <72, 72-76 and >76, respectively (Kumar *et al*., 2014). The average egg shape index (%) values obtained from Bovans Brown was heavier 74.5 than Sasso chicken was 72.7 reared in two agro ecologies under traditional management system in Boricha District, in Sidama Zone, Southern Ethiopia (Serkalem *et al*., 2019). The other study conducted in North Showa Zone, Ethiopia showed that the mean value of shape index percentage of Sasso chicken in highland (77.52) and in midland (76.08) which was round shape index (Melkamu *et al*., 2019). The egg shape index was calculated by using the formula given by (Van Den Brand *et al*., 2004).

$$\text{Egg shape index (\%)} = \frac{\text{Width of egg}}{\text{Length of egg}} * 100$$

The egg shell quality is given through the weight and the percentage of shell thickness and the strength. The differences in egg-shell quality depend on the environmental conditions, season of production, rearing practices, relative humidity, feed quality, and chicken breed (Zita *et al*., 2009). One of the main issues is that as hen's age, their egg weight increases without an increase in the amount of calcium carbonate deposited in the shells, which results in a decrease in the quality of the eggshell. Egg shell is an external trait and very important structure component of egg since it serves to carry its contents to the consumer without cracking under normal handling conditions. According to Shi *et al*. (2009), it acts as a gas exchange medium, creates an embryonic chamber for the developing chick, prevents against bacterial contamination, provides mechanical protection for the contents, and it is unique package for a valuable food. The average shell weight of eggs collected from exotic Sasso chicken was 4.66±0.06g in two agro ecologies of Daro Lebu District, West Hararghe Zone, Ethiopia (Jaleta, 2021).

The finding of Serkalem *et al*. (2019) who reported that in Sidama Zone, Southern Ethiopia, indicated that the Bovans brown and Sasso chicken breeds reared in midland had higher egg width and shell thickness values than those reared in the lowland. The shell thickness of an egg in highland (0.35±0.03 mm) was slightly greater than in midland (0.33±0.03mm) for Sasso chicken in North Showa Zone, Ethiopia (Melkamu *et al*., 2019). This difference might be due to agro-ecological variation as well as feed type which affects egg shell thickness; because as the temperature level increased the chicken feed intake decreased, the consequence not getting enough calcium for egg shell formation. On the other hand, the study conducted in Hawasa town Yonas *et al*. (2019) who reported that the mean egg shell thickness of 0.26mm and 0.24mm for Sasso and Bovans Brown, respectively.

2.6.2. Internal quality of chicken eggs

The relative sizes of the different internal components, the integrity of the shell membrane, and the albumen quality as indicated by the Haugh Units (HU) are used to measure the internal quality. The internal quality of eggs including yolk weight, albumin weight, yolk color, albumin height, yolk height, Haugh unit, and yolk width. In addition to the genotypes of the chickens in Boricha District, Sidama Zone, Southern Ethiopia, the quality and quantity of feed given to the chickens also affects the internal egg quality characteristics (Serkalem *et al*., 2019).

The average mean yolk height of exotic (SassoT44) breed collected from midland agro ecologies was 14.94 ±0.05mm in Daro Lebu district of Western Hararghe Zone, Ethiopia (Jaleta, 2021). The finding of Melkamu *et al*. (2019) who reported that the Sasso chicken breed in the North Shewa Zone of Ethiopia had an overall mean yolk height of 18.79±1.04 mm in the midland area and 18.83±1.24 mm in the highland area. According to Tunsisa and Berihun (2022) study, which was also carried out in the Sidama Region, midland agroecology had larger yolk weights than highland agroecology.

Yolk color is a quality measure in eggs that is quite variable and easily changed. The diet of the hen has the greatest influence on yolk color. The values of egg yolk color collected from Bovans brown chicken was (10.3±1.7) and Sasso chicken was (10.4±1.7) in midland agro ecologies. This yolk color values of Sasso chicken breeds being higher than the yolk color of Bovans Brown hens in Boricha District, Sidama Zone, Southern Ethiopia, this might be due to feed quality difference (Serkalem *et al*., 2019). Another study from North West Amhara performed by Halima (2007) who indicated that the scavenging hens had free access to green plants and other meal sources high in nutrients, which results in their eggs having deeper yolk colors.

Albumen refers to the white of an egg and consists of a thick and thin portion. The thick albumen is the portion immediately surrounding the egg yolk, whereas the thin albumen comprises the rest of the white portion. The height of the albumen determines the HU of the egg and the higher the height of the albumen, the greater the HU and the better the quality of the eggs. The height of the albumen indicates the freshness of the egg and can be measured using a tripod micrometer. In terms of average albumin height, the egg taken from the midland was heavier than the egg gathered from the lowland agro ecological in Daro Lebu District, West Hararghe, Ethiopia (Jaleta, 2021).This differences might be attributed due to environmental variation (the availability of high environmental temperature in lowland than midland agro ecology) and egg storage condition. The other study conducted in the North Showa Zone of Ethiopia by Melkamu *et al*. (2019), who reported that the Sasso chicken breed average albumen height in highland areas was 8.04±0.99 mm, which was slightly higher than the mean albumen height in midland areas (7.57±0.86 mm), this might be due to agro ecological difference.

The height of the inner thick albumen and the weight of an egg are used to compute the Haugh Unit (HU), which is regarded as a common indicator of albumen quality. Haugh Units for fresh eggs should range from 72 to 110 (Stadelman and Cotterill, 2007). The average Haugh unit value recorded from Bovans Brown chickens in Lume and Ada'a of East Shewa Zone of Ethiopia, were 81.68 (Desalew, 2012). The other study conducted in Sidama Zone of Southern Ethiopia reported by Serkalem *et al*. (2019) stated that the mean Haugh unit values for Bovans brown and Sasso chicken were (78.5) and (78.4) in midland agro-ecologies, respectively. The Haugh unit and yolk index are significantly highest in the highland agroecology and lowest in the midland agroecology of Sidama Region, Ethiopia (Tunsisa and Berihun, 2022). Based on the albumen's thickness, albumen height is usually converted into Haugh units, which are used to describe the internal quality and freshness of eggs. The better the quality of the egg, the higher its Haugh unit value.

Individual Haugh Units (HU) were calculated from the two parameters; height of albumen (AH) and egg weight (EW). Haugh unit (HU) was calculated using the formula:

$$HU = 100\log(AH - 1.7EW^{0.37} + 7.6)$$ (Haugh, 1937).

Where HU=Haugh Unit, AH=Albumen height (in millimeters) and EW=Egg weight (in grams).

Yolk diameter was estimated as the average of yolk length and breadth. Yolk index were calculated from the two parameters; yolk height and yolk diameter. Yolk index was calculated using the formula:

$$Yolk\ index(\%) = \frac{\text{Yolk Height (mm)}}{\text{Yolk Diameter (mm)}} * 100$$

2.7. Constraints of Chickens Production in Ethiopia

There are many complex and constraints to chicken production systems, which in turn influence their production and productivity. The major and most significant economic constraint to the smallholder chicken production system was the high occurrence of chicken diseases, particularly Newcastle disease, which led to a decline in the number and productivity of chickens (Halima, 2007). Similarly, Tarekegn *et al*. (2015) also reported that the major constraints of chicken production in Ethiopia were the high incidence of NCD and Coccidiosis, those are primary constraint to the village scavenging chicken production in eastern Hararghe. The main causes of the prevalence of NCDs throughout a wide range of the country were found to be a lack of attention and a lack of knowledge about vaccinations and vaccines.

Predator was also the other economically important problem affecting village chicken production and reported as the major causes for the loss of chicken. In the Daro Lebu District of West Hararghe, Ethiopia, the most often mentioned predators by the respondents were kites and eagles, known locally as "Risa, kite (hawk) locally called “Culullee” which affects mostly the chicks, wild animals such as Fox, wild cat, dogs, and cat in their order of importance (Jaleta, 2021). According to Almaz (2015) who indicated that the major constraints to chicken production in Dugda Woreda, East- Shewa Zone, Ethiopia, were prevalence of disease, lack of knowledge about chicken management practices, lack of time due to farming activities, shortage of supplementary feed, attacks of predators, financial problem and thieves. Additionally, the existing improper management such as improper supplementary feed, lack of appropriate disease prevention measures, and poor housing are major constraints for chicken production (Hailu *et al*., 2012).

3. MATERIALS AND METHODS

3.1. Description of the Study Woreda

The study was conducted in Doba District, which is located in the West Hararghe administrative Zone of Oromia Region, Ethiopia. The District is located at 382 km from Addis Ababa to the Eastern part of the country and 45 km from West Hararghe Zone capital chiro town. It shares boundaries with Chiro district in the South, Mieso District in the West, Somali Regional State in the North, East Hararghe Zone of Goro Gutu District in the East, and Tulo District in the South East. Currently, the district has 40 rural kebele and 2 small towns with a total area of about 729 km^2 (72,900 hectares). The topography of the District is characterized by sloppy hills, mountains and rugged. Based on rain fall, temperature and altitude the district is sub divided into highland, midland and lowland area. The district comprises an altitude ranging from 1400 -2500 m.a.s.l (DWAO, 2022).

The district agroecologies are 3.6% highland (*dega*), 41.6% medium highland (*woyna dega),* and 54.6% lowland (*kola*). It receives bi-modal average annual rainfall ranging from 550 mm to 800 mm. The spring rain extends from March to April, while the summer rain lasts from mid-June to the end of September and has a daily mean temperature ranging from 18°C to 26°C (Doba Woreda Agricultural Office, 2022).

The livelihood of the population is mixed farming depends mainly on crop and livestock production. The food crops that are produced are sorghum, maize, haricot beans, chat, coffee, sweet potatoes, tomatoes, and onions. Livestock fattening, milk production, and small ruminant rearing and fattening are the major livestock products used as (livelihood) income activity and food by smallholder farmers in the district. The estimated livestock populations in the district are 112,000 cattle, 43,000 sheep, 62,000 goats, 13,000 camels, 319,630 local chickens, and 26,368 exotic chickens (Doba Woreda Agricultural Office, 2022).

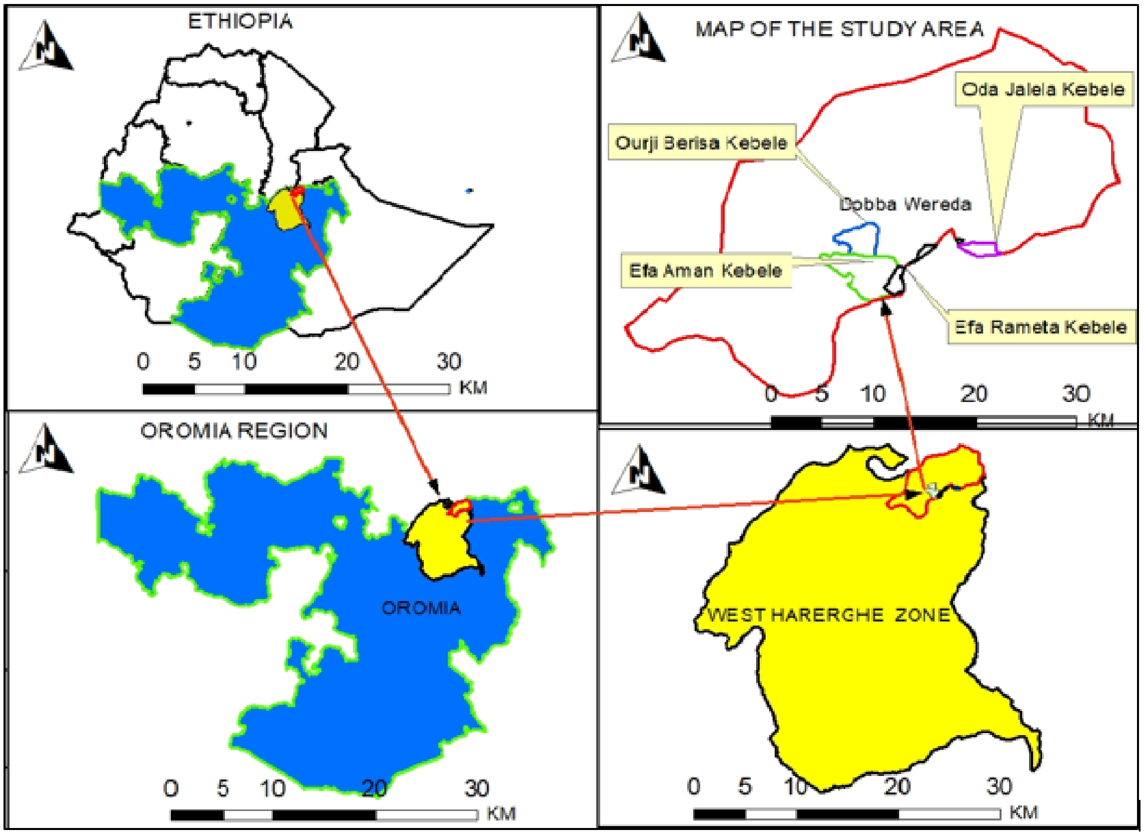

Figure 1. Map of the study area (Source: GIS data base, 2023)

3.2. Study Design and Population

The study was carried out to evaluate the chicken husbandry practices and productive performance of Bovans Brown and Sasso layer chickens using semi-structural questionnaires. For egg quality parameters, eggs collected from Bovans Brown and Sasso chickens in the highland and midland agroecologies of the study area were employed. The populations studied were Bovans Brown and Sasso layer chickens distributed in highland and midland agroecologies of the study district.

3.3. Selection of the Study Woreda

A multi-stage sampling procedure (purposive and random) were used to select the study Kebele, agro-ecologies, and sampling households. The study Woreda was selected purposively based on chicken production potential, the presence of Bovans Brown and Sasso chickens, and the accessibility of the study sites. Doba Woreda consists of 40 rural kebele, which are situated in three agro-ecologies, namely, highland (7 kebele), midland (17 kebele), and lowland (16 kebele). From the three agro-ecologies, highland and midland were purposively selected as they do have a good distribution of Bovans Brown and Sasso chicken potential compared to the lowland. Out of a total 40 rural kebele in the Woreda, four kebele (two from highland and two from midland agroecologies) were selected purposively based on chicken production potential, the presence of Bovans Brown and Sasso chicken distribution, and the accessibility of the study sites. The development agents and livestock experts of the Doba Woreda Agriculture and Natural Resource Office actively participated in the selection of representative kebele. Accordingly, Efa Aman and Ourji Berisa from midland and Efa Rameta and Oda Jalela from highland agroecologies were selected.

3.4. Selection of the Study Households and Sampling Technique

Household's beneficiaries of Bovans Brown and Sasso chicken distribution in all selected kebele were listed separately from each selected kebele. For the study, the chicken owner those having only flock of Bovans Brown and only flock of Sasso chickens were taken and used as sampling frame. All chicken-owner households that keeping Bovans Brown and Sasso chicken in the selected four kebele (Efa Aman and Ourji Berisa from midland, Oda Jalela and Efa Rameta from highland) were registered as sampling frames. As a result, the total number of households producing Sasso and Bovans Brown chicken breeds was found to be 265 (from two kebele of midland and two kebele of highland).

The total sample size for the study area was calculated based on the total number of households that participate in Bovans Brown and Sasso chicken production in each selected kebele, as determined by the Yamane (1967) sample size determination formula with a 95% confidence interval and a precision level of 5% for households.

$$n = \frac{N}{1+N(e)^2} = \frac{265}{1+265(0.05)^2} = 160$$

Where: n= designates sample size required

N=designates population size of the study area =265

e= desired precision level (in this case, e = 5%)

Therefore, the total sample size for the study area was 160. The households that have better chicken production practices were selected purposively and then stratified based on the breeds of chickens they rear. Using the following formula, the sample size distributions for each kebele and agroecology division were determined:

n' = n (N'/N) . . . . (Israel, 1992)

Where:

n'= number of sample respondents selected per kebele,

n =Total number of households living per a single selected kebele,

N =Total sum of households living in all selected sample kebele and

N'= the total required calculated sample size of the population.

Proportional sampling techniques were used for the determination of the sample size of households from each kebele and agro-ecological-based stratified sampled kebele. Hence, midland 84 (44 from Efa Aman, 40 from Ourji Berisa), and highland 76 (40 from Oda Jalela, 36 from Efa Rameta) households were used.

Table 1. Sample size distribution and number of HHs per selected kebele and District.

Total number of HHs keeping chicken					Total sample size selected from each kebele		
Agro ecology	Kebele	Bovans brown chicken Producer HHs	Sasso chicken Producer HHs	Total HHs	For Bovans brown chicken producers	For sasso chicken producers	Total Sample Size
Midland	Efa Aman	40	33	73	24	20	44
	Ourji Berisa	28	38	66	17	23	40
	Total	68	71	139	41	43	84
Highland	Oda Jalela	32	35	67	19	21	40
	Efa Rameta	28	31	59	17	19	36
	Total	60	66	126	36	40	76
	District total	128	137	265	77	83	160

Source: Doba Woreda Agricultural Office, 2022. HHs= Households, Sa = Sasso, BB=Bovans Brown

3.5. Data Collection

Both primary and secondary data sources were used. The primary data was gathered by using semi-structured questionnaire, focus group discussions with key informants, and field observations. Secondary data were also collected by reviewing unpublished sources and reports of the Doba Woreda Agriculture and Natural Resource Office. The information regarding the total number of Bovans Brown and Sasso chickens distributed, the total number of households producing chicken for the Woreda, and the study kebele were obtained from secondary data sources. Field observations were also made to assess available chicken feed resources, feed and feeding practices, and other observable parameters of chicken production.

The primary data includes the purpose of keeping chickens (for cash income, egg production, and home consumption), the sources of Sasso and Bovans Brown chicken, the characteristics of households, the number of eggs produced per hen per year, the mature body weight of layer (kg), the age of the pullet at first egg (months), the chicken husbandry practices related to feeding, watering, housing systems, prevalence of diseases, and controlling methods, and the constraints of chicken production. In the study, qualitative data like the purpose of keeping chickens, chicken husbandry practices such as feed resources and feeding practices of chickens, frequency and source of water used for chickens, housing, prevalence of diseases and controlling methods, and constraints of chicken production were collected through individual interviews using a semi-structured questionnaire. The quantitative data, like the mature body weight of Sasso and Bovans Brown Layer chickens, was measured using a hanging spring balance in kg.

In addition to semi-structured questionnaires, focus group discussions were held in each study kebele with participants composed of development agents, animal health technicians, kebele head of female affair, livestock experts of the Woreda, model farmer those with more experience in chicken rearing, and elders (socially respected individuals who have better knowledge of the economic status of the area and who know the kebele very well). The respondents, those with more experience in chicken rearing, were employed to collect basic information on the purpose of keeping chickens, husbandry practices (feeding practices, watering, housing, prevalence of diseases, and controlling methods), chicken productive performances, and constraints of chicken production. Information obtained from the focus group discussion was used to supplement information collected from the household survey.

3.6. Chicken Performance Evaluation

3.6.1. Chicken body weight

Body weight was measured using a hanging spring balance. The chicken owners were told in advance to keep their chickens at their house to make body weight measuring easy. Accordingly, the body weights of distributed pullets of Bovans Brown and Sasso chickens at greater than 20 weeks of age were recorded using a randomly selected one pullet per household per flock.

3.6.2. Age at first egg laying and egg production

Data on egg production and age at first laying of the distributed Bovans Brown and Sasso layer chickens were collected using the questionnaire prepared. The average number of egg laid per hen per year, and age at first egg of chickens were collected by individual interviewing using a semi-structured questionnaire.

3.6.3. Egg quality

For the evaluation of egg quality, a total of 160 fresh eggs (80 of Bovans Brown and 80 of Sasso chickens), 80 eggs from each agroecology, and 40 eggs from each Kebele, which means 20 eggs per breed, were purchased from households raising Bovans Brown and Sasso chickens in the study area. Before the egg collection process, 20 households from each kebele, which means 10 households raising Bovans brown and 10 households raising Sasso chickens, were purposely selected from each sample kebele based on the households that have better chicken production practices. The fresh eggs (2 eggs per individual household) were purchased. The eggs were labeled correctly based on agro-ecology and breed. Eggs were collected from households using a plastic egg tray and transported to the Haramaya University poultry farm for quality analysis. To prevent physical damage during transportation, the eggs were carefully handled and stored in their carton with a *teff* straw.

External egg quality parameters such as egg weight (g), egg shell weight (g), shell thickness (mm), egg length (mm), and egg width (mm) were determined. Egg weight (g) and egg shell weight (g) were measured by using a digital weighing balance to the nearest of 0.01 g accuracy. Egg length (mm) and egg width (mm) were measured by using a ruler. Before measuring shell thickness, the inner shell membrane was removed from the shells; the cleaned eggshells were dried on open-air for 24 hours. Then, the eggshell thickness was measured to the nearest of 0.01 mm with the help of a digital micrometer gauge at different points (center, broad and narrow ends), and the average of the three measurements was taken as shell thickness of each egg. The egg shape index was calculated using the following formula:

$$\text{Egg shape index}(\%) = \frac{\text{Width of egg}}{\text{Length of egg}} * 100.$$

The internal egg quality traits that were evaluated include yolk weight, albumen weight, yolk height, Yolk diameter, albumen height, Yolk color and Haugh unit. The internal egg quality measurements were obtained by carefully breaking the egg followed by separation of the albumen and the yolk contents. Thick albumen and yolk heights were measured using a tripod micrometer. The thick albumen height (AH) was measured at its widest part in a position half way between the yolk and the outer margin. Yolk height was measured at the center of the yolk. The albumen was carefully removed from the yolks. The weights of the albumen and yolk were measured individually using a digital weighing balance. Yolk diameter (the average of yolk length and width) was measured by a ruler after breaking the egg on a flat tray in millimeter. Yolk color was measured after the yolk membrane was removed, and a yolk sample was taken on pieces of white paper and computed by Roche fan measurement strips, which have 1–15 strips ranging from pale to deep orange yellow. The average Haugh unit value for each breed was calculated using the formula given by Haugh (1937).

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

Where, HU=Haugh Unit, AH=Albumen height (in millimeters) and EW=Egg weight (in grams).

Yolk index was calculated by using the formula given by (Van Den Brand *et al*., 2004).

$$Yolk\ index(\%) = \frac{\text{Yolk Height (mm)}}{\text{Yolk Diameter (mm)}} * 100$$

3.7. Data Management and Statistical Analyses

Data were entered using a Microsoft Excel spreadsheet and imported to JMP® pro 17 software (SAS Institute, 2023) and SPSS 21.0 for statistical analysis (SPSS, 2016). All survey data were analyzed by SPSS (Statistical Package for Social Sciences) version 21, except for the productive performance of chickens. A chi-square test was used to analyze the categorical variables such as the demographic profile of households (sex, age, marital status, and educational level), chicken production system, and chicken husbandry practices (feeding resources and feeding practices, frequency and source of water, housing systems, prevalence of diseases, and controlling methods). The egg production per hen year, body weight of chicken (kg), pullet age at first egg (month), and evaluation of egg quality parameters (like egg weight, shell weight, albumen weight, yolk weight, yolk height, albumen height, yolk diameter, yolk index, haugh unit, and shell thickness) were analyzed by two-way analysis of variance (JMP® pro 17 software (SAS Institute, 2023)by fitting the two agroecologies (highland and midland) and two breeds (Sasso and Bovans Brown) as main effects and their interactions among them. To determine the mean separation, the Tukey HSD test was used. All values were considered significant at the 5% level of significance ($p<0.05$).

The following statistical models were used for the analysis of the data:

$$Y_{ij} = \mu + A_i + B_j + (AB)_{ij} + e_{ij}$$

Where:

Y_{ij} =response of the observed variables (egg production, body weight, age at first egg, egg weight, yolk height, etc.) of k^{th} chicken of the i^{th} breed reared in the j^{th} agro ecology

μ = the overall mean of the observed variables

A_i= the effect of i^{th} chicken breed (i= Bovans Brown and Sasso chicken) on egg quality and productive performance

B_j= the effect of j^{th} agro-ecology (j = highland, and midland)

$(AB)_{ij}$= the interaction effect between agro-ecology and chicken breed on egg quality and productive performance.

e_{ij}= the random error.

Data records on yolk color was analyzed by using ordinal logistic regression. The ordinal logistic regression model was below:

$$\ln\left(\frac{\pi}{1-\pi}\right) = \beta 0 + \beta 1 X 1$$

Where;

π = probability

β_0 = intercept

β_1 = slope or regression coefficient of breed or agroecology

X_1 = Breed or agroecology

Ranking analyses were used to determine data on the major production constraints for chickens and the purposes of raising chickens in the study areas, as described by Kosgey (2004). The following formula was used to calculate the indexes:

$$Index = Rn * C1 + Rn - 1 * C2 \ldots. + R1 * Cn \text{ for one trait / } (\mathbf{\Sigma Rn * C1} + \mathbf{Rn - 1 * C2} \ldots. + \mathbf{R1 * Cn}) \text{ for all traits.}$$

Where Rn is the value given for the least ranked level, Cn = Counts of the least ranked level, and the count of the 1st rank = C1). The variable with the highest index value was the most economically important trait.

4. RESULTS AND DISCUSSION

4.1. Household Characteristics of Respondents

Household characteristics of chicken producers in the study area are indicated in Table 2. In this study, the majority of respondents (62.5%) fall in the range of 31–40 years of age, followed by 20–30 (15.6%), and 41–50 (16.9%). The age groups of those under 20 and those over 50 comprise the least percentage of the households interviewed (1.9%) and (3.1%), respectively.

Table 2. Household characteristics of the respondents in Doba District.

Parameter	Description	Midland N=84	Highland N=76	Overall N=160	$\chi 2$	P. value
Age (%)	< 20 years	2(2.4)	1(1.3)	3(1.9)		
	20-30 years	11(13)	14(18.4)	25(15.6)		
	31-40 years	52(61.9)	48(63.2)	100(62.5)	2.593	0.628^{NS}
	41-50 years	15(17.9)	12(15.8)	27(16.9)		
	> 50 years	4(4.8)	1(1.3)	5(3.1)		
Sex (%)	Male	15(17.9)	19(25)	34(21.3)	1.216	0.270^{NS}
	Female	69(82.1)	57(75)	126(78.8)		
Marital Status (%)	Married	72(85.7)	61(80.3)	133(83.1)		
	Single	2(2.4)	1(1.3)	3(1.9)	2.864	0.413^{NS}
	Divorced	6(7.1)	5(6.6)	11(6.9)		
	Widowed	4(4.8)	9(11.8)	13(8.1)		
Educational Background (%)	Illiterate	66(78.6)	59(77.6)	125(78.1)		
	Grade 1-4	10(11.9)	12(15.8)	22(13.8)	3.015	0.555^{NS}
	Grade 5-8	5(5.9)	3(3.9)	8(5.0)		
	Secondary School (9-12)	1(1.2)	2(2.6)	3(1.9)		
	Colleges and above	2(2.4)	0(0)	2(1.3)		
Chicken holding (Mean± SE)		10.2±0.64	8.6±0.38	9.4±0.51		0.041*

Note: $\chi 2$ = chi square, * = significant, N = number of household, NS= Non significant

The high proportion of respondents in age ranges between 31–40 years observed in this study implies that the respondents engaged in chicken production were in active productive age groups. The present study is in line with the findings of Jaleta (2021), who found 61.1 % of households in the age between 31 and 40 years in two agroecologies of Daro Lebu District, West Hararghe Zone, Ethiopia.

This study showed that the majority of respondents (75% and 82.1%) were females, whereas males accounted for only 25% and 17.9% in the highland and midland agro-ecologies, respectively. The high proportion of females involved in chicken raising than males indicate that chicken rearing is mainly the responsibility of female. The primary reason for the high percentage of female-headed households raising chickens could be because they use the income from raising chickens to cover household expenses. The findings of this study are consistent with those of Emebet *et al*. (2013) and Tareke (2016), who reported that a high proportion of respondents who participated in chicken production were female in southern Ethiopia and in the South Wollo Zone.

The current findings showed that the majority of respondents in the study area were married (83.1%), followed by widowed (8.1%), divorced (6.9%), and single (1.9%). The educational status of the interviewed respondents in this study showed that about 78.1% were illiterate, 13.8% had learned primary education of the first cycle (1-4), 5% had learned primary education of the of the second cycle (5-8), 1.9% had learned secondary education (9-12), and 1.3% had learned colleges and above in the study district. There was no significant difference between the highland and midland agro-ecologies in terms of marital status and educational background of the households in the study area.

The mean number of Bovans brown and Sasso chickens held in the study area per household in highland agroecology (8.6±0.38) was significantly lower ($P <0.05$) than midland (10.2±0.64) agroecologies. This difference might be due to the availability of grain feeds and the favorable environmental conditions of midland agro-ecologies compared to the highland agro-ecologies of the study area. This is higher than the report of Hailu et al. (2012), which revealed that the mean number of Bovans brown chicken per household in the midland (4.29 ± 0.52) was higher than in the highland (4.28 ± 0.63) agroecology of Amhara regional state, Northwest Ethiopia. The current findings are also higher than the report of Habtamu *et al*. (2023), who reported that the average chicken holding per household in midland (5.44 ± 0.20) chickens was significantly higher in highland (3.53 ± 0.22) agro-ecologies of Northwest Ethiopia. This difference in the number of chicken holdings might be due to chicken production, which appears to be an important activity in both the highland and midland agroecologies of the study area.

4.2. Sources of Exotic Chicken

The type and sources of exotic chicken in the study area are presented in Table 3. The study's findings indicate that most producers raise Sasso and Bovans Brown chickens for the purpose of selling eggs and chickens; the overall result indicated that about 51.9% and 48.1% of respondents in the study area raised dual-purpose Sasso and Bovans brown chicken, respectively. The results were similar to those of Aman *et al*. (2017b), which reported that most respondents were raising more Sasso chicken (40.4%) and 72.7% in highland and midland agro-ecologies, respectively, than Bovans brown in southern Ethiopia. This could be attributed to the availability of Sasso chickens provided by private poultry farms, especially by Ethio-chicken private farms.

Table 3. Types and Source of Sasso and Bovans brown chicken in study areas.

Variables	Parameter	Midland N=84	Highland N=76	Overall N=160	$\chi 2$	P. value
Chicken type available (%)	Sasso	43(51.2)	40(52.6)	83(51.9)	1.645	0.2000^{NS}
	Bovans Brown	41(48.8)	36(47.4)	77(48.1)		
Source	NGO	42(50)	31(40.8)	73(45.6)	1.775	0.412^{NS}
	Ethio- chicken	39(46.4)	40(52.6)	79(49.4)		
	Market	3(3.6)	5(6.6)	8(5.0)		
	Overall	84(100)	76(100)	160(100)		

Note: $\chi 2$ = chi square, NS= non-significant, N=number of households, NGO= Non-governmental organization

According to information gathered from interviewed respondents, the three micro-enterprises (local cooperatives) that are located in the study area brought one-day-old of Sasso breed chicks from an Ethio-chicken private farm. The majority of the respondents bought Sasso chickens from the three enterprises when the chicks' growth reached 56 days. As a result, 45.6% of respondents who owned Bovans brown chickens obtained their chickens from non-governmental organizations (World Vision) through the Doba Woreda Agricultural and Natural Resource Office, and the remaining 5% rarely purchased chickens from the local market. Sasso chickens were obtained by 49.4% of respondents from private farms (Ethio-chicken private farm) through the three micro-enterprises (local cooperatives) that are located in the study area.

4.3. Purpose of Keeping Chicken

The results on the purpose of Bovans brown and Sasso chicken rearing in the study district are presented in Table 4. According to this study, the majority of respondents keep their chickens primarily for immediate source of cash (income generation), followed by egg production and home consumption in their order of importance, respectively.

Table 4. Purposes of keeping Bovans brown and Sasso chicken in the study area.

Purposes of keeping Chicken	Agro-ecologies									
	Midland (N=84)					Highland (N=76)				
	R1	R2	R3	Index	Rank	R1	R2	R3	Index	Rank
Cash income	46	28	10	0.40	1st	42	25	9	0.34	1st
Egg production	21	42	18	0.34	2nd	21	39	16	0.31	2nd
Home consumption	13	12	51	0.25	3rd	9	9	37	0.21	3rd

Priority index = Sum of [3 x for rank 1+2 x rank 2+1 x rank 3] for one trait divided by the sum of [3 x rank 1+2 x rank 2+1 x rank 3] for all counted values mentioned by the respondents (Kosgey, 2004). R= Rank, R1= number households of ranked 1, R2= number of households ranked 2…

According to the results of this study, the majority of producers raise chickens to generate income by selling eggs and chickens. The current study was similar to the report by Moges *et al*. (2010) and Duressa and Betelhem (2022), indicated that 51% and 67.01% of households sell the live chickens for income generation in Bure district, North West Ethiopia, and Assosa Town, Benishangul Gumuz Region, respectively. The present study area, most households kept chickens for the purpose of selling eggs and raising live chickens for income generation.

4.4. Chicken Production System

The chicken production system is presented in Table 5. The extensive or scavenging and semi-intensive production system are the two major dominant chicken production systems used in the study area. The extensive or scavenging production system has kept few chickens; specific chicken houses are rare; scavenging and occasional feeding with home grains; and there is no regular health program with no biosecurity. The semi-intensive production system in this study was characterized by good management practices in terms of feeding, watering, housing, and a minimal level of biosecurity. The house was made from local materials; the chickens scavenge with regular supplementation, and they have access to veterinary services. The extensive or scavenging production accounted for 91.9% of the production systems used or practiced by the study's respondents (94.7% for highland and 89.3% for midland), and semi-intensive production accounted for 8.1% (5.3% for highland and 10.7% for midland).

Table 5. Chicken production System in Doba District

production system	Agro-ecologies				
	Midland N=84	Highland N=76	Overall N=160	$\chi 2$	P. value
Extensive	75(89.3)	72(94.7)	147(91.9)	1.588	0.208 [NS]
Semi-intensive	9(10.7)	4(5.3)	13(8.1)		
Total	84(100)	76(100)	160(100)		

Note: $\chi 2$ = chi square, NS= non-significant, % = Percent, N=number of households

According to this study, the majority of the respondents managed chickens extensively under scavenging production systems. The reason might be due to the poor awareness of respondents, which could be the result of a lack of strong extension service. The result of this study is in line with the report to Yeki District, South Western Ethiopia, which indicated that the dominant chicken production system (95%) was free scavenging (Adem and Teshome, 2016). Similarly, it is also closely related to the study conducted in Daro Lebu District, West Hararghe Zone, which reported extensive (94.1%) and semi-intensive (5.9%) chicken management systems (Jaleta, 2021).

4.5. Chicken Husbandry Practices

4.5.1. Feed resources and feeding practices

The major feed resources and feeding practices for chicken in the study area are shown in Table 6. The major feeding practice was scavenging with additional feed supplementation. The study findings indicate that 100% of the respondents reported practicing a scavenging system with additional supplementary feeding. This result is consistent with findings by Bosenu and Takele (2014), who reported that 100% of respondents in the Haramaya district of Eastern Ethiopia practiced a scavenging system with supplementary feeding. This study result is also similar with the finding of Jaleta (2021), who reported that all respondents (100%) used a scavenging system with additional supplementary feeding in Daro Lebu District, West Hararghe Zone, Ethiopia.

Table 6. Type of feeds, sources and feeding systems of chickens in the Doba District.

Variables	Parameter	Midland N=84	Highland N=76	Overall N=160	$\chi2$	P-value
Feeding system	Scavenging only	0(0)	0(0)	0(0)		
	Scavenging with supplement	84(100)	76(100)	160(100)	----	----
Supplementation	Yes	84(100)	76(100)	160(100)	----	----
	No	0(0)	0(0)	0(0)		
Type of feeds used as supplement	Maize and Sorghum	16(19)	17(22.4)	33(20.6)	6.661	0.155
	Sorghum and Wheat	15(17.9)	9(11.8)	24(15)		
	Maize and wheat	12(14.3)	20(36.3)	32(20)		
	Maize, Sorghum and wheat	32(38.1)	19(25)	51(31.9)		
	Maize, wheat, sorghum, Wheat bran, and household leftovers	9(10.7)	11(14.5)	20(12.5)		
Source of supplemental feed	Market	10(11.9)	5(6.6)	15(9.4)	4.350	0.114
	own farm	23(27.4)	32(42.1)	55(34.4)		
	Own farm and market	51(60.7)	39(38.2)	90(51.3)		

Note: $\chi2$ = chi square, NS= non-significant, % = Percent, N=number of households

The results of the study about 100% of the chicken owners provided supplementary feed for their chickens due to supplementary feed increases the production of eggs and meat yield. Supplementary feed in this study was any feed not obtained from scavenging. This result indicates that all of the respondents in both the highland and midland agro-ecologies of the study area have adequate experience providing supplementary feed for their chickens. This result is similar to the study conducted in the central zone of Tigray and in the Bench Maji zone of south-western Ethiopia by Alem (2013) and Getachew *et al*. (2016), who reported that about 100% of chicken producers were offered supplementary feed for their chickens.

According to this study, the most commonly used feed types to supplement their chicken were maize, sorghum, and wheat (31.9%), maize and sorghum (20.6%), maize and wheat (20%), sorghum and wheat (15%), and maize, wheat, sorghum, wheat bran, and household leftovers (12.5%) in the study area. Therefore, the major types of supplementary feed given to chickens in the highland and midland agro-ecologies of the study area were grains like maize, sorghum, and wheat. This is because the main crops cultivated in the study areas were cereal grains, especially wheat, sorghum, and maize. However, the amount of each grain and frequency of giving depend on the husbandry practices of individual households as well as the availability of feed resources at the household level.

The results of the study are similar with the findings of Jaleta (2021), who reported in both agroecologies of Daro Lebu District, West Hararghe Zone, Ethiopia, the majority of the respondents used maize, wheat, sorghum, and household waste products as the main supplementary feeds given to chickens. This finding also agrees with the study conducted by Hailemichael *et al*. (2015) in the Southern Zone of Tigray, Northern Ethiopia, which revealed that the main supplements used for chicken feed were sorghum, wheat, and maize.

The respondents in the highland and midland agro-ecologies of the study area indicated that the major sources of supplementary feed for the chickens were from their crop harvest/own farm (34.4%), both from their own farm and purchased from the market (51.3%), and from the local market (9.4%). The findings of this study are similar with those of Jaleta (2021), who stated that in the Daro Lebu District, crop harvest and purchases from the market (54.0%), from the market (25.6%), and from crop harvest or own farm (20.4%) were the major sources for supplementary feed for the chickens.

The mode of provision and frequency of feeding their chickens in the study area are shown in Table 7. Regarding the frequency of supplementary feeding, in the study area, about 45% of the respondents were provided their chickens supplementary feeds once a day, followed by 31.3% twice a day, 20.6% three times a day, and 3.1% ad libitum (available all the time). A significant difference was observed in the frequency of feeding between the two agroecologies of the study area. This might be due to the difference in awareness, attention given, and availability of grain feeds between the respondents from two agroecologies in the study district. This study findings disagreed with the study of Tilahun *et al*. (2017), who reported the frequency of feeding practiced by chicken was 66.67% and 68.89% of the respondents feed evening and morning, whereas morning, evening, and afternoon 7.78% and 1.11%, afternoon only 13.33% and 11.11%, and morning only 12.22% and 18.89% in highland and midland agro-ecologies of North Western Amhara, Ethiopia, respectively.

Table 7. Mode of provision and frequency of feeding chickens in the study area.

Parameters	Descriptions	Midland	Highland	Overall	$\chi2$	P- value
		N=84	N=76	N=160		
Mode of provision	In feeder	35(41.7)	20(26.3)	55(34.4)	4.168	0.041*
	On floor	49(58.3)	56(73.7)	105(65.6)		
Types of feeder used	Plastic	30(35.7)	17(22.4)	47(29.4)	4.173	0.124^{NS}
	Metal	5(5.9)	3(3.9)	8(5)		
	Total	35(41.7)	20(26.3)	55(34.4)		
Frequency of feeding per day	Once	24(28.6)	48(63.2)	72(45)	21.151	0.000*
	Twice	34(40.5)	16(21.1)	50(31.3)		
	Three	24(28.6)	9(11.8)	33(20.6)		
	Ad libitum	2(2.4)	3(3.9)	5(3.1)		

Note: $\chi2$ = chi square, * = significant (P<0.05) NS= non-significant, N=number of households.

Chicken owners in the midland had better access to extension services than those in the highland. There was a significant difference ($P<0.05$) in the mode of provision of feeding their chicken between the highland and midland agroecologies of the study area. About 65.6% of respondents provided supplementary feed for their chickens by spreading on the floor, and the rest (34.4%) of the respondents were provided by feeders as a mode of provision in the study area. This difference might be due to the difference in awareness and attention given between the respondents of the highland and midland agroecologies of the study. This study result indicated that 65.6 % of respondents do not have feeding troughs, and only the rest (34.4%) have feeding troughs for their chickens. The types of feeding troughs used by chicken owners in the study area were made of plastic and metal.

4.5.2. Water sources and watering systems

Water sources and watering practices in the highland and midland agroecologies of the study area are presented in Table 8. In terms of watering, the current study findings showed that all chicken owners in the study areas were experienced the provision of water to their chickens. This finding is similar to that of the study conducted in Assosa Town, Benishangul Gumuz Regional State, Ethiopia, by Duressa and Betelhem (2022), which found that all respondents (100%) provided water for their chickens. The present study findings were also in line with research conducted in the southern region of Tigray and the Daro Lebu District, West Hararghe Zone, Ethiopia, by Hailemichael *et al*. (2015) and Jaleta (2021), where all chicken producers (100%) provided water to their chickens.

Concerning the source of water, households use various sources of water for their chickens based on the availability of water in their vicinity. However, the majority (56.3%) use tap water, followed by spring water (38.8%) and pond water (5%) in the highland and midland agroecologies of Doba district. This result is consistent with the study by Jaleta (2021), which found that in two agroecologies in the Daro Lebu District, West Hararghe Zone, Ethiopia, the main sources of water for their chicken were tap water (35.9%), spring water (33%), pond water (30.7%), and river water (0.4%).

Table 8. Water sources and watering practices of chicken in Doba District.

Parameters	Descriptions	Agro-ecologies		Overall	$\chi 2$	P value
		Midland N=84(%)	Highland N=76(%)	N=160(%)		
Providing water for chicken	Yes	84(100)	76(100)	160(100)	---	----
	No	0(0)	0(0)	0(0)		
Source of water	Spring water	28(33.3)	34(44.7)	62(38.8)	3.534	0.171^{NS}
	Tap water	53(63.1)	37(48.7)	90(56.3)		
	Pond water	3(3.6)	5(6.6)	8(5)		
Frequency of Watering	Once a day	27(32.1)	39(51.3)	66(41.3)	6.569	0.087^{NS}
	Twice a day	24(28.6)	13(17.1)	37(23.1)		
	Three times	5(6)	3(4)	8(5)		
	Free access	28(33.3)	21(27.6)	49(30.6)		
The use of waterer	Yes	84(100)	76(100)	160(100)	---	----
	No	0(0)	0(0)	0(0)		
Type of waterer	Plastic made	57(68)	55(72.4)	112(70)	1.054	0.590^{NS}
	Locally made wooden trough	5(6)	6(7.9)	11(6.9)		
	Metal made	22(26)	15(19.7)	37(23.1)		

Note: $\chi 2$ = chi square, NS= non-significant, N=number of households.

In the highland and midland agroecologies of the study area, the majority of chicken producers (41.3%) water their chickens once a day at any time; 30.6% practice adlibtum, giving their chickens free access to water at all times by placing one location; 23.1% water their chickens twice a day; and 5% water their chickens three times a day. This finding is consistent with a study by Tilahun *et al*. (2017) that found that in North Western regions, 85.56% of respondents from high land and 88.89% from midland agro-ecologies provided water once a day at any time, and 11.11% from midland agro-ecologies and 14.44% from high land provided water twice a day. According to this study, 100% of chicken owners provided their chickens with a watering trough. The most popular types of watering troughs in this study area were those made of plastic (70%), metal (23.1%), and locally made wooden troughs (6.9%). The findings of this study were consistent with the findings of Tagesse (2016), who found that in all agro-ecologies in Kersa District, East Hararghe Zone, Ethiopia, the majority of chicken owners (79.1%) provide water using plastic watering troughs, followed by clay (22.1%) and wood (1.8%).

4.5.3. Chicken housing system

A chicken housing system is presented in Table 9. The current study's findings indicate that, in highland and midland agroecologies, the majority of respondents (81.9%) did not have separate chicken houses; instead, they shared houses with family dwellings (56.9%), in the kitchen (21.9%), and in baskets or sucks (3.1%) at night as their residencies. The remaining 18.1% of respondents have a separate house constructed for raising chickens.

Table 9. Chicken housing system in the study area.

Parameters	Descriptions	Agro-ecologies		Overall	$\chi 2$	P. value
		Midland N=84	Highland N=76	N=160		
Separate chicken house	Yes	15(17.9)	14(18.4)	29(18.1)	0.09	0.926[NS]
	No	69(82.1)	62(81.6)	131(81.9)		
Reason for the absence of separate chicken house	Lack of awareness	40(47.6)	28(36.8)	68(42.5)	6.206	0.184[NS]
	Lack of attention	8(9.5)	7(9.2)	15(9.4)		
	Risk of predators	9(10.7)	19(25)	28(17.5)		
	Lack of construction materials and financial resources	12(14.3)	8(10.5)	20(12.5)		
	Total	69(82.1)	62(81.6)	131(81.9)		
Night Perch/ shelter	In the kitchen	18(21.4)	17(22.4)	35(21.9)	1.283	0.733[NS]
	Family dwellings	48(57.1)	43(56.6)	91(56.9)		
	In the basket	3(3.5)	2(2.6)	5(3.1)		
	Total	69(82.1)	62(81.6)	131(81.9)		

Note: $\chi 2$ = chi square, NS= non-significant, N=number of households.

The majority of the chickens in this study were kept overnight inside the family house and released early in the morning to search for feed. This suggests that the respondents in the study area were not enough knowledgeable regarding the importance of constructing a separate housing for chickens. Consequently, creating awareness among the households about the construction of chicken houses and promoting understanding of the importance of constructing separate housing for chickens.

The study area's focus group discussion suggested that the main causes of the absence of a separate chicken house were lack of awareness (lack of knowledge), risk of predators, lack of attention, and lack of construction materials and financial resources to establish their own chicken house. The overall result shows that the main causes of the absence of separate chicken houses in the highland and midland agroecologies of the study area were lack of awareness (42.5%), risk of predators (17.5%), lack of construction materials and financial resources (12.5%), and lack of attention (9.4%). The findings of this study regarding separate chicken houses corresponded with those of previous studies conducted in the Bure district of North West Ethiopia, where it was reported that only 22.1% of farmers had prepared separate overnight houses for their chickens, and 77.9% of respondents did not have separate chicken houses (Moges et al., 2010). The findings of this study also agreed with the reports of Almaz (2015), who stated that in Dugda Woreda, East-Shewa Zone, Ethiopia, about 22.5% of smallholder chicken owners construct separate chicken houses, and 43.1% of smallholder chicken owners provide night shelter to their chickens.

4.5.4. Chicken diseases and health care

The occurrence of chicken diseases and control measures in the study district are presented in Table 10. The findings show that, about 95.6% of the interviewed respondents could identify the occurrence of chicken diseases, which are the main causes of the loss of Bovans brown and Sasso chicken in the highland and midland agroecologies of the study area. Even though the remaining respondents (4.4%) stated that there is no occurrence of disease in their flock, they further explained that they do not observe disease in their flock because they maintain their chickens in good management conditions. There was a significant difference ($P<0.01$) was observed between the highland and midland agroecologies in the occurrence of disease. This could be due to difference in environmental conditions and management practices of the chicken owners of the study area.

This findings was in line with those of Jaleta (2021), who reported that in the midland and lowland agroecology of the Daro Lebu district of the West Hararghe zone, Ethiopia, 95.9% of the chicken owners interviewed were able to recognize the existence of chicken diseases. The findings of this study were also consistent with those of Tagesse (2016), who found that 95.8% of the chicken owners interviewed could identify the presence of chicken diseases in all agro-ecology of Kersa District, East Hararghe Zone, Ethiopia.

Table 10. Chicken diseases and health care practices in Doba District

		Agro-ecology				
Parameters	Descriptions	Midland N=84	Highland N=76	Overall N=160	$\chi2$	P-value
Diseases occurrence	Yes	77(91.7)	76(100)	153(95.6)	6.623	0.01*
	No	7(8.3)	0(0)	7(4.4)		
	Total	84(100)	76(100)	160(100)		
Prevalent diseases	Newcastle disease	49(58.3)	47(61.8)	96(60)	7.282	0.122^{NS}
	Coccidiosis	12(14.3)	13(17.1)	25(15.6)		
	External Parasite	4(4.8)	6(7.9)	10(6.3)		
	Fowl typhoid	12(14.3)	10(13.2)	22(13.8)		
	Total	77(91.7)	76(100)	153(95.6)		
Control measures	Traditional	51(60.7)	56(73.7)	107(66.9)	8.254	0.041*
	Treatment	23(27.4)	16(21.1)	39(24.4)		
	No control measures	3(3.6)	4(5.3)	7(4.4)		
	Total	77(91.7)	76(100)	153(95.6)		
chicken vaccinate	Yes	20(23.8)	14(18.4)	34(21.3)	0.692	0.405^{NS}
	No	64(76.2)	62(81.6)	126(78.8)		
	Total	84(100)	76(100)	160(100)		
Reason for not vaccinating Chickens	No information	39(46.4)	41(53.9)	80(50)	4.005	0.405^{NS}
	Lack of vaccine	8(9.5)	8(10.5)	16(10)		
	Lack of attention	17(20.2)	11(14.5)	28(17.5)		
	Others	0(0)	2(2.6)	2(1.3)		
	Total	64(76.2)	62(81.6)	126(78.8)		

Note: $\chi2$ = chi square, * = significant ($P<0.05$) NS= non-significant, N=number of households

The study area most prevalent chicken diseases, according to information gathered from animal health experts during the focus group discussion, are Newcastle diseases, coccidiosis, fowl typhoid, and external parasites. In the highland and midland agroecologies of the study area, it is stated to be the first major cause of chicken death in the district, accounting for 60% of

Newcastle disease, followed by coccidiosis (15.6%), fowl typhoid (13.8%), and external parasites (6.3%).

The result indicates that the most important economic disease in the study area was Newcastle disease (NCD). This was one of the limitations to chicken production in the highland and midland agroecologies of the study area. The most prevalent chicken diseases raised in the study areas are in agreement with the result of Dejene (2021), who reported that Newcastle disease (NCD) was the major chicken disease in Pawe District, Beneshangul Gumuz Regional State, Ethiopia. This study result was also in line with the result reported by Halima (2007) in North West Amhara, who reported that the major causes of death for chickens were seasonal outbreaks of diseases, specifically Newcastle disease. Additionally, Bikila and Mengistu (2013) also reported that the major diseases, in order of their importance, were 85% Newcastle disease (NCD) and 15% other diseases (Coccidiosis, Fowl Pox, and Fowl Typhoid) in Chelliya District. Respondents could not differentiate between types of diseases, but they knew the symptoms of diseases like white or yellow diarrhea, fluid in the mouth and eye, head and wing dropping, poor appetite, and deaths within a few days.

Regarding the overall control measures, 66.9% of respondents (60.7% and 73.7%) treated sick chickens with traditional treatments or medicines; only 24.4% (27.4% and 21.1%) used modern medicine; and the remaining 4.4% (3.6% and 5.3%) of respondents did not take any control measures in the midland and highland agroecologies of the study area, respectively. There was a significant difference between the two agro-ecologies of the study area. This might be due to the fact that the chicken owners in the midlands had better access to extension services than those in the highlands. In the highland and midland agroecologies of the study area, chicken owners reported using traditional treatments and medicines to treat sick chickens. These included cutting under the wing of the chickens to remove infected blood, especially for fowl typhoid disease, and using onion, lemon juice, hot pepper (*mitmit*a), ginger, and tetracycline capsules for different diseases.

According to the interviewed household, the amount of traditional drugs used for sick chicken treatment was not measured or known. This might have an impact on the health status of the chickens. The respondents used traditional treatment due to a lack of knowledge about the advantages of modern drugs, the accessibility and low prices of traditional treatment, and the unavailability of veterinary services in their locality. But those respondents who know the negative effect of traditional treatment on the health of chickens treated at animal health posts and veterinary clinics in the study area. Therefore, about 24.4% of the respondents used modern medicine to treat sick chickens at animal health centers (health institutions organized at the kebele level) and veterinary clinics (health institutions organized at the woreda level), and the rest (4.4%) of the respondents did not take any control measures. This result agrees with the finding of Addisu *et al*. (2013), who reported that the majority of respondents (88.2%) used traditional medicines like lemon juice, ginger, and onion to treat their chickens in north Wollo, Ethiopia.

Most of the respondents in the study area revealed that 78.8% of the chicken owners had no practice of vaccinating their chickens against diseases, while only 21.3% of the respondents vaccinated their chickens to prevent and control different diseases, especially NCD, in the highland and midland agroecologies of the study area. This finding was in line with the result of Tareke (2016), who reported that 12.22% of their chickens were vaccinated and 87.78% were not vaccinated in Wogdi, Borena, and Legambo Districts. However, the current result was not in agreement with the result of Desalew (2012), who reported that about 50.6% (21.2% in Ada and 80% in Lume districts) of the chicken owners had vaccination programs before the occurrence of disease outbreaks to control chicken diseases.

The current results indicated that the majority of the respondents did not vaccinate their chickens in the study area. This implies that most of the chicken owners do not have access to vaccines because small packs of vaccines are not available at the farmer's level for small flocks of chickens, and farmers did not give attention to the healthcare of their chickens before the disease outbreak. The respondents in the highland and midland agroecologies of the study area mentioned several major reasons why they are not vaccinating their chickens, including difficulty taking the whole chickens to the Animal Health Center (1.3%), lack of vaccines (10%), lack of information about the presence of vaccines for chickens (50%), and lack of attention to vaccinate chickens (17.5%). Overall, the results of this study indicated that chicken producers have poor experience with the vaccination of chickens. Vaccinations and regular healthcare for our chickens are essential to achieving sustainable chicken productivity.

4.6. Major Constraints of Bovans Brown and Sasso Chicken Production

Major constraints on chicken production in the study area were assessed through focus group discussions with the development agency, participants' households, and other chicken keepers in the highland and midland agroecologies of the study area, as presented in Table 11. The index ranking technique was used to indicate chicken production constraints in order of their severity. Hence, the major constraints of chicken production in the study area were prevalence of disease (1st rank), attacks of predators (2nd rank), inadequate veterinary services (3rd rank), lack of housing (4th rank), shortage of feed services (5th rank), and poor extension services (6th rank).

Table 11. Ranking of the major constraints of chicken production in Doba District.

	Agro-ecologies			
	Midland (N=84)		Highland (N=76)	
Constraints	Index	Rank	Index	Rank
Disease prevalence	0.26	1st	0.25	1st
Attacks by predators	0.23	2nd	0.23	2nd
Inadequate veterinary services	0.17	3rd	0.17	3rd
Lack of housing	0.15	4th	0.14	4th
Shortage of feeds	0.12	5th	0.13	5th
Poor extension services	0.07	6th	0.07	6th

(Rank 1 = the major constraints) (Rank 6= Least constraints), Index = Sum of (6* for rank 1) + (5* for rank 2) + (4* for rank 3) + (3* for rank 4) + (2* for rank 5) + (1* for rank 6) + dived by the sum of all weighed value mentioned by the respondents (Kosgey, 2004).

The first and most important constraint on Bovans brown and Sasso chicken production in the study district was the prevalence of disease outbreaks, especially NCD and Coccidiosis diseases, which are diseases of economic importance that hinder the expansion of chicken production in the study area, respectively. The current result agrees with the study of Jaleta (2021), who revealed that disease was the most important constraint affecting chicken productivity, followed by predators in two agroecologies of Daro Lebu District, West Hararghe Zone, Ethiopia. The current findings were also consistent with the finding of Tarekegn *et al*. (2015), who reported that the major constraints on chicken production in Ethiopia were the high incidence of NCD and Coccidiosis, which are the primary constraints on village scavenging chicken production in eastern Hararghe. Additional results were also reported by Hunduma *et al*. (2010), who reported that the major constraint of village chickens in the rift valley area of Oromia was commonly disease, mainly Newcastle locally known as fungil, followed by predator.

Another important economic constraint to chicken production was predators, which were also reported as the second major cause of chicken loss in the study area. This findings was similar with that of Hailemichael *et al*. (2015), who indicated that disease and predators were the major and economically important constraints for the existing chicken production in the Southern Zone of Tigray, Northern Ethiopia. The current result was also in line with the result of Teklemariam (2017), who found that the main challenges to the adoption of exotic or hybrid chickens in Tselemti Woreda and Tahtay Koraro Woreda were diseases and predators.

In the current study, it was found that chicken were easily attacked by predators. Accordingly, the most common predators reported by respondents in the study area were wild animals such as foxes and wild cats, which are the main causes of chicken losses, especially in young chickens, in order of importance in both the highland and midland agroecologies of the study area. This may be due to the scavenging feeding system of chickens and the suitability of the area for the presence of predators. This implies that the respondents suffered serious losses due to predation constraints, so the households gave attention to all the predators' problems. Respondents in the study district were reported to use various predator protection measures, such as restricting free movement, keeping dogs around the home, and using fences. The third major constraint of chicken production in the study area was inadequate veterinary health services, followed by a lack of chicken housing, a shortage of supplementary feed, and a lack of extension services in order of economic importance in the highland and midland agroecologies of the study area.

4.7. Performance of Sasso and Bovans Brown Chickens

4.7.1. Age at first egg lay, egg production, and mature body weights of Sasso and Bovans Brown chicken

The average age at first egg lay, eggs laid per hen per week, average number of eggs per hen per year, for the Sasso and Bovans Brown chickens in the study district are presented in Tables 12 and 13. The average age at first egg lay for the Sasso chicken was 5.77±0.03 months (5.64±0.044 months, 5.90±0.042 months), whereas that of the Bovans Brown chicken was 5.38±0.031 months (5.32±0.041 months, 5.48±0.048 months) in the midland and highland agroecologies of the study area, respectively. According to the current study finding revealed that there was a significant difference ($P<0.05$) observed between chicken breeds and agroecologies in terms of age at first egg lay. The result indicated that Bovans Brown reach an earlier age at first laying than Sasso breeds, which is attributed to breed variation. The difference in agro-ecology might be attributed to the difference in management practices like feeding, housing, and health care of the respondents and environmental factors between the two agro-ecologies of the study area. Relatively better feeding and housing management were observed in midland agro-ecology, so Sasso and Bovans brown chicken performed better in midland agro-ecology than highland.

The findings of this study were in line with the results reported by Aman *et al*. (2017b), who found that in the highland and midland agro-ecologies of southern Ethiopia, respectively, the average age at first egg lay for Sasso hens was (5.9, 5.7) months and for Bovans Brown chickens it was (5.6, 5.6) months. According to Birtukan *et al*. (2023), who stated that the average age at first laying of Bovans Brown (132.8±14.4 days) had shorter age of the first egg lay than that of Sasso T44 (164.8±11.3 days) in South Gondar zone, Ethiopia. These observed differences in age at the first egg of the two breeds might be due to genotype differences. The findings of this study were also consistent with Alem (2014) findings, which stated that the age at first lay for the Sasso chicken was 5.86 months in the midland agroecologies of Central Tigray, Ethiopia.

Table 12. Age at first egg, egg production, and the female body weights of Sasso and Bovans Brown chicken in Doba District (Mean±SE)

Parameters	Chicken breeds	Agro-ecologies		Overall	P. value
		Midland N=84	Highland N=76	N=160	
Age at first egg (month)	Sasso	5.64^{a}±0.04	5.90^{b}±0.042	5.77±0.03	0.0001*
	Bovans brown	5.32^{a}±0.041	5.48^{b}±0.048	5.38±0.031	0.0001*
Average eggs per hen per week	Sasso	5.05^{b}±0.09	4.77^{a}±0.087	4.9±0.063	0.0023*
	Bovans brown	5.73^{a}±0.085	5.45^{b}±0.099	5.6±0.065	0.0023*
Average egg per hen per year	Sasso	233.69^{a}±2.14	221.5^{b}±2.04	227.32±1.48	0.0001*
	Bovans brown	252.8^{b}±1.99	243.45^{a}±2.33	248.86±1.53	0.0001*
Weight of laying hen >20 weeks (kg)	Sasso	2.49^{a}±0.04	2.26^{b}±0.039	2.4±0.028	0.0001*
	Bovans brown	2.18^{a}±0.038	1.95^{b}±0.045	2.1±0.029	0.0001*

Note: $^{a-b}$ Means with different superscript letters within a row are significantly different ($P<0.05$), * = significant, SE=Standard Error

The findings of this study were in line with the results reported by Aman *et al*. (2017b), who found that in the highland and midland agro-ecologies of southern Ethiopia, respectively, the average age at first egg lay for Sasso hens was (5.9, 5.7) months and for Bovans Brown chickens it was (5.6, 5.6) months. According to Birtukan *et al*. (2023), who stated that the average age at first laying of Bovans Brown (132.8±14.4 days) had shorter age of the first egg lay than that of Sasso T44 (164.8±11.3 days) in South Gondar zone, Ethiopia. These observed differences in age at the first egg of the two breeds might be due to genotype differences. The findings of this study were also consistent with Alem (2014) findings, which stated that the age at first lay for the Sasso chicken was 5.86 months in the midland agroecologies of Central Tigray, Ethiopia.

The current study revealed that the mean age at first egg laying of the Bovans brown hens was relatively earlier in age at first egg laying than the results of Brehanu et al. (2017), who reported that the age at first egg laying for Bovans brown chicken was 6.34 months and 6.41 months in the midland and highland agroecologies of Southern Tigray, North Ethiopia, respectively. The other finding was also reported by Tunsisa and Fiseha (2024), who stated that in Sidama Zone and Halaba Special Woreda, Ethiopia, the average age of the first egg laid was 25.93 weeks for

Sasso and 24.31 weeks for Bovans brown breed. This shows there is a significant difference among breeds in average age at first egg laying: the Bovans brown start to lay eggs earlier than the Sasso breed.

Egg production is one of the important traits of chicken production. In this study, the overall mean value of eggs laid per hen per week for Sasso chicken was 4.9±0.063 (5.05±0.09 and 4.77±0.087), and Bovans Brown chicken was 5.6±0.065 (5.73±0.085 and 5.45±0.099) for midland and highland agroecologies, respectively. This study result indicated that there was a significant difference ($P<0.05$) between chicken breeds and agroecologies in terms of eggs laid per hen per week in the study district. This could be attributed to breed variation and environmental variation among the two agroecologies of the study area

The average number of eggs per hen per year for Sasso chicken was 227.32±1.48 (233.69±2.14 and 221.5±2.04), and Bovans Brown chicken was 248.86±1.53 (252.8±1.99 and 243.45±2.33) in midland and highland agroecologies of the study area, respectively. Regarding the total number of eggs laid per hen per year in the study area, there was a significant difference ($P<0.05$) between the two agro-ecologies and chicken breed; however, there was no significant difference ($p > 0.05$) between the interaction of agro-ecologies and chicken breeds. This showed that the total number of eggs collected per hen per year from midland agroecology was higher than that of highland, as well as the fact that the average egg performance of the Bovans Brown breed was higher as compared to Sasso chicken. This could be due to breed variation, the husbandry practices of the producers, and environmental variation among the two agroecologies of the study area.

Furthermore, both the Sasso and Bovans brown chicken breeds perform slightly better in the midland agroecology of the study area than in the highland agroecology due to the availability of grain feeds and favorable environmental conditions. The current study findings were consistent with the results of Aman *et al*. (2017a), who reported that the average number of eggs laid per year per hen was 229 for Sasso chickens in southern Ethiopia. The results of the current study were also similar to the finding of Jaleta (2021), who showed that the average number of eggs per hen per year for Sasso chicken was 230.56±3.06 in two agro ecologies of Daro Lebu District, West Hararghe Zone, Ethiopia.

The average mean egg production of Bovans brown chickens in the study area was higher than that of Brehanu *et al*. (2017), who reported that the number of eggs laid per hen per year for Bovans brown chickens was 229.70±5.23 and 227.71±5.23 in the midland and highland agroecologies of Southern Tigray, North Ethiopia, respectively. The results of the current study were also higher than the findings of Elias and Tegegn (2023), which conducted in the Malle district and Jinka town of Ethiopia, the average number of eggs laid per hen per year for the Bovans Brown breed was 200 eggs, while the Sasso chicken breed was 150 eggs. This indicates that the Bovans Brown breed performs better than the Sasso breed in terms of egg production; this could be due to breed variation and management differences. In addition, the present study result was higher than the average mean number of annual egg production for Bovans Brown chicken, which was 133 and 135 eggs in the highland and midland agroecologies of North Western Amhara, Ethiopia, respectively, (Tilahun *et al*., 2017).

Additionally, the current study was also higher than the mean number of egg production per hen per year for the Bovans brown breed (127.11, 133.49) and the Sasso breed (118.61, 112.87) in the highland and midland agroecologies of Northwest Ethiopia, respectively (Habtamu *et al*., 2023). This indicates that the mean number of annual egg production for the Bovans brown breed in the midland agroecology is higher than in the highland agroecology. This might be due to the difference in environmental variation and management differences. Hence, Bovans Brown breeds had better annual egg production performance than Sasso breeds, which could be attributed to breed variation.

However, the findings of the present study were lower than those of Desalew (2012), who reported that the average results were 266.32 eggs per hen per year for Bovans Brown breed chickens in East Shewa, Ethiopia. The variation in egg yield in this study relative to various authors could be attributed to differences in the amount and nutritive quality of feed resources available for scavenging and better improvement in the husbandry practices of chicken producers in the study area.

The average mean of the female body weights of Sasso and Bovans brown chickens raised in midland and highland agroecologies of the study area is shown in Tables 14. This study indicated that the overall mean body weight of female Sasso chicken was 2.4±0.028kg and the weight of female Bovans brown chicken was 2.1±0.029kg at the age of greater than 20 weeks were reared in midland and highland agroecologies of the study area. According to these results, there are differences in the average mean female body weights of Sasso and Bovans brown chickens at greater than 20 weeks of age among the agroecologies, with higher body weight values recorded in the midlands.

In the study area, there was a significant difference ($P<0.05$) in the performance of chickens breeds body weight at greater than 20 weeks of age. This variation might be due to breed differences, Sasso chickens had higher body weights than Bovans brown chickens. The present study findings is line with those of Elias and Tegegn (2023), who reported that the Sasso chicken's mature body weight at the age at which it first laid eggs was 2.5 kg, greater than the Bovans Brown chicken's body weight at the same age, which was 1.82 kg in the Malle district and Jinka town, Ethiopia. The Bovan Brown breed is a commercial egg layer, while the Sasso breed is a dual-purpose breed. As a result, Bovan Brown breeds showed a lower body weight than Sasso breeds.

The maturity of Sasso and Bovans brown chicken was later in highland than in midland agro-ecology. This might be attributed to the difference in management practices like feeding, housing, and health care of the chicken producers and environmental factors between the two agroecologies of the study area. The average mature female body weights of Sasso and Bovans brown chickens at greater than 20 weeks of age in this study result were lower than the result of Yonas *et al*. (2020), who reported the average body weight of mature egg-laying hens were 2.82 ± 0.39kg for Sasso chickens and 2.65 ± 0.24 kg for Bovans brown chickens at the age of greater than 20 weeks reared in Yirgalem and Hawasa towns, Ethiopia. The finding of the present study was also lower than the result of Aman *et al*. (2017a), who revealed that the body weight of the female Sasso chicken at the age of greater than 20 weeks was 2.73 kg in southern Ethiopia.

However, the findings of the present study revealed that the mature female body weights of Sasso and Bovans brown chickens were higher than the results of Desalew *et al*. (2013), who reported that the adult female body weights of Bovans Brown chicken was 1.55 kg in East Shewa, Ethiopia. The finding of the current study was also higher than the body weight of hens at maturity of Bovans Brown (1.6±0.01, 1.57±0.05kg) and Sasso T44 (1.6±0.01, 1.6±0.01kg) in the midland and highland agroecologies of the South Gondar Zone, Ethiopia, respectively (Birtukan *et al*., 2023). This indicates the average mature body weight of Sasso and Bovans Brown hens in midland has a higher mature body weight than in highland. This higher body weight of matured hens might be due to the increase in feed intake in midland compared to highland agroecology.

4.8. Egg Quality Evaluation of Bovans Brown and Sasso Chicken

4.8.1. External egg quality

External egg quality traits in the midland and highland agro-ecologies of the study area for eggs collected from Bovans brown and Sasso chickens are shown in Tables 15 and 16. The effect of agroecology was significant for all external egg quality traits except for egg shape index. Similar to this, the effect of breed was significant for all external egg quality traits except for egg shape index and egg shell thickness. There was a significant difference ($P < 0.05$) was observed between the two agro-ecologies and chicken breed in terms of the mean egg weight. This finding indicated that the average weight of the eggs laid by Bovans Brown and Sasso Chicken varied across the study agroecologies, with higher values recorded in the midland (57.8±0.56g for Bovans Brown and 59.6±0.61g for Sasso Chicken) than the eggs recorded in the highlands (55.6±0.66g for Bovans Brown and 58.2±0.58g for Sasso Chicken), respectively. This difference in egg weights could be attributed to differences in the husbandry practices of the producers and agro-ecological factors.

Table 13. The external egg quality traits of Sasso and Bovans brown chicken in Doba District (Mean±SE)

Parameters	Breed	Agro-ecologies		Overall	P. value
		Midland	Highland		
Egg weight (g)	Sasso	59.6^{a}±0.61	58.2^{b}±0.58	58.8±0.42	0.0035*
	Bovans brown	57.8^{a}±0.56	55.6^{b}±0.66	56.9±0.43	0.0035*
Egg width (mm)	Sasso	44.7^{a}±0.58	43.5^{b}±0.55	44.2±0.39	0.0276*
	Bovans brown	43.3^{a}±0.54	42.1^{b}±0.63	42.8±0.41	0.0276*
Egg length (mm)	Sasso	59.6^{a}±0.48	58.2^{b}±0.45	58.9±0.33	0.0095*
	Bovans brown	57.6^{a}±0.44	56.6^{b}±0.52	57.2±0.34	0.0095*
Egg shape index (%)	Sasso	75.3±0.87	74.8±0.83	75±0.61	0.4288
	Bovans brown	75.2±0.82	74.5±0.95	74.9±0.62	0.4288
Shell weight (g)	Sasso	7.9^{a}±0.22	5.7^{b}±0.21	6.8±0.15	0.0001*
	Bovans brown	6.3^{a}±0.2	5.0^{b}±0.24	5.7±0.16	0.0001*
Shell Thick ness (mm)	Sasso	0.31^{b}±0.01	0.29^{a}±0.004	0.30±0.004	0.0203*
	Bovans brown	0.32^{a}±0.006	0.30^{b}±0.007	0.31±0.004	0.0203*

Note: $^{a\text{-}b}$ Means with different superscript letters within a row are significantly different ($P<0.05$), SE=Standard Error, * = significant.

The average weight of eggs collected from Sasso chickens was higher (58.8±0.42g) than eggs collected from Bovans Brown chickens (56.9±0.43g) in the study area. This could be attributed to differences in breed and in the quality of feed used. There is no significant difference in the interaction between agro-ecology and chicken breed on egg weight. The current study's finding on egg weight agreed with that of Desalew *et al*. (2013), who indicated that the average egg weight of 60.27g for Bovans Brown in East Shewa, Ethiopia. The current finding were also similar to the study of Duressa and Betelhem (2022), who reported that the mean egg weight of Sasso T44 chicken breeds was 60.90 ± 0.13 grams and that of Bovans brown chicken breeds was 59.20 ± 0.13 grams in the traditional production system in Assosa Town, West Ethiopia.

The average egg weight of the Sasso was higher than the result of Jaleta (2021), who found 54.9 g the egg weight for Sasso chicken was in two agroecologies of the Daro Lebu district. The present study results were also greater than those of Serkalem *et al*. (2019), who revealed that in two agro-ecologies of Boricha district, Sidama Zone, Southern Ethiopia, the average egg weight of Sasso chicken was 53.8±4.9g and the egg weight of Bovans Brown chicken was 49.5±4.9g. This difference in egg weights could potentially be attributed to various factors, such as differences in environmental conditions or management practices between the study areas and previous studies.

There was a significant difference ($P<0.05$) between the two agroecologies and breeds of chicken in terms of egg length in the study area. In the study area, the mean egg length measured from Sasso chickens was found to be higher at 58.9±0.33mm compared to the 57.2±0.34mm of eggs gathered from the Bovans Brown breed. This could be due to breed differences. The average egg length of the eggs collected from midland was higher (58.6±0.33mm) than the eggs collected from highland (57.5±0.34mm) in the study area. This might be attributed to agro-ecological differences. The result on egg length in the current study is in agreement with the study of Melkamu *et al*. (2019), who indicated that the average mean egg lengths of sasso chicken were 58.38 mm and 56.46 mm in highland and midland, respectively, in North Showa Zone, Ethiopia. These findings also similar with those of Nebiyu (2016), who found that the Bovans brown chicken had an average mean egg length of 56.4±0.16 mm.

The current result was higher than that of Serkalem *et al*. (2019), who found that in the Boricha district, Sidama Zone, southern Ethiopia, the average egg length of Sasso breeds was 55.0±4.2mm and that of Bovans Brown breeds was 54.8±1.7mm. Additionally, the current study result were higher than the average egg length for Sasso chicken was 55.63±7.56 mm, and for Bovans Brown chicken was 55.39±3.02 mm in Yirgalem and Hawasa towns, Ethiopia (Yonas *et al*., 2019).

Regarding the width of eggs in the study area, there was a significant difference ($P<0.05$) between the two agroecologies and chicken types. The average egg width for Sasso chickens (44.2±0.39mm) was higher than Bovans Brown chickens (42.8±0.41mm). This might be differences in breed or genetics. Eggs gathered from the highland in the study area had an average egg width of 42.9±0.42mm, but eggs from the midland had a greater average egg width of 44±0.39mm. This could be due to variations in agro-ecology. There is no significant difference in the interaction between agro-ecology and chicken types on egg width. The results of this study are consistent with those of Melkamu *et al*. (2019), who showed that the sasso T44 in highland and midland agroecologies in the North Showa Zone of Ethiopia had an overall mean egg width of 45.21±2.33mm and 42.89±1.94 mm, respectively.

There was a significant difference ($P<0.05$) between the two agro-ecologies and chicken types and an interaction between agro-ecology and chicken types in terms of shell weight in the study area. The average shell weight of eggs collected from Sasso chicken was higher (6.8±0.15 grams) than the eggs collected from the Bovans Brown chicken breed (5.7±0.16 grams) in the study area. This might be due to breed or genetic differences. The average shell weight of eggs collected from midland was higher (7.03±0.15 grams) than the eggs collected from highland (5.4±0.16 grams) in the study area. This could be attributed to agro-ecological differences. The present result was higher than the average shell weight of eggs collected from exotic (Sasso T44) chickens, which was 4.66±0.06 grams in two agroecologies of Daro Lebu District, West Hararghe Zone, Ethiopia (Jaleta, 2021).

The average egg shell thickness of the eggs collected from Bovans Brown chickens was 0.31±0.004mm and Sasso chickens was 0.30±0.004mm in the study area. There was no significant difference ($P > 0.05$) between the chicken breeds in the two agroecologies of the study area in terms of egg shell thickness. This study also revealed that the average egg shell thickness obtained from midland was heavier (0.31±0.004mm) than that of the eggs collected from highland (0.29±0.004mm) in the study area. The average egg shell thickness of eggs across the highland and midland agroecologies of the study district showed a significant difference ($P<0.05$). The variation in shell thickness among the two agroecologies of the study area could be due to agro-ecological variation and differences in feed type.

The current study was similar to the finding of Serkalem *et al*. (2019), who reported that exotic sasso chicken was 0.301±0.02 mm in the midland agroecologies of Boricha district, Sidama zone, southern Ethiopia. The present result is higher than the mean egg shell thickness of 0.26mm and 0.24mm for Sasso and Bovans Brown, respectively, in Yirgalem and Hawasa towns, Ethiopia (Yonas *et al*., 2019). However, the current study was lower than the average egg shell thickness of an egg of the Sasso chicken (0.34 ± 0.03mm) and (0.35 ± 0.02 mm) in highland and midland agroecology, respectively, in the Silte Zone, Southern Ethiopia (Serkalem *et al*., 2023). This difference in egg shell thickness could be attributed to differences in feed types, management practices, and environmental conditions between midland and highland agroecology.

The eggs shapes most often encountered are sharp, normal (standard), and round eggs, which are enumerated on the shape index as <72, 72–76, and >76, respectively (Kumar *et al*., 2014). The findings indicated that the average egg shape index percentages obtained from Sasso chicken (75±0.61) and Bovans brown chicken (74.9±0.62) in the study area were normal, indicating that there was no significant difference ($P > 0.05$) between the two breeds. There was no statistically significant difference observed between the midland and highland agroecologies in terms of egg shape index. The interaction of agroecology by breed was also not significant in terms of egg shape index. This study was in agreement with the results of Serkalem *et al*. (2019) in the midland agroecologies of Boricha district, Sidama zone, southern Ethiopia, who reported that the overall average egg shape index percentage values were 74.2±3.6 for Bovans brown and 73.9±3.6 for exotic Sasso chicken, which was the normal shape index.

The findings of the current study are lower than those of Melkamu *et al*. (2019) in North Showa Zone, Ethiopia, who reported the mean value of the shape index of Sasso chicken in highland (77.52) and in midland (76.08), which was a round shape index. The results of the current study are also lower than those of the study conducted in the Silte Zone, Southern Ethiopia, by Serkalem *et al*. (2023), who reported the egg shape index for the Sasso chicken in the midland (78.3 ± 7.4) and highland (77.5 ± 4.7). The observed variation in the egg shape index may be attributed to differences in the environmental conditions or management practices between the study area and the previous study areas.

Table 14. Effects of chicken breed, agroecology, and their interaction on external egg quality of Sasso and Bovans brown chicken in Doba District (Mean±SE)

External Egg Quality Traits	Breed		Agro-ecologies		p-value		
	Sasso	Bovans brown	Midland	Highland	(B)	(AE)	B x AE
Egg weight (g)	58.8^{a}±0.42	56.9^{b}±0.43	58.6^{a}±0.41	57.1^{b}±0.44	0.0004	0.0035	0.5241
Egg width (mm)	44.2^{a}±0.39	42.8^{b}±0.41	44±0.39	42.9±0.42	0.0114	0.0276	0.9089
Egg length (mm)	58.9^{a}±0.33	57.2^{b}±0.34	58.6±0.33	57.5±0.34	0.0002	0.0095	0.6613
Egg shape index	75±0.61	74.9±0.62	75.3±0.59	74.7±0.63	0.8678	0.4288	0.9054
Shell weight (g)	6.8^{a}±0.15	5.7^{b}±0.16	7.03^{a}±0.15	5.4^{b}±0.16	0.0001	0.0001	0.0322
Shell Thick ness (mm)	0.30±0.004	0.31±0.004	0.31^{b}±0.004	0.29^{a}±0.004	0.0964	0.0203	0.8520

Note: $^{a-b}$ Means with different superscript letters within a row are significantly different (P<0.05), B = Breed, AE = Agro ecology, B x AE = the interaction of Breed and Agro ecology.

4.8.2. Internal egg quality

Internal egg quality parameters of Sasso and Bovans brown chicken reared in midland and highland agro-ecologies of the study area are shown in Tables 17 and 18. The overall mean value of albumin weight in the study area was 39.3±0.50g in midland and 36.7±0.53g in highland agroecologies, respectively. This finding indicated that the average mean value of albumin weight obtained from Sasso chicken (40.2±0.51g) and Bovans brown breed chicken (35.8±0.52g) reared in midland and highland agro-ecologies of the study area. This study result reported that the overall mean values of albumin weight in the district showed a significant difference between the two agroecologies and chicken breeds, but there was no significant difference (P > 0.05) in the interaction between agroecology and chicken breeds in terms of average albumin weight. This difference might be due to agro-ecological factors, the husbandry practices of the producers, and breed differences. The current study result is similar to the study of Melkamu *et al*. (2019) in North Shewa Zone, Ethiopia, which reported the overall mean albumin weight in midland (34.47±3.17 grams) and highland (40.56±4.41 grams) for the Sasso chicken breed.

Table 15. The internal egg quality of Sasso and Bovans brown chicken in Doba District (Mean±SE)

Parameters	Breed	Agro-ecologies		Overall	P-value
		Midland	Highland		
Albumin weight (g)	Sasso	41.8^{a}±0.75	38.8^{b}±0.85	40.2±0.51	0.0001*
	Bovans brown	37.1^{b}±0.53	34.1^{a}±0.74	35.8±0.52	0.0001*
Albumen height (mm)	Sasso	7.2^{a}±0.21	7.72^{b}±0.18	7.5±0.15	0.0001*
	Bovans brown	6.58^{a}±0.19	8.15^{b}±0.27	7.2±0.15	0.0001*
Yolk weight (gm)	Sasso	19.9^{b}±0.59	16.2^{a}±0.34	17.98±0.29	0.0001*
	Bovans brown	16.4^{a}±0.29	14.2^{b}±0.38	15.42±0.298	0.0001*
Yolk height (mm)	Sasso	14.5^{a}±0.19	13.7^{b}±0.17	14.1±0.12	0.0101*
	Bovans brown	14.9^{a}±0.14	14.2^{b}±0.18	14.3±0.124	0.0101*
Yolk diameter (mm)	Sasso	41.3^{a}±0.43	40.49^{b}±0.36	40.9±0.29	0.0420*
	Bovans brown	40.7^{b}±0.36	39.8^{a}±0.51	40.3±0.30	0.0420*
Yolk index (%)	Sasso	35.1±0.49	34.0±0.56	34.5±0.40	0.5633
	Bovans brown	35.5±0.59	35.9±0.68	35.7±0.42	0.5633
Haugh unit (%)	Sasso	83.8^{a}±1.39	87.5^{b}±1.09	85.7±0.91	0.0001*
	Bovans brown	80.5^{b}±1.29	90.7^{a}±1.42	84.8±0.94	0.0001*

Note: $^{a-b}$ Means with different superscript letters within a row are significantly different (P<0.05), * = significant.

The results showed that the average albumin height measurements in the study area were 7.5±0.15mm for Sasso chicken and 7.2±0.15mm for Bovans brown chicken. There was no significance difference (P>0.05) between the breeds in terms of the overall mean of albumin height. In the midland and highland agroecologies of the study area, the mean albumin height was 6.9±0.14mm and 7.9±0.154mm, respectively. There was significant difference (P<0.05) within agro ecology and the interaction between two agro ecology and breeds in terms of the overall mean of albumin height. Regarding the total mean albumin height result in the study district, the egg obtained from the highland agroecology was heavier than the egg from the midland agroecology. The differences might be due to agro-ecological variation (the availability of a higher environmental temperature in midland than in highland agro-ecology) and egg storage conditions. The current study findings are consistent to those of Serkalem *et al*. (2023) study conducted in Southern Ethiopia Silte Zone, which revealed that the Sasso chicken breed's overall mean albumin height was 6.5 ± 0.8 in the midland and 7.5 ± 0.9 in the highland. The variation in albumen height between midland and highland agroecology may be due to variations in management practices or environmental factors.

The current study findings are consistent with the result of Melkamu *et al*. (2019), conducted in North Showa Zone, Ethiopia, which reported that the average height of albumen in highland areas was 8.04±0.99 mm, which was slightly higher than the mean albumen height in midland areas (7.57±0.86mm) for the Sasso chicken. There could be an agro-ecological difference. The present result was higher than the study result of Jaleta (2021), who reported the overall mean value of albumin heights was 4.94±0.06mm for Sasso chickens in two agroecologies of Daro lebu district of Western Hararghe zone, Ethiopia. The current finding suggests that the higher albumen height may be due to the freshness of the eggs and the storage conditions of the eggs in the study area.

Bovans brown chickens had an overall mean yolk weight of 15.42±0.298 grams, while Sasso chickens had a mean of 17.98±0.29 grams. The two chickens differed significantly ($P<0.05$), with Sasso eggs having greater values in the midland and highland agroecologies of study areas. Additionally, a significant difference ($P<0.05$) has been observed between the eggs collected from the midland and highland agroecologies of the study area. This difference can occur due to differences in breed and environmental variation. The present study's mean yolk weight for the sasso breed is comparable to Jaleta (2021) findings, which indicated that the exotic (SassoT44) breed's average yolk weight was 17.16 grams in Daro Lebu district of Western Hararghe Zone, Ethiopia. The overall mean value of yolk weight recorded from Bovans brown breed chickens in this study was also similar to the result of Desalew (2012), who reported that the overall mean value of yolk weights for Bovans brown chickens was 15.97±1.77 grams in East Shewa, Ethiopia. Another study also reported by Tunsisa and Berihun (2022), who reported that the higher yolk weight was recorded in midland agroecology than in highland agroecology in Sidama Region, Ethiopia.

According to the current results, the yolk heights measured from the midland and highland agroecologies of study area were 14.4±0.12mm and 13.93±0.13mm, respectively. There is a statistically significant difference ($P<0.05$) between the eggs collected from the midland and highland agroecologies of the study area. This could be due to differences in management practices or agro-ecological variation between the midland and highland agroecologies of the study area. The overall mean of yolk heights was 14.1±0.12mm for Sasso chickens and 14.3±0.124mm for Bovans brown chickens, and there was no significant difference between the two breeds in midland and highland agroecologies of the study area. The current finding similar with the study of Jaleta (2021), who showed that the average mean yolk height of the Sasso chicken collected from midland agroecologies was 14.94 ±0.05mm in Daro Lebu district of Western Hararghe Zone, Ethiopia.

The present result was lower than the finding of Melkamu *et al*. (2019), who reported that the overall mean yolk height in midland area (18.79±1.04mm) and highland area (18.83±1.24 mm) for the Sasso chicken breed in North Shewa Zone, Ethiopia, The current study result is also lower than the study of Serkalem *et al*. (2023) in Silte Zone, Southern Ethiopia, which stated that the overall mean yolk height in midland (17.6 ± 0.9) and highland (18.2 ± 1.1) for the Sasso chicken breed. This difference in yolk height could be due to differences in management practices or environmental conditions between midland and highland agroecology.

The mean values of yolk diameter for this study were 41±0.28mm and 40.2±0.29mm in the midland and highland agroecologies of the study area, respectively. Yolk diameter is higher in midland than in highland agroecology. There were significant differences in the yolk diameter of Bovans Brown (40.3±0.30mm) and Sasso chickens (40.9±0.29mm) among the midland and highland agro-ecologies of the study district. This variation in yolk diameter could be attributed to differences in agro-ecological factors and the husbandry practices of the chicken producers.

The average result of yolk index percentage value in midland and highland agroecology of the study district was 35.3±0.40 and 34.8±0.42, respectively. The yolk index percentages did not show a significant difference ($P > 0.05$) between the different egg sources (agroecology, breed, and their interaction) in the study district. The average result of yolk index percentage value was 35.7±0.42 and 34.5±0.40 for Bovans brown and Sasso breeds, respectively, with no significant difference ($P > 0.05$) between the two breeds. The present result on the average egg yolk index of Sasso and Bovans brown chicken was lower than the finding of Serkalem *et al*. (2019), who reported that the overall mean value of yolk index values was 40.7±4.7 for Bovans brown and 40.2±3.9 for Sasso chicken in the midland agroecologies of Boricha district, Sidama zone, southern Ethiopia.

A higher value of the Haugh unit is a good indicator of better egg quality. Fresh eggs should have a Haugh Unit of 72–110 (Stadelman and Cotterill, 2007). The average value of Haugh units recorded from Sasso chicken (85.7±0.91) and Bovans brown chicken (84.8±0.94) in the study area. The haugh unit values were not significantly different ($P > 0.05$) between Bovans brown and Sasso chicken breeds.

The Haugh units are significantly highest in the highland agroecology and lowest in the midland agroecology. The overall mean percentage value of the Haugh unit score in highland agroecology (88.9±0.95) was significantly higher than the value recorded in midland (82.0±0.89) agroecology of the study district. A significant difference was observed ($P<0.05$) between the two agroecologies and their interaction. This variation in the Haugh unit could be attributed to differences in management practices or environmental conditions between the midland and highland agroecologies of the study areas. This finding is similar to the result of Serkalem *et al*. (2023), who reported that the mean value of the Haugh unit of Sasso chicken was 85.6 ± 5.4 and 78.8 ± 6.4 in the Highland and midland agro-ecologies of Silte Zone, Southern Ethiopia, respectively. The current finding is higher than the study result of Serkalem *et al*. (2019), who reported that the mean values of Haugh units of Bovans brown and Sasso chicken were (78.5) and (78.4) in the midland agro-ecologies of Boricha district, Sidama Zone, southern Ethiopia. A higher value of the Haugh unit was recorded in a study area. Therefore, higher Haugh units mean better egg quality. This result indicated that the higher Haugh unit may be due to the freshness of eggs and the young age of hens in the study district.

Table 16. Effects of agro-ecology, chicken breed and their interaction on internal egg quality (Mean±SE)

Internal egg quality traits	Breed		Agro-ecologies		p-value		
	Sasso	Bovans brown	Midland	Highland	B	AE	B x AE
Albumin weight (g)	40.2^{a}±0.51	36.8^{b}±0.52	39.3^{a}±0.5	36.7^{b}±0.53	0.0001	0.0001	0.9874
Albumen height (mm)	7.5±0.15	7.2±0.15	6.9^{a}±0.146	7.9^{b}±0.154	0.6425	0.0001	0.0149
Yolk weight (gm)	17.98^{a}±0.29	15.42^{b}±0.29	18.02^{a}±0.29	15.32^{b}±0.30	0.0001	0.0001	0.0662
Yolk height (mm)	14.1±0.12	14.3±0.124	14^{a}±0.12	13.93^{b}±0.13	0.2252	0.0101	0.1049
Yolk diameter (mm)	40.9±0.29	40.3±0.3	41^{b}±0.28	40.2^{a}±0.29	0.1335	0.0420	0.9310
Yolk index (%)	34.5±0.40	35.7±0.42	35.3±0.40	34.8±0.42	0.0509	0.5633	0.2187
Haugh unit	85.7±0.91	84.8±0.94	82^{a}±0.89	88.9^{b}±0.95	0.9553	0.0001	0.0143

Note: $^{a-b}$ Means with different superscript letters within a row are significantly different (P<0.05), B = Breed, AE = Agro ecology, B x AE = the interaction of Breed and Agro ecology.

The mean values of the yolk color count are presented in Table 19. The logistic regression results for yolk color showed statistically significant differences (pr>χ^2 <.0060 and pr>χ2 <.0021) between agroecology and breeds, respectively, with a Wald chiSq value of 7.56 among agroecology and 9.46 among the breeds.

The mean values of yolk color count for this study were 9.39±0.44 and 10.4±0.42 in highland and midland agroecologies, respectively. The yolk color shows a statistically significant difference (P<0.05) between the two agroecologies of the study district. This indicates that the variation might be due to the availability of grain feed resources for scavenging and better improvement in the husbandry practices of chicken producers in the midland than in the highland of the study area. The average result of yolk color value was 9.28±0.29 and 10.54±0.31 for Bovans brown and Sasso breeds, respectively, with a statistically significant difference (P<0.05) between the two breeds. This result shows that the yolk color values of Sasso chicken breeds are higher than the yolk color of Bovan brown hens. This might be due to a feed quality difference. Green grass during scavenging might be responsible for carotenoid deposits in the yolk, which improves the color. The yolk color during laboratory analysis ranged from 5 to 15. The lower yolk color might be due to chicken feed or household leftover feed. Whereas the high yolk color (deep yellow) was due to the chicken being fed green plant and grain feed.

Table 17. Effect of agro-ecology and breed on yolk color by logistic regression (Mean±SE)

	Agro-ecology				Breed			
Parameter	Highland	Midland	Wald Chi-Square	Pr > ChiSq	Bovans Brown	Sasso	Wald Chi-Square	Pr > ChiSq
Yolk color	9.39[a]±0.44	10.4[b]±0.42	7.56	<.0060*	9.28[a]±0.29	10.54[b]±0.31	9.46	<.0021*

Note: [a-b] Means with different superscript letters within a row are significantly different (P<0.05), SE=Standard Error, * = significant.

The egg yolk color of both Sasso and Bovans brown chicken reared in the study areas corresponds to the findings of Serkalem et al. (2019), who stated that in the midland agroecologies of Boricha District, Southern Ethiopia, the egg yolk color of Sasso chicken was 10.4±1.7 and that of Bovans brown chicken was 10.3±1.7. This showed that Sasso chicken breeds had greater yolk color values than Bovan brown chickens; this could be because of variations in feed quality. The current study findings higher than those of Yonas et al. (2019), who reported that the average yolk color of Sasso chicken was 9.36±1.83 and 9.24±1.67 and Bovans brown chicken was 7.66±1.49 and 7.26±1.21 in Yirgalem and Hawasa towns, Ethiopia, respectively. This might be due to the types of feed consumed.

5. SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. Summary and Conclusions

This study was conducted with the overall objective of assessing husbandry practices and evaluating the productive performance and egg quality of Bovans Brown and Sasso chicken in Doba District, West Hararghe Zone, Oromia Region, Ethiopia. The study was thus composed of a survey and egg quality examination of Bovans Brown and Sasso chickens in the highland and midland agroecologies of the study area. For the survey, a total of 160 households with better chicken-producing practices were selected purposively and interviewed using semi-structured questionnaires. For the evaluation of egg quality traits, a total sample of 160 freshly laid eggs containing eggs from Sasso and Bovans Brown chickens was collected and evaluated at the Haramaya University poultry laboratory. SPSS version 21 and JMP® pro version 17 (SAS Institute, 2023) were statistical software tools used to analyze the data.

The majority (62.5%) of respondents were found in the age group of 31–40 years, which implies that the respondents were in an active productive age group and participated in chicken production. Most chicken rearing in the highland and midland agro-ecologies of the study area is highly undertaken by females (78.8%). The main purposes of keeping chickens in the study area were for an immediate source of cash (income generation), followed by egg production. The majority (91.9%) of the chicken production system were extensive or scavenging production systems in the highland and midland agroecologies of the study area.

According to the results of this study, all of the chicken owners (100%) in the highland and midland agro-ecologies of the study area provide supplementary feed and water to their chickens. The result indicated that all of the chicken owners in both agro-ecologies of the study district have experience of giving supplementary feed to enhance production and productivity for their chickens. Cereal grains like maize, sorghum, and wheat were the major types of supplementary feed given to chickens. The majority of chicken owners (65.6%) provided supplementary feed for their chickens by spreading it on the floor as a mode of provision.

The majority of 81.9% of the chicken owners in the study area did not have separate chicken houses, and most of them shared their main houses with their chickens during the night. The study area's focus group discussion suggested that the main causes of the absence of a separate chicken house were lack of awareness, risk of predators, lack of attention, and lack of construction materials and financial resources to establish their own chicken house. The result showed that the major chicken disease was Newcastle disease, followed by Coccidiosis diseases, which are diseases of economic importance that hinder the expansion of chicken production in the highland and midland agroecologies of the study area. The majority of respondents (66.9%) used traditional treatments or medicines for the treatment of sick chickens.

The current results indicate that the majority of respondents did not vaccinate their chickens in the study area. The vaccination of chickens has been very poor as one of the methods of disease control due to a lack of vaccines and a lack of awareness. The result of the study revealed that the prevalence of disease outbreaks (mainly Newcastle disease), followed by predators, inadequate veterinary services, chicken housing problems, a shortage of supplementary feed, and poor extension services were the major constraints to the production of Bovans Brown and Sasso chickens in the highland and midland agro-ecologies of the study area. In general, there is poor housing, feeding, and vaccination systems for chickens in the study area.

Concerning chicken productivity a significant difference ($P < 0.05$) was observed between the two agro-ecologies and chicken breed; however, there was no significant difference ($p > 0.05$) between the interaction of agro-ecologies and chicken breeds in terms of the pullet's age at first egg and the total number of eggs produced per week and per year with higher results in midland agro ecology than in the highland agroecology of the study area. This indicates that the Bovans Brown breed performs better than the Sasso breed in terms of egg production and also Bovans Brown reach an earlier age at first egg laying than Sasso breeds. The average mean for female body weights of Sasso and Bovans brown chickens at greater than 20 weeks of age is higher in the midlands, and the Sasso chickens performed higher body weights than Bovans brown chickens.

The results showed that egg quality traits with a significant difference ($P<0.05$) between the two agro-ecologies in terms of egg weight, egg length, shell weight, shell thickness, yolk weight, yolk color, yolk height, yolk diameter, and albumen weight of eggs collected from midland were higher than those of eggs from highland. However, the highest values for albumen height and Haugh unit were observed on eggs collected from highland. There was a significant difference ($P<0.05$) between eggs collected from the Sasso breed with higher values than Bovans brown eggs in terms of egg weight, egg width, shell weight, egg length, albumin weight, yolk color, and yolk weight. The interaction of agroecology and chicken breed has an effect on shell weight, Haugh unit, and albumen height. In general, both the Sasso and Bovans Brown breeds perform better in midland than in highland agro-ecologies in terms of egg production, body weights, and the majority of egg quality traits. This suggests that there is variation between the two agro-ecologies, which may be due to differences in the environmental conditions, the availability of feed resources, and management practices followed by households in the study area.

5.2. Recommendations

Based on the above conclusions, the following improvement options are recommended:

- Provision of proper training to chicken producers on husbandry practices could be important to improve the awareness of chicken producers
- Therefore, it is strongly recommended to implement appropriate interventions in disease and predator control measures, and improving chicken husbandry practices should focus on improving ways of feeding, housing, watering, and vaccinating chickens to improve overall chicken productivity
- Finally, to improve overall egg quality traits, attention should be paid to the adequate quality of feed and feeding system.

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7. APPENDICES

7.1. Appendix A. Sample Questionnaires

Semi-structured questionnaire on the title; Evaluation of Chicken production Practice, Performance and Egg Quality of Bovans Brown and Sasso Chickens in Doba District, West Hararghe Zone, Oromia Region, Ethiopia

Name of Enumerator ______________________ Date ________Code no_______

Sign______Woreda ______________________ Kebele____________________

I. Survey of Chicken Production practices

A. Household Characteristics

1. Name of respondent ____

2. Sex of respondent: 1. Male 2. Female

3. Age of respondent _____ years 1) < 20, 2) 20-30, 3) 31-40, 4) 41-50, 5) > 50

4. Agro-ecology: 1. Highland 2. Midland

5. Family size/household: 1. Male______2. Female______3. Total______

6. Marital status of the respondent: 1) Married 2) Single 3) Divorced 4) Widowed

7. Educational background of a respondent: 1) Illiterate 2) From 1-4 Grades 3) From 5-8 Grades 4) Secondary school (9-12) 5) Colleges and above

B. Socio-economic characteristics of the household

1. Total land Size owned /household _____ Hectare (ha).

2. Livestock holding of the household/respondent

Category						
Sheep	Goats	Cattle	Donkeys	Chickens	Horses	Mules

C. Chicken Breeds Adopted

1. What types of exotic chicken breeds do you keep? 1) Sasso chicken 2) Bovans Brown chicken

2. What is the source of your exotic breed chicken? 1) Purchased from market 2) From NGO (World vision) 3) From Ethio-chicken

3. Purpose of keeping chicken in order of importance (Rank index). 1) For Sale (for income generation 2) for egg production 3) For home consumption

D. Chicken Housing Condition

1. What type of production systems do you practice for your chicken rising? 1) Extensive 2) Semi-intensive

2. Do you have separate chicken house (other than family dwellings)? 1) Yes 2) No

3. If No for Question 2 above, what are the reasons for absence of separate chicken house? 1) Lack of awareness 2) Lack of attention 3) Risk of predators 4) Lack of construction materials and financial resources

4. If your answer to question 2 is No, where do your exotic chickens stay at night? 1) In the kitchen 2) Family dwellings 3) in the basket/suck 4) others, specify____________________

E. Chicken Feed and Feeding System

1. What type of chicken feeding system do you practice? 1) Scavenging only 2) Scavenging with supplementation

2. Do you provide supplementary feed for your chickens? 1) Yes 2) No

3. If yes in Q.2, specify the type of supplements? 1) Maize and Sorghum 2) Sorghum and Wheat 3) Maize and Wheat 4), Maize, Sorghum and Wheat 5) Maize, wheat, sorghum, wheat bran, household leftovers and others (mention) ____________________

4. If yes in Q.2, where is the source of your grain feeds? 1) Purchased from market 2) From their own farm/crop harvest 3) Crop harvest and purchase

5. If yes for Q.2 above, what is the frequency of your supplemental feeding? 1) Once a day 2) Twice a day 3) Three times a day 4) Ad libitum/free access

6. What is your mode of provision for Supplementary feeding of your chicken? 1) By feeder 2) Spreading on the floor 3) other (specify) _______________

7. Do you have feeding trough for your chickens? 1. Yes 2. No

8. If yes, which type of feeding trough do you have from the following? 1) Plastic made 2) Metal made material

F. Source of water and Watering System

1. Do you provide water for your chickens? 1. Yes 2. No

2. If yes for Q.1, What is the source of water? 1) Spring 2) Tap water 3) Pond water

3. Do you have watering trough for your chickens? 1. Yes 2. No

4. If yes, which type of watering trough do you have from the following? 1) Plastic made 2) Locally made wooden trough 3) Metal made material 4) Others__________________

5. How frequent do you provide water? 1) Once a day 2) Twice a day 3) Three times a day 4) Ad libitum

G. Chicken Disease and Health Care practices

1. Is there any chicken diseases in your area? 1. Yes 2. No

2. If yes, what is the most prevalent diseases affecting chicken in the area? 1) Newcastle disease (Fengil) 2) Coccidiosis 3) External parasites 4) Fowl typhoid

3. Do you ever seen/observe sick chickens in your flock? 1. Yes 2. No

4. If your answer for Q3 is yes, what is your immediate measure when you observe sick chickens in your flock? (1) Treat them by myself (2) Call in veterinarian/take to veterinarian (3) Call in development agents (4) Slaughter them all immediately for home Consumption (5) Sell them all immediately(6) Isolation (7) Leaving with the flock

5. What Control measures do you use? 1) Traditional method 2) treatment 3) No control measure

6. If you say traditional method, what type of traditional control measures (Indigenous knowledge) you used to prevent the prevalence of diseases? 1.___________2.____________3.______________4.______________

7. Do you practice annual vaccination for your chicken? 1. Yes 2. No

8. If no, what is the reason? 1) No information 2) Lack of vaccine 3) Lack of attention 4) Others
9. If yes, against which diseases do you vaccinate your chicken? 1) Newcastle disease (fengil) 2) Coccidiosis 3) External parasites 4) Fowl typhoid

10. Is there any predator problem in your locality? 1) Yes 2) No

13. If yes, what are the major predators (wild and domestic animal attacking chicken) in your area? 1) ___________2) ___________3) ____________4) ___________ 5) ____________

14. What are the major causes of chicken losses? 1) Diseases 2) Predators 3) Others

H. Ranking of the major constraints of chicken production

1. Prevalence of disease

2. Shortage of feeds

3. Attacks of predators

4. Lack of housing

5. Inadequate veterinary services

6. Poor extension services about chicken husbandry practices

7. Any other, if any____

I. Performance Parameters Recording Format

A. production performance of Sasso and Bovans Brown Chicken

Exotic Chicken breed type	Age at first mating (month)	Age at first egg laying (weeks)	number of eggs laid per hen/week	Total number of eggs laid per hen/year
Bovans Brown				
Sasso				

b. The mature body weight of chicken

No.	Category	Live weight (Kg) according to breed type	
		Bovans Brown	Sasso
1	Laying hen (>20 weeks) (Kg)		

II. Laboratory Egg quality parameters data collection sheet

No.	Egg quality traits	Chicken types	
		Bovans Brown	Sasso
A	External egg quality parameter		
1	Egg weight (g)		
2	egg shell weight (g)		
3	Egg length (mm),		
4	egg width (mm)		
5	Shell thickness (mm)		
6	Egg shape index (%)		
B	Internal egg quality parameters		
1	Yolk height, (mm)		
2	Albumin height (mm)		
3	Yolk weight (g)		
4	Yolk color (1-15)		
5	Albumin weight (g)		
6	Haugh Unit		
7	Yolk index (%)		
8	yolk diameter		

7.2. Appendix B. List of ANOVA Tables

Appendix Table 1. Effect of agro ecology, chicken breed and their interaction on average age at first egg of Sasso and Bovan brown chicken in Doba district.

Source of variation	DF	Sum of Squares	Mean Square	F Ratio	Prob>F
Agro-ecology	1	1.7304803	1.7304803	23.0231	<.0001*
Breed	1	5.6144027	5.6144027	74.6967	<.0001*
Agro-ecology*Breed	1	0.0957278	0.0957278	1.2736	0.2608^{ns}
Error	156	11.725382	0.07516		
Corrected Total	159	19.849750			

Appendix Table 2. Effect of agro ecology, chicken breed and their interaction on average egg production per /hen/year of Sasso and Bovan brown chicken in Doba district.

Source of variation	DF	Sum of Squares	Mean Square	F Ratio	Prob>F
Agro-ecology	1	4568.334	4568.334	25.5198	<.0001*
Breed	1	16614.405	16614.405	92.8120	<.0001*
Agro-ecology*Breed	1	76.736	76.736	0.4287	0.5136^{ns}
Error	156	27925.765	179.01		
Corrected Total	159	51169.744			

Appendix Table 3. Mature body weight of Sasso and Bovans brown chickens in the study areas (Mean ± SE)

Source of variation	DF	Sum of Squares	Mean Square	F Ratio	Prob>F
Agro-ecology	1	2.1085797	2.1085797	32.0300	<.0001*
Breed	1	3.7795794	3.7795794	57.4130	<.0001*
Error	156	10.269693	0.06583		
Corrected Total	159	15.651000			

Appendix Table 4. Effect of agro ecology, breed and their interaction on egg weight of Sasso and Bovans brown chickens in Doba District.

Source of variation	DF	Sum of Squares	Mean Square	F Ratio	Prob>F
Agro-ecology	1	125.87530	125.87530	8.7698	0.0035*
Breed	1	185.97650	185.97650	12.9571	0.0004*
Agro-ecology*Breed	1	5.85202	5.85202	0.4077	0.5241ns
Error	156	2239.1068	14.3532		
Corrected Total	159	2524.2438			

Appendix Table 5. Effect of agro ecology, breed and their interaction on shell weight of Sasso and Bovans brown chickens in Doba District.

Source of variation	DF	Sum of Squares	Mean Square	F Ratio	Prob>F
Agro-ecology	1	118.63950	118.63950	64.2139	<.0001*
Breed	1	55.72502	55.72502	30.1613	<.0001*
Agro-ecology*Breed	1	8.62852	8.62852	4.6702	0.0322*
Error	156	288.22039	1.8476		
Corrected Total	159	460.97500			

Appendix Table 6. Effect of agro ecology, breed and their interaction on shell thickness of Sasso and Bovans brown chickens in Doba District.

Source of variation	DF	Sum of Squares	Mean Square	F Ratio	Prob>F
Agro-ecology	1	0.00735177	0.00735177	5.5018	0.0203*
Breed	1	0.00373923	0.00373923	2.7983	0.0964^{ns}
Agro-ecology*Breed	1	0.00004664	0.00004664	0.0349	0.8520^{ns}
Error	156	0.20845497	0.001336		
Corrected Total	159	0.22079750			

Appendix Table 7. Effect of agro ecology, breed and their interaction on egg shape index of Sasso and Bovans brown chickens in Doba District.

Source of variation	DF	Sum of Squares	Mean Square	F Ratio	Prob>F
Agro-ecology	1	0.002487	0.002487	0.0001	0.9928^{ns}
Breed	1	10.202669	10.202669	0.3359	0.5630^{ns}
Agro-ecology*Breed	1	86.190106	86.190106	2.8380	0.0941^{ns}
Error	156	4737.7199	30.3700		
Corrected Total	159	4831.3865			

Appendix Table 8. Effect of agro ecology, breed and their interaction on albumin height of Sasso and Bovans brown chickens in Doba District.

Source of variation	DF	Sum of Squares	Mean Square	F Ratio	Prob>F
Agro-ecology	1	43.011134	43.011134	24.1400	<.0001*
Breed	1	0.385364	0.385364	0.2163	0.6425^{ns}
Agro-ecology*Breed	1	10.803152	10.803152	6.0633	0.0149*
Error	156	277.95076	1.7817		
Corrected Total	159	332.44400			

Appendix Table 9. Effect of agro ecology, breed and their interaction on albumin weight of Sasso and Bovans brown chickens in Doba District.

Source of variation	DF	Sum of Squares	Mean Square	F Ratio	Prob>F
Agro-ecology	1	0.00735177	0.00735177	5.5018	0.0203*
Breed	1	0.00373923	0.00373923	2.7983	0.0964^{ns}
Agro-ecology*Breed	1	0.00004664	0.00004664	0.0349	0.8520^{ns}
Error	156	3266.3566	20.938		
Corrected Total	159	4400.2438			

Appendix Table 10. Effect of agro ecology, breed and their interaction on egg yolk height of Sasso and Bovans brown chickens in Doba District.

Source of variation	DF	Sum of Squares	Mean Square	F Ratio	Prob>F
Agro-ecology	1	7.9550540	7.9550540	6.7852	0.0101*
Breed	1	1.7385118	1.7385118	1.4829	0.2252^{ns}
Agro-ecology*Breed	1	3.1193984	3.1193984	2.6607	0.1049^{ns}
Error	156	182.89575	1.17241		
Corrected Total	159	196.65694			

Appendix Table 11. Effect of agro ecology, breed and their interaction on egg yolk weight of Sasso and Bovans brown chickens in Doba District.

Source of variation	DF	Sum of Squares	Mean Square	F Ratio	Prob>F
Agro-ecology	1	348.29364	348.29364	51.2792	<.0001*
Breed	1	314.85479	314.85479	46.3560	<.0001*
Agro-ecology*Breed	1	23.24323	23.24323	3.4221	0.0662^{ns}
Error	156	1059.5673	6.792		
Corrected Total	159	1700.9750			

Appendix Table 12. Effect of agro ecology, breed and their interaction on Haugh unit of Sasso and Bovans brown chickens in Doba District.

Source of variation	DF	Sum of Squares	Mean Square	F Ratio	Prob>F
Agro-ecology	1	1930.4236	1930.4236	28.6576	<.0001*
Breed	1	0.2126	0.2126	0.0032	0.9553^{ns}
Agro-ecology*Breed	1	413.6639	413.6639	6.1409	0.0143*
Error	156	10508.408	67.362		
Corrected Total	159	12827.737			

Appendix Table 13. Effect of agro ecology, breed and their interaction on yolk diameter of Sasso and Bovans brown chickens in Doba District.

Source of variation	DF	Sum of Squares	Mean Square	F Ratio	Prob>F
Agro-ecology	1	27.970145	27.970145	4.2049	0.0420*
Breed	1	15.131063	15.131063	2.2747	0.1335^{ns}
Agro-ecology*Breed	1	0.050093	0.050093	0.0075	0.9310^{ns}
Error	156	1037.6809	6.6518		
Corrected Total	159	1076.9750			

7.3. Appendix C. List of Sample Figures

Appendix Figure 1. Spreading way of chicken supplementation with cereal grains in study area.

Appendix Figure 2. Sample chicken feeding and watering practices with feeder and waterer in the Doba District.

 

Appendix Figure 3. Sample mature body weight of Sasso and Bovan brown chicken measurement in study area.

 

Appendix Figure 4. Measurement of egg weight and egg shell weight in the egg quality laboratory by using digital balance.

Appendix Figure 5. Measurement of egg albumin and yolk height in the egg quality laboratory.

Appendix Figure 6. Sample figure for measurement of egg yolk length, yolk width, albumin length, and albumin width in the egg quality laboratory.


Appendix Figure 7. Sample figure for measurement of egg albumin and yolk weight in the egg quality laboratory.


Appendix Figure 8. Measurement of egg shell thickness in the egg quality laboratory.