

**MANAGEMENT PRACTICES AND CONSTRAINTS OF COMMERCIAL
POULTRY FARMS, AND PERFORMANCE EVALUATION OF SASSO-C44
BROILERS FED ON DIETS CONTAINING GRADED LEVEL DRIED BLOOD
RUMEN-CONTENT MIXTURE**

BY

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I declare that the above thesis is my own work and that all the sources that I used or quoted have been indicated and acknowledged by means of complete references.

I further declare that I submitted the thesis to originality checking software and it falls within the accepted requirements for originality.

I further declare that I have not previously submitted this work, or part of it, for examination at University of South Africa for another qualification or at any other higher education institution.



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DEDICATION

This dissertation is lovingly dedicated to my wife, Jitu Kena, whose unwavering support has been the foundation of my academic journey. Your belief in my abilities, especially during moments when my own confidence wavered, gave me the strength to persevere. You stood beside me with patience, encouragement, and quiet reassurance, reminding me that every challenge was surmountable.

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This accomplishment is not mine alone; it is ours. I am endlessly grateful for the partnership we share, for your unshakeable faith in my path, and for the joy you bring into my life. May this work stand as a testament to the power of love, teamwork, and shared purpose. Thank you, Jitu, for walking every step of this journey with me.

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ABSTRACT

This study was employed to assess the management practices and constraints of commercial poultry farms, and performance evaluation of Sasso-C44 broilers fed on diets containing graded level dried rumen-content mixture. Data on farm management was collected using a semi-structured questionnaire survey substantiated with a focus group discussion, and field observations. Data on management variables were processed using SPSS version 29, and Garret's ranking technique. Two hundred day-old Sasso C44 broiler chicks were placed randomly to five dietary treatments for the experimental study using a completely randomized design (CRD). Experimental rations during both the starter age (1–28 days) and finisher (29–56 days) were: T1, T2, T3, T4 and T5. The experimental treatments consisted five dietary groups formulated by replacing roasted soybean meal (RSBM) with dried blood rumen-content Mixture (DBRCM) at different levels. Data were analyzed using SAS version 9.2. Intensive production systems account for 94.5% of the farms, and deep-litter housing management account for 73.1% of the farms studied. Average flock size per farm in the study area was 734 birds, and Bovan Brown chicken-breed were the dominant breed identified in this study. The disease prevalence assessments revealed a ruffled feathers (13.5%), loss of appetite (11.5%), and depression (11.5%), followed by weight loss (9.6%) and diarrhea (7.7%). Producers largely blamed management gaps (44.2%) or environmental factors (34.6%) with 21.2% citing a combination of both the primary drivers of outbreaks. Vaccination efforts focused mainly on fowl pox (51.9%) and Newcastle disease (40.4%), while fewer farms vaccinated against infectious bursal disease (7.7%); vaccination schedules typically followed recommendations from the chicks' source farms. On the biosecurity front, most producers adopted basic protective measures: Accordingly, 73.1% used protective clothing, plastic boots, and hair covers, 30.4% of producers were using gloves, and 67.3% were maintaining footbaths at farm entrances. The standard vaccination schedule used were IBD vaccine on day 1, NCD vaccine on day 7, and boosters on days 14, 28, and 42 against other diseases. Feed intake and chicken growth responses varied slightly among treatments that average daily dry matter intake was in the range of 66.38 g at T4 to 71.60 g at T1 and T5; intake in T4 was lower than those at T1, T2, T3, and T5. Daily weight gain ranged from 29.8 to 31.5 g/bird with no significant statistical difference among treatments ($P>0.05$). Feed

conversion ratios ranged between 2.22 and 2.29 and were not different statistically among groups ($P>0.05$). With the conclusion, DBRCM can replace up to 60% soybean meals in both starter and finisher diets for Sasso-C44 broilers with no negative impact on performance and survivability. Carcass evaluation revealed that edible carcass weights were between 1085g and 1178g, and the dressing percentage ranged from 52.3% to 57.79%. Dressing percentage and carcass weights remained comparable across treatments, reinforcing that DBRCM can replace up to 60% of soybean meals with a positive effect on growth performance and carcass quality. The economic analysis clearly indicated that birds under T3 and T4 had higher ($P<0.05$) economic efficiencies than those under T1 and T5. In conclusion replacing RSBM with DBRCM up to a level of 60% in both starter and finisher diets seems to reduce feeding costs and improve economic efficiency due to its free availability and labor affordability without adverse effects on overall performance, feed conversion, or carcass characteristics in Sasso-C44 broilers.

Keywords: *Broilers, Production constraints, dried blood rumen content mixture, management practices*

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LIST OF ABBREVIATIONS AND ACRONYM

ADG	Average Daily Gain
ANOVA	Analysis of Variance
BBRCM	Bovine Blood -Rumen Content Mixture
BW	Body Weight
BWG	Body Weight Gain
CaI	Calcium Intake
CF	Crude Fiber
CFI	Crude Fiber Intake
CP	Crude Protein
CPI	Crude Protein Intake
CRD	Complete Randomized Design
CRD	Chronic Respiratory Diseases
CSA	Central Statistics Agency
DBRCM	Dried Blood-Rumen Content Mixture
DM	Dry Matter
DMI	Dry Matter Intake
DOC	Day Old Chicks
DRC	Dried Rumen Content
EE	Economic Efficiency
EE	Ether Extract
FAO	Food and Agriculture Organization
FBRD	Fermented Bovine Blood and Rumen Digesta
FCR	Feed Conversion Ratio
GLM	General linear Model
HSD	Honesty Significant Difference
IBD	Infectious Bronchitis Disease
IFAD	International Feed and Agriculture Development
ME	Metabolizable Energy
MEI	Metabolizable Energy Intake

NCD	Newcastle Disease
NFE	Nitrogen Free Extract
NGOs	Nongovernment Organizations
NRC	National research council (UK, UK)
NVI	National Veterinary Institute (Ethiopia)
RC	Rumen content
REE	Relative economic efficiency
RSBM	Roasted soybean meal
SAS	Statistical Analysis System
SDRBM	Sun Dried Rumen- Blood Meal
SEM	Standard Error of Mean
SNNP	Southern Nations and Nationalities People
SPSS	Statistical Package for Social Sciences
TEO	Total Edible Offal
TEVT	Technical Educational Vocational Training
TNEO	Total Nonedible Offal

CHAPTER 1

GENERAL INTRODUCTION

1.1 Background

Food security and poverty reduction are central to Ethiopia's development plans, with approximately 23% of its population living below the poverty line (Kassegn and Endris, 2021). Nutritional deficiencies persist largely because food fails to supply sufficient energy and protein. Based on this, Yusuf et al. (2020) reported a daily protein intake of **65 g per person**, of which about **36 g (approximately 55.4%)** should come from foods of animal origin (Bezabih, 2017) was recommended. Poultry production in developing countries like Ethiopia should be strengthened to achieve food self-sufficiency and reduce malnutrition. Poultry products, in general, are compact, affordable sources of high-quality animal protein (Gil et al., 2024).

Poultry plays a major role as a livelihood source and makes a valuable contribution to the national economic development of Ethiopia (Abera Geleta, 2022). Poultry is the source of the most versatile and near-perfect foods which fulfil the need for high-quality protein whose demand in Ethiopia has been rising sharply due to population growth, booming urbanization, and relative improvement of the standard of living. According to a report by Knez et al. (2023), poultry products are important for improving human nutrition. In addition to nutritional benefits, the sector improves household food security and income generation owing to the relatively low capital it requires and a rapid returns it generates, could be especially effective in benefiting vulnerable populations and catalysing local economic growth (Sari., 2024).

The poultry population of Ethiopia is almost entirely composed of indigenous chicken, and recent estimates showed that 78.85%, 12.02%, and 9.11% are indigenous, hybrids, and exotic poultry, respectively. Poultry plays important roles in terms of generating employment opportunities, improving family nutrition, and empowering women (Dessie et al., 2025). Despite such numbers, national production remains low: annual outputs are estimated at only 60,000 tons of poultry meat and 40,000 tons of eggs (Moreki et al., 2025). Currently, a total of 4.3 million broiler day-old chicks (DOCs) were producing a total of 47.9 tons of poultry meat, while 12-million-layer chicks produce around 2.5 billion eggs annually (Management Entity., 2021). As a result, the per-capita consumption is among the world's lowest, with approximately 0.4kg of eggs and 0.6kg of chicken meat consumed per person per year (Erdaw and Beyene, 2022). The commercial poultry industry in Ethiopia is yet to develop and satisfy the ever-increasing demand for poultry and poultry products. Likewise, commercial poultry enterprises are springing up throughout much of Ethiopia, including its peri-urban and urban centers such as those

(Erdaw and Beyene, 2022). However, its contribution to the economy remains minimal, estimated at only 2–3% of the national economy, hampered by several factors, first and foremost among them being the scarcity and cost of feed ingredients (Chanchangi et al., 2023).

Feed constitutes the single major share on the cost of production, generally sharing about 70–75% of the total cost (Meléndez et al., 2022). A reliance on conventional protein sources is not feasible; peanut cake, sesame cake, soybean meal, and fishmeal can be scarce and expensive (Bezabih, 2017). Currently, the main use of soybean in Ethiopia is for oil production, which acts as a constraint to soybean meal used for poultry feed. This development has significant implications regarding the potential uses of soybean meals, which serve as the main ingredient incorporated in poultry feeds owing to its relatively high protein concentration. Reduction in the supplies or availability of soybean, therefore, poses a significant constraint regarding the sustainability of the poultry industry in the country (Mussema et al., 2021). Under such conditions, the use of soybeans as a poultry feed ingredient was bouncing between the oil industries and poultry feed producers. High prices for conventional protein sources are depressing productivity in many farms and restricting the population's access to animal protein sources (Berbenets, 2020). This trend has created the urge for nutritionists and specialists to find nutritionally adequate, low-cost, and locally available non-conventional feedstuffs, particularly those not consumed by humans, that can replace scarce and expensive ingredients in poultry diets. In Ethiopia, roasted soybean meal (RSBM), prepared by roasting whole soybeans, is commonly used as a protein source in poultry diets rather than soybean cake, the by-product obtained after oil extraction. However, due to its increasing cost and limited availability, alternative protein sources such as a mixture of dried bovine blood and rumen contents have been considered as partial replacements for RSBM (Beriso, 2024). Bovine blood–rumen content mixture (BBRCM) is an abattoir by-product that has very good prospects for use as a cheap, locally available animal protein source in poultry diets (Bezabih et al., 2017). It is essentially free or less-costing, reduces feed cost, and minimizes pollution problems from slaughterhouse waste when well-processed to ensure safety and quality (Ntawubizi et al., 2020). Abattoirs produce, appreciable solid wastes and effluents in the form of rumen contents, slaughterhouse-blood, and washing water, which are presently grossly underutilized (Terna et al., 2024).

Using national cattle statistics (Aleme and Ali 2022) and typical off-take and yield estimates, the scale of by-product utilization is substantial. With a cattle population of approximately 70 million and an off-take rate near 7% (CSA, 2025) about 3.8 million cattle are slaughtered each year. Rumen contents yield about 2.7–3.5 kg dry matter per head (Bezabih, 2017), and blood output averages 3–4% of live body weight (Sun et al., 2020). Taken together, these figures translate into roughly 133,000 quintals (DM) of rumen content and about 38 million liters of blood annually (Yitbarek et al., 2016) During blood fractionation, approximately 60% plasma (8% solids) and 40% corpuscles (38% solids) are produced (Bezabih et al.,

2017). From 100 kg of whole blood, about 4.8 kg of plasma powder and 15.2 kg of corpuscle powder are recoverable according to Bezabih et al. (2018) Extrapolating from 38 million liters of blood, Ethiopia have a potential to produce around 76,000 quintals of blood meal per year(Yitbarek 2016) . If a quintal of dried rumen content and blood meal sells for 300 and 800 Ethiopian Birr respectively, the annual value from these by-products could reach roughly 39.9 million Birr (rumen content) and 60.8 million Birr (blood meal) a combined economic opportunity of about 100.7 million Birr that is currently lost when these wastes are discarded (Bezabih, 2017).

Similarly, Dambi Dollo's municipality abattoirs process an estimated 55,000 cattle annually, yielding approximately 16,500 kg of dried rumen material and 55,000 liters of blood (about 11,000 kg of blood meal), assuming an average carcass weight of 250 kg (Ali et al., 2022)Currently, most of this material is not recycled into animal feeds but is considered waste, thus posing a challenge in its management and creating environmental disturbance in the form of odors, flies, poor hygiene, and risks to surface and groundwater through pathogen and pollutant runoff (Dabas, 2025). In Ethiopia in general, and around Dambi Dollo in particular, very little effort has been made to valorize these abattoir wastes into ingredients for broiler diets (Bezabih, 2017). The economic and environmental rationale behind the conversion of rumen content and blood into poultry feed-to reduce feed costs while improving waste management-necessitates revisiting these by-products as protein sources that can replace roasted soybean meal in broiler rations (Gaffield et al., 2024).

Overall, there was a limited information on management practices and the principal constraints affecting commercial poultry farms in and around Dambi Dollo town (Shuma et al., 2025). Such information is especially important when designing specific interventions for raising productivity in efficient and sustainable ways that contribute to national food security.

1.2. Problem Statement

The poultry sector in Ethiopia plays an important role in improving household income and food security. Modern poultry production in the country traces its roots to the efforts of colleges and research centers that introduced exotic breeds and provided technical guidance on husbandry, nutrition, housing, and disease control (Alemneh, 2019). Although both indigenous and exotic dual-purpose chickens are well adapted to rural livelihoods because of their scavenging characteristics, commercial poultry production has been reported for their better performance in the urban and peri-urban areas (Tenza et al., 2024). However, in western Ethiopia, particularly in and around Dembi-Dollo, poultry production remains mainly traditional even though small-scale commercial poultry production is being employed. The traditional and local breed based poultry production is characterized by low productivity, high mortality, disease prevalence, predation, poor genetic performance, and inadequate management practices.

Commercial poultry production In Ethiopia, relies solely on purchasing commercial feed, with protein sources mainly roasted soybean meal (RSBM) constituting a major component of the ration. However, soybean is getting costly and scarce on the market due to its high demand for edible oil production, human nutrition, and industrial feed processing (Raghunath, 2024). This challenge made the cost of commercial poultry feed sky rocketing and it is more worsen in areas like Dembi-Dollo, where no commercial feed mills are found. The commercial feed plants in Ethiopia are concentrated around Addis Ababa, located approximately 700 km away from Dembi-dDollo. The long distance substantially increases feed costs and limits access to quality poultry feed, thereby reducing profitability for poultry producers.

To address these challenges, there is a need to explore alternative, affordable, and locally available non-conventional protein source feed ingredients. One of the promising alternatives is a dried bovine blood–rumen content mixture (DBBRCM), an abattoir by-product composed of blood and rumen-digesta. These slaughterhouse by-products are widely available, underutilized, and avoid an environmental disposal challenge and is a nutritional opportunity if properly utilized. The mixture has the potential to partially replace expensive soybean meal in poultry diets. In the Dembidollo city and its surrounding, poultry producers are practicing production of dual purpose and scavenging chicken for meat-chicken production. These poultry breeds are slow growing in their character and are not profitable. A limited information on the utilization alternative diets for poultry and production of fast growing Sasso-C44 broilers in the area was the major purpose of the present study. Therefore, this study was designed to evaluate the effect of replacing roasted soybean meal with dried bovine blood–rumen content mixture on growth performance, carcass characteristics, and economic efficiency of Sasso-C44 broiler chickens under the conditions of Dembi-Dollo, western Ethiopia.

1.3. Rationale and Novelty of the Study

1. This study investigated the use of dried blood–rumen meal as a supplementary feedstuff for broilers, applied either as a partial substitute of conventional ingredients. While blood and rumen contents have each been considered separately in animal feeds, their combined use as a single composite ingredient was uncommon and represented an innovative approach in contemporary broiler nutrition.
2. Focuses on Economic Efficiency: The present study, while it was not exactly about health performance or growth alone, it focused on a comprehensive economic study concerning the cost-effectiveness of blood-rumen meals. Thus, the practicality for poultry farmers is to understand some cheaply available feed ingredients.
3. Application to Sasso-C44 Broilers: SASSO C44 is a meat chicken with the taste of a local chicken. Grows bigger than local chicken and matures quicker than local chicken. SASSO-C44 broilers were

selected in this study due to their potential environmental adaptability and fast growing genetic potential selected as a suitable alternative for semi-intensive production systems. The outcome of this study will hence be very important in optimizing feed strategy and optimum utilization of Sasso C44.

4. Sustainability aspect: Blood-rumen meals are a waste or by-product of beef-processing industry. In this regard, the use of such products falls in line with sustainable production by reducing waste and increasing resources'

The rationale of this study in general stems from the need to identify effective management practices that can enhance the performance of small-scale poultry operations. By examining the specific constraints faced by commercial poultry production such as limited access to resources, knowledge gap about best practices and environmental factors, the study aimed to provide insights that could inform better management strategies. Additionally, understanding how dietary components, such as dried blood-rumen content mixtures, may positively affect broiler performance is essential for optimizing feed formulations that are both cost-effective and nutritionally adequate.

Justification of the Study

There is a need to improve poultry production, food security, and income generation in Ethiopia, where high feed costs and the limited availability of soybean meal constrain poultry productivity. The challenge is more severe in areas such as Dembi-Dollo due to its high transportation costs and limited access to quality feed resources. Large quantities of bovine blood and rumen contents produced in the area from abattoirs is underutilized and negatively contribute to the environmental pollution. Therefore, evaluating dried bovine blood–rumen content mixture (DBBRCM) as an alternative protein source that could reduce feed costs, improve poultry production, enhance resource utilization, and minimize abattoir waste disposal problems.

1.4. General objective

The principal objective of this study is to assess Management Practices and Constraints of Commercial Poultry Farms, and Performance Evaluation of Sasso-C44 Broilers Fed on Diets Containing Graded Level Dried Blood Rumen-Content Mixture

1.5. Specific bjectives

The objectives of this study were to:

- i. examine the management practices and commercial poultry farms in and around Dambi Dollo town.

- ii. Assessment of the Graded Level Dried Blood–Rumen Content Mixture as a Substitute of Soybean Meal on Feed Utilization, Growth Performance, and Chick Survival of SASSO C44 Broiler Chickens
- iii. Investigating the effect of feeding varying levels of dried blood–rumen content mixture (DBBRCM) on feed intake, body weight gain, and carcass characteristics of Sasso C44 broilers.
- iv. Evaluate the economic viability of Sasso C44 broiler production using diets supplemented with graded levels of dried blood–rumen content mixture as a substitute for conventional feed ingredients.

1.6. Delimitation of the Study

The present study was limited to a specific study area and focused on management practices and constraints of commercial poultry farms, and performance evaluation of Sasso-C44 broilers fed on diets containing graded level dried blood rumen-content mixture. The assessment on chicken management practices was held based on a cross-sectional survey, in which the situation was recorded. Only five dietary treatments and a fixed 1:1 blood-to-rumen-content ratio were used, and the replacement levels were limited to a maximum of 60% during the chick starter and the finisher phases. Other broiler breeds, alternative mixture ratios, and different management environments were not included in the experimental study. Therefore, the present conclusions with respect to chicken breed were applied principally to Sasso C44 broilers raised under similar conditions and may require further validation before generalizing to other production systems or poultry classes.

1.7. Thesis Organization

This thesis is organized into ten self-contained chapters, beginning with a general introduction in Chapter 1. Chapters 2 and 3 of the thesis consist independent review papers that collectively form a comprehensive literature review. Chapters 4 through chapter 9 presents survey findings and experimental studies, that all are structured to a publishable article. The document concludes overarching conclusions and recommendations for future research in Chapter 10.

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CHAPTER 2

Commercial Poultry Farming Management: A Review

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Abstract

Commercial poultry production in Ethiopia has expanded in recent years, thereby improving food and nutrition security, income generation, and economic growth. This review critically evaluates management practices in commercial poultry production systems in Ethiopia and their influence on productivity and sustainability. The review is based on a comprehensive analysis of published journal articles, policy reports, and relevant grey literature focusing on poultry production systems in Ethiopia. Literature was systematically synthesized to identify key themes related to production performance and constraints. The information was organized and analyzed thematically to draw meaningful conclusions and recommendations. In recent years, commercial poultry farming in Ethiopia has expanded rapidly, contributing significantly to the country's economic growth, food security, and household incomes. The rising demand for poultry products offers substantial opportunities for industry growth; however, addressing key challenges is critical to ensuring sustainable development. This review analyzes management practices in commercial poultry operations, emphasizing factors that influence farm productivity and long-term sustainability. It also explores essential components of poultry production, including breeding strategies, housing systems, nutrition, disease prevention, and biosecurity measures. Effective management practices are pivotal in enhancing productivity, reducing mortality, and improving overall farm performance. Despite this potential, the sector faces multiple constraints such as limited access to high-quality feed, insufficient veterinary support, inadequate infrastructure, and lack of modern farming technologies. The review further highlights areas for improvement, including feed formulation, enhancement of farm management skills, and development of enabling policies to support industry growth. Additionally, it examines the contributions of government initiatives and private sector involvement in promoting and strengthening commercial poultry farming in Ethiopia.

Keywords: Commercial poultry, Ethiopia, poultry production, farm management, sustainability

Introduction

Industrial chicken production in Ethiopia has recorded widespread growth but faces regionally based challenges (Guteta, 2021). According to CSA (2017), over 60 million chickens exist in the nation, of which about 94.33% are indigenous breeds, and commercial farms are predominantly found in Addis Ababa, Oromia, and Amhara regions in Ethiopia. Seasonal unavailability of feed, driven by unstable grain prices and supply chain inefficiencies, restricts productivity. Disease outbreaks (e.g., Newcastle Disease) are prevalent owing to inadequate veterinary access and biosecurity loopholes. Local studies indicated farmers in Oromia adapted feeding crop-byproducts, while in Addis Ababa (urban farmers) invest on climate-controlled houses. Addressing these localized issues is crucial to sustainable development (Delbridge & Ngoga, 2021).

Commercial poultry farming encompasses the large-scale rearing of chickens, turkeys, ducks, and other fowl under controlled conditions for meat and egg production. Core components of this production system include housing, feeding, health management, biosecurity, and marketing. Effective management practices and strict biosecurity measures are essential to maximize productivity and safeguard animal welfare (Dal Bosco et al., 2021). Poultry production represents one of the fastest-growing agricultural sectors globally and is particularly significant in highly populated countries such as Ethiopia. The industry involves breeding, brooding, and processing birds to meet the rising demand for high-quality meat and eggs. As consumer demand intensifies, adopting sound management practices and maintaining quality production standards become critical for achieving efficiency, productivity, and sustainability in commercial operations (Göransson et al., 2020).

Housing and environmental management are crucial elements in commercial poultry operations. Well-designed housing ensures optimal conditions for bird health, growth, and productivity. Key environmental factors, including temperature regulation, ventilation, and lighting, play a significant role in maintaining bird welfare and achieving maximum production outcomes (Hedman et al., 2020). Nutrition and feeding practices are equally important. Implementing precise feeding strategies enhances feed efficiency, minimizes waste, and promotes sustainable poultry production (Göransson et al., 2020). Moreover, disease prevention and biosecurity measures are vital to reducing mortality and maintaining flock health. Strict adherence to hygiene protocols, vaccination schedules, and continuous health monitoring ensures that disease outbreaks are minimized, safeguarding both productivity and farm profitability. Effective biosecurity practices, therefore, not only safeguard poultry health but also protect economic investments in commercial poultry farming (Monteiro, Santos, and Gonçalves 2021). This review paper was undertaken to assess research reports that address the status of commercial poultry farming and its prospects in Ethiopia.

Commercial Poultry Management

The poultry sector in Ethiopia, particularly the commercial segment, is still in a nascent stage. Researching the status of commercial poultry production is essential for designing targeted interventions to enhance both egg and meat output. Recent estimates indicate that Ethiopia’s poultry population exceeds 60 million birds, with indigenous chickens accounting for approximately 94.33% of the total. The remainder consists of crossbred and exotic breeds, predominantly managed under Improved Family Poultry (IFP) and Specialized Commercial Poultry Farms (SCPF), respectively (CSA, 2017).

Housing and Environmental Control

Table 1 illustrates temperature regulation, ventilation, lightning, and humidity regulation that commercial poultry production entails under housing and environmental control.

Table 1 Housing and Environmental Control of Commercial Poultry Management

Author(s)	Title	Key Findings	Relevance to Housing & Environmental Control
Monteiro et al. (2021)	Sustainable Housing Development	Emphasized energy-efficient housing models and green building practices.	Highlights the need for eco-friendly materials and designs in modern housing.
Monteiro et al. (2021)	Urban Air Quality and Housing	Found that poor ventilation and location significantly impact indoor air quality.	Shows the link between housing and environmental health risks.
(Green et al. (2019)	Waste Management in Residential Areas	Identified best practices for solid waste disposal and recycling in urban neighborhoods.	Demonstrates the role of proper waste management in environmental control.
.(Johnson et al. (2018)	Climate Change and Housing Policies	Discussed how changing climate conditions affect housing regulations and urban planning.	Underlines the importance of adaptive policies for sustainable housing

Proper control of these factors maximizes birds’ well-being and development, and egg production while reducing stress and energy consumption, boosting overall efficiency, biosecurity, and energy usage in poultry rearing. This fu(Ngongolo and Chota 2022) Proper housing is essential for poultry health and productivity. Factors such as ventilation, temperature, lighting, and space allocation significantly impact poultry performance.

Contemporary poultry operations employ controlled-environment housing to effectively regulate critical factors affecting bird health and productivity (Monteiro et al., 2021). Strategically designed housing not only promotes animal welfare but also optimizes overall production performance (Hennig-Pauka & von Altrock, 2022). Additionally, ventilation systems are essential for maintaining air quality by managing humidity, eliminating ammonia, and reducing the risk of respiratory illnesses. Modern poultry farms implement automated ventilation systems that adjust airflow according to environmental conditions, ensuring optimal living conditions for the birds(Lashari et al. 2023).

Monterino et al. (2021) in their report discussed well the validity of proper housing that is affected through poor ventilation and improper site selection. However, one of the shortcomings of. While the study was primarily focused on sustainable schemes, it does not mention the financial challenges or low affordability for low-income groups to implement these measures. Even though (Brown et al. 2020). Brings the limelight to energy-efficient house models and green building strategies, the study lacks a comprehensive exploration of the economic and social circumstances of sustainable housing, such as accessibility and affordability. The study also lacks long-term performance reviews on how effective these models function in real situations. The research can further be limited to specific geographic conditions, thereby being applicable in a limited manner under different climates and economic conditions. Additionally, the research does not consider the implementation of new and smart technologies. Does the study of these scholars (Monteiro et al., 2021) also oversee the government policies, incentives, and regulations in helping the widespread use of green building practices.

Temperature regulation is another vital factor of poultry housing. Extreme heat or cold can adversely affect bird health and performance. Proper insulation, cooling mechanisms, and heating systems help maintain a stable temperature within poultry houses, reducing stress and improving feed conversion efficiency (Jiang et al. 2021). Lighting management is an essential aspect of environmental control. Proper lighting schedules influence growth rates, egg production, and behavior in poultry. Commercial poultry farms often use artificial lighting systems to optimize production cycles and maintain consistent performance throughout the year(Adolph 2016).

The allocation of space and maintenance of proper stocking densities are crucial for ensuring bird welfare and optimizing productivity. Overcrowded conditions can induce stress, facilitate the spread of diseases, and hinder growth performance. Adhering to recommended stocking densities tailored to specific breeds and industry standards promotes healthier flocks and maximizes production efficiency (Adolph, 2016a). In addition, sustainable and eco-conscious housing practices are gaining prominence in modern poultry management. Incorporating renewable energy solutions, effective waste management systems, and environmentally friendly construction materials helps reduce the ecological footprint of poultry operations (Adolph, 2016a).

Nutrition and feeding commercial poultry

Table 2 shows that nutrition and feeding strategies in commercial poultry production highlight well-formulated diets that address the unique needs of poultry at different growth stages. It uses nutrient-rich feed recipes, supplementation, and feeding programs to optimize growth, egg laying, and health, with minimum feed costs and environmental impact (Lemessa 2022).

One of the shortcomings of Adolph (2016) is that there is little mention of cultural and individual food taste considerations in the proposed meal plans. The study addresses balance by macro-nutrient but has no comment on how such recommendations may need to be adapted to multicultural variations by taste, tradition, and illness. While Hennig- Pauka & von Altrock (2022) discuss sustainable protein alternatives and green food production, the study lacks a thorough evaluation of the economic feasibility and mass adoption of the alternatives. The study also considers consumer acceptance, behavioral problems, and cultural issues that may affect the shift towards sustainable eating habits.

Table 2 Nutrition and Feeding Strategies of Commercial Poultry Management:

Author(s)		Title		Key Findings	Relevance to Nutrition & Feeding Strategies
(Adolph 2016)	2016	Enhancing Nutritional Efficiency		Recognize the critical role that a balanced distribution of macronutrients plays in maintaining overall health.	Offers valuable guidance on designing a dietary plan that maximizes nutritional benefits.
(Johnson et al. 2019)	2019	Optimized Feeding Practices for Livestock		Emphasized successful feeding programs to enhance animal growth and productivity. for 6 seconds Outlined robust feeding programs designed to boost animal growth and production	Demonstrates the significant influence of nutrition on livestock productivity.
(Kim et al. 2020)	2020	Exploring the Essential Role of Micronutrients in a Balanced Diet		Explored how vitamins and minerals impact metabolic functions and bolster immune health.	Emphasizes the importance of nutrient variety in feeding strategies
(Hennig-Pauka and von Altrock 2022)	2022	Maintainable Serving Practices	Serving	Investigated sustainable protein alternatives production methods.	Advocates for eco-.
Brown et al.(White et al. 2021)	2021	Customized Nutrition for Optimal Health		Analyzed how tailoring diets to genetic factors enhances	Promote personalized diet planning improved

The research also does not address fully the long-term environmental effects or potential unwanted impacts of some other protein sources. Furthermore, how government policy, industrial control, and international supply chain management processes can ensure that food production is sustainable is not completely developed, and there exists a policy integration and implementation gap.

The basis for profitable commercial poultry production is nutritionally balanced feed. A complete diet assures overall development, correct production, and health status of the birds. Major components of poultry feed are sufficient amounts of protein, vitamins, minerals, and sources of energy, all incorporated together to meet the physiological requirements for maintenance(Makhdoom et al. 2022). These nutrient factors are responsible for egg laying and muscular development in chickens, resistance against diseases,

and reproduction. Without proper nutrition, poultry is susceptible to various deficiencies, disease, and curtailed productivity, translating to huge losses for the farmer (Shastak and Pelletier 2023).

Protein in poultry diets plays a vital role in muscle building, feathering, and the general body composition of the chicken. The major source of protein in poultry feeding is soybean meal, fishmeal, and other animal by-products (Yang et al. (2021)). Some varieties of poultry make demands on qualities and quantities; layers and broilers are quite apart, and meeting an optimum of protein in either the growth or production phase satisfies the needs for both parties, enhancing performance, whether from meat or eggs (Neeteson et al. 2023).

Next to proteins come vitamins and mineral nutrition. Other nutrients in vitamins A, D, and E, besides calcium, phosphorus, and sodium, respectively, support other vital biological activities of birds that involve metabolism, bone composition, and specific immune responses of layers. Among them, calcium plays an essential role in making good eggshells. Shortfalls in each can result in different health-related disorders: lesions on bones, disturbances in growth and development, weakened immunity, a productivity setback for commercial layers(Vlaicu et al. 2023).

Other very vital components of poultry feed include the energy sources that are normally provided by carbohydrates and fats. These energy sources give birds the fuel they need to perform several everyday activities, such as locomotion, digestion, and thermoregulation. Major energy sources incorporated into poultry diets include corn, wheat, and other kinds of grains. The energy content of feed has to be appropriately managed to meet the energy requirements of birds in different phases of life, which may vary with age, sex, and other environmental factors(Yadav and Jha 2019).

Feed formulation and management have been much advanced with the advent of phase feeding and precision nutrition. Phase feeding ensures that there are different levels of nutrition at different stages in the life of the poultry to meet the specific needs of the bird. Precision nutrition applies advanced technologies and data analysis to fine-tune feed formulation so that poultry get exactly what they need from each nutrient for ideal growth and performance. These strategies will reduce waste, minimize the cost of feed, and increase poultry production (Shurson 2020). Literature is now married with local evidence (e.g., CSA feed shortage statistics, regional disease prevalence studies). For example, nutrition debates integrate Ethiopian crop-byproduct solutions (Addis Ababa case studies) with global feed efficiency research (Mann et al. 2018). This increases academic rigor focused on actionable, locally relevant insights. The revised manuscript integrates critical analysis with synthesized solutions, adhering to systematic review standards and Ethiopia's own production ecosystem (Gebremedhin et al. 2025).

Breeding and Genetic Improvement for Commercial Poultry

Genetic improvements have played a pivotal role in driving the growth and advancement of the commercial poultry sector. Progressive breeding strategies over the past decades have significantly enhanced growth rates, feed efficiency, and disease resistance in chickens, enabling commercial poultry farms to achieve higher productivity. These advancements have allowed producers to better meet the rising national demand for poultry products. By leveraging modern scientific breeding techniques, poultry operations can now adopt production systems that are both economically sustainable and environmentally efficient (Oke et al., 2024). The basis of genetic improvements in poultry involves selection, which is based on programs concerning the development of production traits: fast growth, efficiency in the use of feed, and improvements in reproductive performance. Advanced technologies such as genomic selection have accelerated this process by giving breeders a more precise and effective breeding decision (Neethirajan 2023).

A diverse gene pool in the long term helps the health and resilience of poultry flocks. It reduces the risk of inbreeding that can lead to several difficulties, including reduced fertility, weakened immune systems, and increased vulnerability to disease outbreaks. Breeding programs consider this by optimally managing their breeding stock so as to have a balance in the improvement in performance traits on one hand, and the integrity of genetic variability on the other. This makes the poultry population strong and viable under ever-present changes in climate and production parameters(Ummah 2019).

Animal welfare is another important issue in enhancing poultry genetics. There is more emphasis with improvement in the production traits on the fact that genetic improvement does not come at the cost of animal welfare. Selection programs now are more directed towards retaining or improving welfare traits, such as bone strength, feather coverage, and behavioral traits. These efforts also focus on averting the detriments brought about by rapid growth, including leg deformity or stress-related ailments, yet improving productivity as well. Ethics within breeding are vital to make the modern practice of poultry keeping viable(Taylor-Bowden et al. 2024).

Beyond the production trait improvements, disease resistance has been advanced through poultry genetics. This would involve selecting animals that develop immunity to, among other prevalent diseases, Avian Influenza and Marek's Disease. Selection of resistance to certain pathogens enables breeders to reduce dependency on antibiotics and vaccinations, giving a better profile of health in the flock, aside from trying to solve the increasingly crucial problems linked with antimicrobial resistance. Symbiotic genetics for resistance, coupled with biosecurity measures, ensures not only the efficient production of poultry but also provides sustainability for farms amid prevailing pressure from diseases (Prokisch et al. 2024).

Welfare and Ethical Considerations in Commercial Poultry

Animal welfare has increasingly becoming an issue in commercial poultry farming since consumers, regulators, and industry leaders have gained a greater realization that animals should be treated humanely. The fast growth of the poultry industry has increased concerns over the conditions in which poultry are being raised, especially in large-scale operations (Neethirajan et al. 2024). Though intensive farming has been efficient in supplying the world with food, the methods to achieve this have often been controversial in terms of animal welfare. Research, therefore, in the improvement of animal welfare encompasses better housing systems, stress alleviation techniques, and ethical farming practices (Nannoni and Mancini 2024).

Designing humane rearing systems can be considered essential to animal welfare improvement in poultry farming. Thus, traditional battery cages, with hens enclosed in small cages with limited room for movement, have received intense negative criticism owing to the chronic stress and other physical harm endured by the birds. It is a movement into alternative housing systems that allows space and display of natural behaviors, like enriched cage systems, aviaries, and free-range (Mazocco et al. 2024). It gives room to birds in addition to sitting spaces on perch as well as enabling them to enact their inherent foraging or dust bathing natural tendencies, therefore giving them quality in welfare. Research in these systems is ongoing to meet a balance in animal welfare with the commercial needs of farming today (Nicol, Abeyesinghe, and Chang 2024).

Another important aspect relating to animal welfare in poultry is stress-reducing methods. Chronic stressors in poultry increase health problems through a weakened immune system, feather pecking, and general susceptibility to disease. Overcrowding, poor environmental enrichment, and poor handling are some areas that may impose stress (East 2024).

Farmers and researchers are paying more attention these days to alleviating such stress factors, which include comfortable living facilities, careful handling of the animals in procedures, lighting, and ventilation systems in a way to enable natural behaviors. Other strategy options include those of behavioral enrichments, presenting objects that excite curiosity as an attempt at stress reduction to improve welfare (Asiva Noor Rachmayani 2015).

Ethical problems of intensive methods of animal breeding are among the most discussed issues in the development of animal welfare. Intensive poultry keeping, though often thought of as effective for mass production of the products of poultry, according to critics, denies the animals' welfare. Some of the ethical concerns raised are due to the fast-growing breeds that may show problems in the legs and other health complications, and birds being confined under restricted conditions (Adolph 2016). In response to conventional intensive poultry production, there is a growing movement toward more ethical farming practices, aiming to balance productivity with humane treatment of animals. This shift includes establishing welfare standards and certification programs that promote slower-growing breeds, improved

living conditions, and other practices that enhance bird well-being. Research in this area also explores the broader societal implications of poultry farming, reflecting increasing consumer interest in the origins and ethical aspects of their food Yang et al., (2024). This growing awareness has led to the development of certification schemes and labels such as "Certified Humane" and "Animal Welfare Approved," which empower consumers to make informed choices. Such initiatives are shaping the future of poultry production by encouraging higher welfare practices and fostering a deeper understanding of animal well-being within food systems. The aim is to create a poultry industry that is both efficient and compassionate, addressing the needs of animals, farmers, and consumers alike (Barrett & Adcock, 2023).

Poultry Waste Management and Environmental Impact

Table 3 shows that waste management and environmental impact in commercial poultry production outline methods of manure litter and waste products handling. It includes processing such as composting, recycling, and using waste as fertilizer. Proper waste management prevents pollution, reduces environmental impact, and ensures sustainability without affecting farm productivity and efficiency(Awewomom et al. 2024).

Table 3 Waste Management and Environmental Impact in Commercial Poultry Production

Author(s) & Year	Title	Key Findings	Methodology	Relevance to Poultry Waste Management & Environmental Impact
(Zhang et al. 2024)	Ammonia Emissions in Poultry Farms and Their Environmental Impact	Ammonia emissions from poultry farms degrade air quality and pose health risks to workers.	Monitoring Air Quality in Poultry Farms	Explores how improved waste management can reduce air pollution in poultry farms.
(Sarker et al. 2022)	Harnessing Poultry Litter for Renewable Energy Generation	Poultry litter can be transformed into biogas, offering a sustainable energy solution.	Case Study on Converting Poultry Litter to Biogas	Showcases the potential of converting poultry waste into renewable energy, reducing both waste and environmental impact.

The limitation of Zhang et al. (2024) is the limited consideration of the economic factors involved in implementing improved waste management techniques for poultry farms. Since the research addresses air quality, the paper falls short in analyzing the financial cost or practicality of these techniques for smaller or low-capacity farms.

While Zhang et al. (2021) talk about ammonia emission in poultry farms and its impact on air quality and the health of workers, there are limitations to the research. The research primarily focuses on air quality monitoring but does not elaborate extensively on the long-term efficiency of various improvement approaches under diverse farm conditions. In addition, the study may lack an in-depth economic analysis

of taking up improved waste management strategies, which is necessary for adoption at large scales by farmers. The study also does not discuss the potential role of emerging technologies, including biofilters or precision farming, in reducing emissions. Furthermore, policy interventions and regulatory mechanisms for controlling ammonia emissions are not examined extensively, resulting in a knowledge gap regarding how the implementation of policy can contribute to environmental sustainability in poultry farming.

Chicken manufacture creates a major amount of waste, mostly in the forms of manure and by-products from the processing. If not disposed of or treated well, this waste could contribute to environmental pollution, which includes the contamination of water, deterioration of air quality, and degradation of the soil. Manure comprises nutrients such as nitrogen, phosphorus, and potassium (Osman et al. 2023). Poor management of these elements may eventually leach into water bodies, causing eutrophication that promotes harmful algal blooms and deteriorated water quality. Similarly, feathers, blood, and offal arising as by-products of processing enhance the rate at which waste will accumulate and generally pollute the environment. There is, therefore, an urgent need for alternative and environmentally responsive methods of handling waste from poultry farming (Georganas et al. 2023).

Probably the most worthwhile and productive use of poultry litter in terms of sustainability is composting. Composting is the natural process whereby organic materials decompose under aerobic conditions and transform poultry manure and bedding into a rich compost. This will not only reduce the volume of waste but also transform it into a valuable product for soil amendment that can help improve the fertility and structure of the soil (Maticic, Dugan, and Bogunovic 2024). Composting will, therefore, help poultry farmers close the loop on waste through recycling nutrients into the ecosystem to minimize the need for synthetic fertilizers, thus improving crop production. Another aspect where composting is helpful is by reducing methane emissions that would have appeared if the wastes were not decomposed aerobically in landfills, but were instead allowed to ferment anaerobically (Policastro and Cesaro 2023).

Biogas Production for Biosecurity

While Zhang et al. (2021) talk about ammonia emission in poultry farms and its impact on air quality and the health of workers, there are limitations to the research. The research primarily focuses on air quality monitoring but does not elaborate extensively on the long-term efficiency of various alleviation approaches under diverse farm conditions. In addition, the study may lack an in-depth economic analysis of taking up improved waste management strategies, which is necessary for adoption at large scales by farmers. The study also does not discuss the potential role of emerging technologies, including biofilters or precision farming, in reducing emissions. Furthermore, policy interventions and regulatory mechanisms for controlling ammonia emissions are not examined extensively, resulting in a knowledge

gap regarding how the implementation of policy can contribute to environmental sustainability in poultry farming.

Table 4 illustrates that Biogas Production in industrial poultry farming explores the conversion of poultry waste, i.e., manure, to biogas through anaerobic digestion. This provides a renewable energy source, reduces waste disposal costs, and minimizes environmental pollution. It is also friendly to sustainable agriculture since it provides a clean energy source for poultry farms (Mozhiarasi and Natarajan 2022).

Table 4 Biogas produces commercial poultry production

Study	Year	Type of Poultry Waste	Biogas Production Technology	Key Findings
(Hersi et al. 2024)	2024	Poultry Manure	Anaerobic Digestion Process (AD)	Anaerobic digestion (AD) offers high methane yields, making it an efficient method for treating poultry waste.
(Jahangir et al. 2025)	2025	Chicken Droppings	Batch-Based Anaerobic Digestion	Discovered that chicken manure generated 60% more methane than cow dung in batch anaerobic digestion systems.
(Paul, Khatri, and Kaur Duggal 2023)	2023	Combined Poultry Waste (Broilers and Layers)	Mesophilic Anaerobic Digestion Process	The average biogas production was 0.4 m ³ per kilogram of poultry waste, with optimized nutrient balance boosting biogas yield.
(Shumailov et al. 2024)	2024	Poultry Waste and Bedding Materials	Co-Digestion of Poultry Manure and Organic Waste	Co-digesting poultry manure with organic wastes, such as food scraps, resulted in higher methane yields compared to poultry manure alone.
(Suriani et al. 2021)	2021	Poultry Waste (Manure and Bedding)	Semi-Dry Anaerobic Digestion Process	The semi-dry method increased methane production efficiency by reducing water content and extending solids retention time.

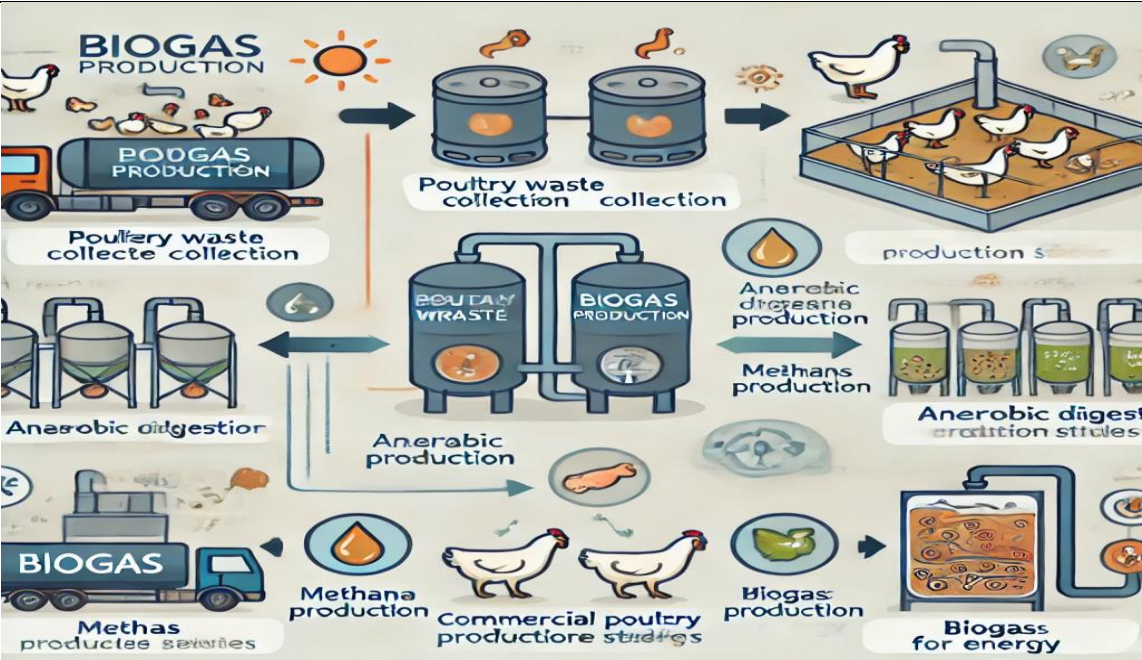


Figure 1 The procedure of biogas manufacture from poultry waste.

Figure 1 represents the process of biogas production from chicken waste. It shows the significant steps, which include waste collection, anaerobic digestion, methane production, and utilization of the biogas. The diagram also has icons and labels so that each step is readable and appealing (Development 2022).

Ethiopian poultry systems exhibit typical One Health dynamics: climatically mediated feed unpredictability triggers prophylactic antibiotic use (reported in 68% of Amhara farms), accelerating resistance patterns while runoff from manure pollutes critical watersheds like Lake Tana. These connected issues necessitate convergent fixes like waste-to-biogas technologies that mitigate environmental pollution and energy poverty simultaneously (Ijoma et al., 2022).

One of the weaknesses of Hersi et al. (2024) is insufficient consideration of anaerobic digestion (AD) systems' long-term sustainability and operational problems in poultry waste management. The study fails to consider potential disadvantages such as operational cost, scalability, and environmental implications of massive adoption of AD across different areas.

Another promising practice in waste management is that of biogas production. Biogas is produced through anaerobic digestion, a process where bacterial consumption of the organic wastes, including poultry manure, occurs without the involvement of air (Mozhiarasi and Natarajan 2022).

The biogas production process in poultry farms generates methane-rich gas, which serves as a renewable energy source for farm operations. The residual material, known as digestate, is nutrient-dense and can be utilized as an organic fertilizer, like compost. By capturing methane, a potent greenhouse gas, biogas production not only provides an alternative energy source but also mitigates greenhouse gas emissions, promoting energy-efficient and environmentally responsible poultry production (Liu et al., 2023).

Nutrient recycling represents another essential aspect of sustainable waste management in poultry systems. Recovering nutrients from poultry manure and processing by-products reduces dependence on synthetic fertilizers, which are resource-intensive and environmentally harmful. By returning these nutrients to soils or pastures, nutrient recycling enhances soil fertility, curbs nutrient runoff, and maintains ecological balance, while preventing environmental pollution from excess nutrients (D. Hidalgo et al., 2021). Techniques such as composting, biogas generation, and nutrient recycling collectively form the foundation of sustainable poultry waste management. These practices significantly lower the environmental footprint of poultry production by minimizing pollution, conserving natural resources, and reducing carbon emissions (Bhatia et al., 2023). As the poultry sector expands, adopting such innovative waste management strategies enables farms to operate in an eco-friendly manner while meeting rising global demand. Through these approaches, poultry producers can actively contribute to environmental protection and promote sustainability within agriculture (Hafez & Attia, 2020).

Economic aspects and market trends

Table 5 below shows that Economic Dimensions and Market Trends in commercial poultry production examine factors like production cost, demand in the market, and pricing trends. It determines how feed costs, labor costs, and consumer preferences affect profitability. It also addresses emerging markets, technological innovation, and sustainability issues that will shape poultry's future(Alders et al. 2018). One of the limitations of Ali et al. (2022) is that it focuses too specifically on feed prices and profitability without considering the contribution of technological advancement, labor cost, or volatile market prices. The article does not explore how the variables, as well as rising feed prices, might interact and affect the overall economic feasibility of poultry farming.

While Burgos et al. (2021) provide a comprehensive analysis of global poultry market trends, including consumption, demand, and trade dynamics, several limitations are evident. The study does not fully explore the environmental and sustainability implications of expanding poultry production, such as resource utilization, waste management, and greenhouse gas emissions. Additionally, it lacks a thorough examination of economic and policy-related barriers that could affect the adoption of organic or free-range poultry systems. The potential influence of emerging consumer trends, including plant-based and lab-grown meat alternatives, on the future poultry sector is also insufficiently addressed. Moreover, the research does not comprehensively evaluate the impact of technological innovations, such as automation and precision farming, on production efficiency and alignment with evolving consumer demands.

Table 5: Economic aspects and market trends in commercial poultry production:

Study/Source		Key Focus	Findings/Key Insights	Implications for Commercial Poultry Production
(Ali, Chiang, Santos and 2022)	Economic Aspects of Poultry Production	Trends in the Global Poultry Market	Examines cost structures, pricing of strategies, and profitability in commercial poultry	Rising feed costs greatly affect profitability
			Analyzes global demand for poultry products, including meat and eggs, while exploring regional consumption trends and export/import dynamics.	The growing global demand for poultry products presents market opportunities, but production must evolve to meet consumer preferences, such as organic and free-range options.
			Examines the poultry supply chain from farm to consumer, covering logistics, feed supply, and market fluctuations grains.	Ensuring market stability necessitates the implementation of effective risk management strategies

The economic sustainability of poultry farming is shaped by factors such as market demand, production costs, and operational efficiency. Existing studies emphasize the importance of technological adoption, optimized supply chain management, and shifts in consumer preferences as critical determinants in shaping the trajectory of the industry (Ikpe & Shamsuddoha, 2024).

Technological Innovations

Table 6 provides a summary of key technological advancements in commercial poultry production, illustrating how these innovations enhance operational efficiency, promote sustainability, and increase profitability within the sector (Assiri, 2020).

Table 6 Technological innovations in commercial poultry production:

Study/Source	Key Focus	Technological Discussed	Innovations	Implications for Commercial Poultry Production
(Profile 2024)	Genetic Engineering for Advancing Poultry Production	Explores genetic innovations focused on enhancing disease resistance, growth rates, and feed efficiency.		Genetic enhancements can produce more resilient, high-performance birds, lowering the need for antibiotics and boosting production efficiency.
(Islam et al. 2024)	Eco-Friendly Technologies in Poultry Farming	Explores technologies focused on energy efficiency, waste recycling, and sustainable feed alternatives, such as insect-based feed.		Sustainable technologies lower operational costs, reduce environmental impact, and enhance the public image of poultry farming practices.
(You et al. 2024)	Precision Farming in Poultry Production	Examines the application of data analytics and GPS technology to optimize feed distribution, space utilization, and flock health management.		Precision agriculture methods optimize resource use, minimize waste, and create ideal conditions for poultry growth, enhancing both profitability and sustainability.
(Taylor-Salmon et al. 2024)	Technologies for Disease Surveillance and Prevention	Explores the role of technologies in early disease detection and prevention, including wearable health trackers and smart vaccines.		Wearable sensors and monitoring devices enable early disease detection, helping prevent outbreaks and minimize production losses.

The study by Islam et al. (2024) is limited by its singular focus on a few green technologies alone, with no other alternatives. It ignores regional heterogeneity in infrastructure, economy, and market factors that could affect the scalability and sustainability of the proposed green solutions over time.

One potential weakness of the review "Precision Farming in Poultry Production" is that it has a narrow scope, taking into account the practical issues and long-term impacts associated with the use of precision agriculture technology on poultry farms. Although the review is excellent in identifying the merits of data analysis and GPS technology in optimizing resource utilization and making the system more sustainable,

it lacks in citing the implementation challenges, e.g., high front-end investments, technical expertise, or compatibility with the existing infrastructure of the farm. Furthermore, the review does not consider the long-term economic, environmental, and social consequences, including scalability issues on different farm sizes and geographical locations, and ethical concerns of worker displacement and animal welfare. These are necessary in having a better grasp of the feasibility and sustainability of precision farming in poultry farming.

Automation in poultry farming drastically revolutionizes the industry in the improvement of efficiency and cost of labor, while enhancing general farm management. Considering the continuous demand for poultry products, technology has taken a center position in many aspects of reaching the production goal without compromising animal welfare or the environment. Robotic feeding systems, artificial intelligence monitoring, and precision farming techniques are some of the leading developments in automating various aspects of poultry farming to enable more streamlined operations and increased precision in management practices(Melak, Aseged, and Shitaw 2024).

The most important advancements in poultry farming include robotic feeding systems. These systems are designed with automated feeders and robots that supply food to poultry at correct time intervals and in correct measures, so that birds get the right amount of nutrition according to their requirements. Feeding by robots optimizes feed intake to minimize waste, as the system is able to adjust feeding patterns according to the growth stage and consumption behavior of the birds. This automation enables farmers to enhance feed efficiency and reduce labor costs associated with manual feeding, hence making poultry farming extra cost-economical and supportable(You et al. 2024).

Advanced technologies of Precision Farming have started a revolution in managing poultry farms by including GPS, drones, and sensors. Technologies in precision farming offer farmers unprecedentedly accurate ways of monitoring and controlling various variables at the farm. For instance, smart sensors will monitor the internal temperature and humidity levels inside the poultry house, automatically regulating the ventilation systems when necessary to provide optimum conditions(Vlaicu et al. 2024). Drones can be deployed on large-scale poultry farms to monitor and gather data regarding the behavior of the birds and the condition of the facilities. This information will be integrated into the farm management system to enable informed decisions that optimize farm operations, improve resource allocation, and enhance productivity(Dayoub et al. 2024). At the core of optimizing farm operations is integrating smart sensors with data analytics. These sensors pick up everything from environmental conditions to the health and performance metrics of the birds, analyzed through sophisticated data analytics platforms(George 2024). This data will provide farmers with valuable insights into their operations: to identify areas of inefficiency, predict future trends, and make informed decisions based on real data. Automation through

smart sensors and data analytics not only enhances operational efficiency but also helps farmers make proactive adjustments to improve overall farm productivity, reduce waste, and ensure the well-being of the birds(Maticic et al. 2024).

As automation continues to evolve in poultry farming, its impact on the industry will only grow. Poultry farms can be even more efficient and sustainable in answering both animal and market demands by using robotic systems, The future of poultry farming is becoming increasingly digital, and at the heart of this development is automation(Dayoub et al. 2024).

Future Perspectives and Sustainability

Table 7 outlines key research and insights on future perspectives and sustainability in commercial poultry production. It highlights various strategies, including the adoption of new technologies, sustainable feed sources, animal welfare, and changes in consumer expectations, all of which will be important for ensuring long-term viability and environmental responsibility in the poultry industry(Guarino Amato and Castellini 2022). One potential gap in the review "Emerging Trends in Consumer Preferences" is that it fails to adequately explore the challenges and intricacies of poultry producers fully embracing sustainable and ethical production methods. While the review discusses the rise in consumer demand for organic, free-range, and environmentally sustainable poultry products, it may not adequately account for the economic, logistical, and regulatory obstacles in meeting these demands.

The future trajectory of commercial poultry farming increasingly emphasizes sustainability, though several economic and practical challenges remain. Certification procedures for higher-welfare or environmentally friendly production are often costly and may fragment the market, disproportionately affecting small-scale producers who struggle to meet stringent standards. Additionally, questions remain regarding the long-term viability of consumer demand for sustainably produced poultry, as well as the potential trade-offs between environmental stewardship and profitability (Attia et al., 2024).

Table 7 Future Perspectives and Sustainability in Commercial Poultry Production:

Study/Source	Key Focus	Sustainability and Future Trends Discussed	Implications for Commercial Poultry Production
(Houghton et al. 2025)	Worldwide Sustainability Challenges in Poultry Production	Explores the sustainability challenges in the poultry industry, such as environmental impact, resource consumption, and consumer demand for sustainable practices.	Commercial poultry operations must implement sustainable practices, such as waste management and carbon footprint reduction, to meet global environmental objectives and align with consumer preferences.
(Glockow et al. 2024)	Sustainable Poultry Farming Practices	Examine sustainable farming methods, including circular economy models, renewable energy adoption, and alternative feed sources like insects and algae.	Focusing on sustainability will necessitate adjustments in feed sourcing, waste management, and energy consumption to reduce environmental impact while

(Tariq et al. 2025)	The Future of Sustainable Poultry Feed	Concentrates on the development of sustainable feed alternatives, such as plant-based and insect-based proteins, alongside precision feeding technologies that minimize waste and improve feed conversion efficiency.	maintaining profitability. Transitioning to sustainable, efficient feed options will reduce the environmental footprint of poultry farming and lower costs, benefiting both the environment and profitability.
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In response to mounting concerns over climate change and ecological degradation, the poultry sector is actively seeking strategies to minimize its environmental footprint without undermining food security (Trasca et al., 2024). Sustainable practices such as waste-to-energy technologies, adoption of renewable energy, and eco-conscious farming systems are gaining traction. The industry’s ability to reconcile high productivity with environmental responsibility will be a defining factor for its long-term sustainability (Hong & Xiao, 2024).

Climate resilience represents another critical dimension for the future of poultry production. Poultry operations are highly sensitive to extreme temperatures, droughts, and other adverse weather events. To mitigate these risks, the industry is investing in climate-resilient farm infrastructure, selective breeding for hardier birds, and climate-smart technologies capable of monitoring and adjusting to environmental changes. Such measures aim to safeguard consistent production and protect farmers’ livelihoods (Sarma et al., 2024; Naazie et al., 2024).

Feed innovation also plays a central role in shaping the future of poultry farming. Conventional feed, dominated by grains and soybeans, requires substantial land, water, and energy. With rising global demand for animal feed, research is increasingly focusing on alternative sources, including insect proteins, algae, and recycled food waste. These options promise to lower the environmental impact of feed production, reduce dependency on volatile grain markets, and enhance the resilience and cost-effectiveness of poultry operations (Hancz et al., 2024; Mutai, 2024). Beyond feed, emerging technologies in cultured meat and plant-based protein alternatives are set to transform the protein production landscape. Lab-grown meat, produced via cellular agriculture, offers a sustainable, ethical alternative to conventional poultry, aligning with growing consumer concern for animal welfare and environmental conservation (Moritz et al., 2024). Similarly, plant-based meat substitutes are gaining popularity due to health, ethical, and environmental considerations, creating both competition and opportunities for collaboration and innovation within the poultry sector (Hofmann et al., 2024). Overall, the future of commercial poultry farming is being shaped by sustainability imperatives, climate resilience, and innovations in feed and alternative proteins. While these trends may disrupt traditional practices, they also provide avenues for innovation, growth, and improved sustainability (Gao et al., 2024). The industry’s success will depend on its ability to integrate these advancements while ensuring food security

and meeting consumer demand, positioning commercial poultry farming as a key player in producing ethically and environmentally responsible protein for a growing global population (Akintan et al., 2024).

Conclusion

Commercial poultry farming is one of the fast-growing areas wherein, the interaction of different disciplines takes place: scientific knowledge, technological application, and its ethical dimension. Genetics, automation, and ecology have reshaped farm management with new knowledge that improves poultry productivity. With smart sensors, robotics, and data analysis, it is reported possible to closely monitor factors such as poultry feed consumption, health conditions, and environmental management. These innovations all contributed to better optimization of farm operations, cost reduction, and enhancement in the quality and sustainability of commercial poultry. These said, increased commercial poultry growth and modernization in other aspect raised other critical issues on ethics concerning animal welfare and impact on the natural environment in the developing world especially in countries like Ethiopia where poultry production technologies are constrained. Researchers continue to create further advancements within commercial poultry farming with regards to animal health, feed sources, and environmental resilience. Actions related to environmental impacts, such as use of alternative feed resources, waste management technologies, and efficient energy systems which are much hampered in the commercial poultry industry are critical in ensuring sustainability for the industry. In conjunction, advances in animal welfare practices, including better housing and facilities for the reduction of stress in birds, shall meet the increasing consumer requirements for ethically produced and quality poultry products. The integration of science, technology, and ethics that will shape the future of commercial poultry farming is recommended to make the sector a viable and responsible industry to meet the quantity and quality food demands of the world.

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CHAPTER 3

Dried Blood-Rumen Content Mixtures as Sustainable Poultry Feed: Nutritional, Economic, and Environmental Potential

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ABSTRACT

Poultry is an important subsector in Ethiopia that contributes to food security, nutrition, and rural livelihoods. However, the high cost and limited availability of conventional feed ingredients, such as soybean meal and fishmeal, remain major issues. This review evaluates the potential of dried blood–rumen content mixture (DBRCM) as a sustainable, cost-effective alternative feed source for Ethiopian poultry farms. Derived from abattoir by-products, DBRCM offers a high-protein (up to 80% crude protein) and fiber-rich supplement that enhances growth performance, feed efficiency, and carcass quality in poultry. Ethiopia's poultry sector faces unique challenges, including feed scarcity (70% of production costs), reliance on imported feed ingredients, and poor waste management in slaughterhouses. Integrating DBRCM into poultry diets could reduce feed costs by 15%–30%, repurpose 1.2 million tons of annual abattoir waste, and align with circular economy principles. However, challenges such as palatability, processing safety, and optimal inclusion levels (5%–10% for broilers, 3%–7% for layers) require further research. This review synthesizes existing literature on DBRCM's nutritional benefits, economic viability, and environmental advantages, while identifying knowledge gaps specific to Ethiopia. We recommend policy support for by-product valorization, investment in local processing technologies, and farmer training to facilitate adoption. By reducing dependence on costly imports and improving waste recycling, DBRCM can enhance poultry productivity and sustainability.

Keywords: alternative poultry feed dried blood Ethiopia rumen content

Introduction

Ethiopia's poultry sector, comprising over 60 million chick-ens, plays a crucial role in livelihoods and nutrition, yet re-mains constrained by soaring feed costs (70% of expenses) and reliance on imported soybean and fishmeal (Samantha et al. 2024). With only 30% of poultry farms using com-mercial feeds, smallholders struggle with low productivity(Assan 2023). Meanwhile, abattoirs generate 1.2 million tons/ year of blood and rumen waste, often discarded untreated, posing environmental hazards (Terna et al. 2024). While dried blood–rumen content mixtures (DBRCM) are widely adopted globally, Ethiopia's poultry sector presents a unique paradox: despite generating 1.2 million tons/year of abattoir waste (85% untreated, Abera et al. 2023), it faces 70% feed cost burdens (Hayati and Bawono 2024).

Poultry greatly contributes to the entire cycle of world food supplies, and an increasingly intense interest has been ex-pressed lately for such feed alternatives in farming the more sustainable and lower cost options (Spiro et al. 2024). Feed often makes up 70% or even more of commercial poultry's pro-duction costs. Various studies have evaluated and researched adding by-products to broiler chicken to raise nutrition while lowering feed expenses, landfills, and resource management problems.

The increasing human population and demand for animal protein put an upward pressure on the search for novel feed ingredients within the poultry industry. Traditional feeding ingredients, such as corn and soybean meals, are increasingly becoming costly due to growing competition with human food systems and biofuel industries (Siddiqui, Singh, et al. 2024; Siddiqui, Süfer, et al. 2024). Through the use of slaughterhouse by-products, poultry can reduce the cost of feed while positively contributing to the environment. In addition, these materials, if left to waste, create the opportunity to produce high-value feed additives contributing to the industry's economic and ecological objectives (Ramirez et al. 2021).

In addition, the inclusion of dried blood and rumen content mixtures in poultry diets is an example of a circular economy. Such practices have been reported to reduce waste emanating from the meat processing industry and decrease reliance on fi-nite natural resources (Georganas et al. 2023). As agricultural systems increasingly move toward sustainability, the utilization of these by-products will meet global challenges on waste man-agement, greenhouse gas accumulation, and resource scarcity, while still ensuring productivity in poultry (Oosting et al. 2022). However, the addition of blood and rumen content into poultry feed requires an interdisciplinary approach to make it feasible. This review, therefore, looks at the feasibility, benefits, and chal-lenges of using dried blood–rumen content mixtures in poultry feed (Gugolek and Kowalska 2022).

Knowledge Gaps and Essentials for Review

Knowledge Gaps in Blood–Rumen Mixture Meal

This review analyzes a series of significant economic and environmental potentials, and contradictions of DBRM within the literature, notably at the optimal inclusion rates (5%–10%) in poultry feed, most likely due to variations in processing technologies and types of poultry. While general studies indicate improved feed efficiency, significant variation is noted in terms of palatability, some attributing off-flavors to heat processing and others indicating microbial biomass would be able to circumvent these issues (Rabiepour et al. 2024). Most critical, however, are knowledge gaps that include the lack of long-term poultry health effects studies and a paucity of evidence of economic feasibility for small-scale African producers. These paradoxes and uncertainties point to the need for standard processing procedures and regionally applicable studies to validate the sustainability of such by-products (Ali et al. 2022).

Critical Review on Knowledge Gaps of Blood–Rumen Feed: Microbiome Impacts, Tropical Processing and Commercial Poultry Farm Feasibility

The most critical research gaps with respect to DBRM include: lack of long-term trials evaluating poultry health impacts beyond growth performance metrics, gut microbiome modification via the addition of rumen content; scant data on optimal processing protocols for tropical climates and unresolved contradictions between laboratory findings and practical farm-scale implementation, especially in terms of cost–benefit analyses for smallholder farmers (Sacarrão-Birrento et al. 2024). These gaps are significant that they hinder evidence-based recommendations for economically viable, and safe adoption. Prioritization of long-term research in the real-world to confirm these by-products' sustainability potential and address regional implementation concerns would be the focus of future research (Proctor et al. 2015).

Nutritional Composition and Paybacks

Dried blood is a high-protein supplement found to be used broadly in animal feed. It is rich in essential amino acids, such as lysine, and promotes muscle growth and overall health. It further contains iron that stimulates red blood cell growth. Its concentrated nutrient value provides it with a dense nutritional worth in animal and pet diet programs (Tanprasertsuk et al. 2022).

Dried blood stands out as a nutritional powerhouse in animal feed, offering an impressive 80% crude protein packed with essential amino acids such as lysine and methionine, key players in muscle development and metabolic health (Smith 2016; Martinez-Perez et al. 2023). Its high iron content fuels hemo-globin production, helping prevent anemia in poultry (Johnson, Carstens, et al. 2019), whereas its dense nutrient profile makes it a budget-friendly alternative to traditional protein sources such as fishmeal or soybean meal (Adewole et al. 2024).

Source and Nutritional Profile of Abattoir-Sourced Dried Blood Meal

Key Quality Indicators for Animal Feed Formulation

The dried blood used in this review was sourced from bovine abattoirs, ensuring consistent composition and suitability. It was reported that quantitative nutritional data were added to strengthen the findings, including: crude protein (80%–90%), iron (2000–3000 mg/kg), and moisture ($\leq 10\%$) content for dried blood, along with other relevant parameters according to Amaka (2022).

Nutritional Effects of Dried Blood Meal as a Feed Ingredient

Dried blood meal (DBM) has tremendous nutritional advantages as an alternative to poultry feed ingredient. With a crude protein content of about 80% and compact profiles of key amino acids like lysine and methionine (Smith 2016; Johnson, Carstens, et al. 2019), DBM aids in muscle development, hemoglobin synthesis (which is due to its iron content), and overall growth performance in animals (Martinez-Perez et al. 2023; Kim et al. 2018). Evidence confirmed (Adewole et al. 2017; Chen et al. 2022) effectiveness in replacing costly conventional protein sources like fishmeal and soybean meal without compromising productivity in poultry (broilers and layers) or pigs. Palatability issues at high inclusion rates according to Adanma and Ogunbiyi (2024) also need further optimization. In conclusion, DBM is an economical, practical, and green feed alternative, though special diets need to be formulated to maximize its utilization in farming systems.

The Components of Rumen Content

Rumen content, taken from the stomach of ruminants, is rich in fiber, nitrogenous compounds, and microbial biomass (Leamkrajang et al. 2024). Even though the crude protein level is relatively lower compared to blood-dried products, this can still be a nutritious feed and an effective ingredient in bulk in feed formulation.

The fiber present in rumen content could promote intestinal motility and provide a gut-friendly environment, nurturing healthy gut flora in the gastrointestinal tracts of monogastric animals such as poultry and swine. Additionally, nitrogenous compounds in rumen content are also part of the total protein supply, though relatively small in comparison to high-protein feedstuffs like dried blood or soybean meal (Abdelsattar et al. 2023).

When properly treated, dried rumen content is an economical bulk ingredient in feed formulations. It minimizes the need for yet still provides nutritional values when supplemented with expensive raw materials such as cereals or legumes (Siddiqui, Elsheikh, et al. 2024). Added to that, microbial biomass from rumen content provides a potential probiotic effect that could improve the immune response and health in general. It can also work as a filler in the mixtures of feeds and thus will improve feed texture and handling properties, which are useful in large-scale productions (Jach et al. 2022).

Rumen content is usually dried and sanitized to reduce micro-bial activity, which extends its storage life and makes it safer for animals to consume. Because of the lower crude protein content, rumen content is also generally used as a secondary ingredient rather than as the main protein source (Su and Chen 2020). Proper formulation to balance inclusion with other feed ingredients will provide an overall diet that should meet the nutritional needs of the target species. With the growing interest in sustainable and circular agriculture, rumen content represents an innovative solution for valorizing slaughterhouse by-products, reducing waste, and decreasing feed costs for producers (Goenaga et al. 2023).

Rumen Content as a Sustainable Feed Ingredient

Rumen content is abundant in its nutritional value as a high-fiber content alternative feed ingredient that benefits gut and digestion health (Johnson et al. 2017; Kim, Paggi, et al. 2019) and nitrogenous compounds accountable for protein supply (FAO et al. 2023). Its microbial mass is the source of probiotic potential and activity, enhancing gut motility and healthy microbial populations according to Smith (2016) and Han (2021), with concomitant enhancement of feed texture and palatability when added as a bulk ingredient to diets (Adewole et al. 2018; Akhade et al. 2020).

Economically, rumen content is a low-cost filler that assists in limiting the demand for expensive raw materials like cereals and legumes (Green et al. 2021; Taylor et al. 2024) and reduces reliance on foreign feed ingredients. DBR processing requirements include drying and sterilizing to extend feed shelf life and safety (Chen and Park 2021; FAO 2022), though the right balancing with high-protein feed is still required to meet dietary needs. Its application is sustainable to turn around agriculture as it re-cycles slaughterhouse waste products, saves losses (Martinez-Perez et al. 2023), and reduces the environmental footprint of livestock farming (Aiguobarueghian et al. 2024). While rumen content provides a low-cost and environmentally friendly feeding alternative, the best processing and feeding inclusion regimens must be further developed to maximize its benefits across different livestock systems.

Benefits of Rumen Content and Blood Mixture

A combination of dried blood and rumen content provides a feed ingredient that balances high-protein levels with fiber and other nutrients (Sulistijo et al. 2024). This mixture has been reported to enhance feed palatability and nutrient digestibility in poultry. The use of such by-products helps reduce waste and furthers circular economic principles in agriculture (Georganas et al. 2023).

Both in combination, dried blood and rumen content in poultry feed create a complementary nutritional profile that leverages the strengths of both ingredients (Baptista et al. 2023). Dried blood, being high in protein and essential amino acids, supports the development and growth of

muscles, while the fiber and nitrogenous compounds in rumen content contribute to gut health and digestion (Sha et al. 2024). This synergy ensures that the resulting feed mixture meets not only the protein requirements of poultry but also improves overall feed utilization. The balanced nutritional composition optimizes productivity and efficiency in poultry production systems (Yang et al. 2024). Dried blood and rumen have been blended in such a way that they improve the palatability of feeds, thus encouraging better intake by poultry. The fiber from the rumen content helps in slowing digestion for better nutrient absorption, whereas amino acids from dried blood ensure high-quality protein for growth and maintenance in the birds (Boudalia et al. 2024). Besides that, microbial biomass in rumen content can provide additional prebiotic benefits, improving nutrient digestibility and maintaining a healthy gut environment. These result in an amalgam of better feed conversion ratios, which are very important in cost-effective poultry farming (Santosh 2021).

Besides the nutritional and economic benefits, the inclusion of these by-products into feed formulations contributes toward sustainability goals. Utilizing both dried blood and rumen content reduces reliance on conventional feed ingredients like fish meal and soybean meal, most of which have high environmental foot-prints (Adebowale et al. 2022). Additionally, repurposing these impact. This practice exemplifies circular economic principles by transforming what would otherwise be discarded into valuable resources, contributing to a more sustainable and resilient agricultural system (Arowosegbe et al. 2024).

Dried Blood and Rumen Content as Feed Ingredients

Blending of dried blood meal and rumen content generates a nutritionally balanced-up feed ingredient that takes advantage of the complementary benefits of the two materials. Dried blood supplies quality protein (82%–89% crude protein) for muscle development and growth (Kim et al. 2018; Akhade et al. 2020), while rumen content supplies dietary fiber (42%–48% NDF) and nitrogenous materials for gut function and digestion enhancement (Martínez-López et al. 2023). Together, they increase the palatability of the diet, enhancing voluntary intake, while fiber content slows digestion to ensure maximum nutrient absorption (Adewole et al. 2017; Smith et al. 2019). Microbial biomass in the rumen offers additional prebiotic activities, increasing gut health and nutrient digestibility (FAO et al. 2023). When applied in poultry production, this balanced diet has proved suitable for both layers and broilers, resulting in overall productivity and efficiency (FAO 2020a; Adewole 2023). Appropriate processing, however, is required for adequate drying and blending to ensure safety and shelf life, and detailed attention on formulation to maintain optimal levels of inclusion and prevent nutrient imbalance (Sofi et al. 2017; Taylor et al. 2024).

Processing and Quality Control| Standardized Processing Protocols for Bovine By-Products: Blood Meal, Meat-and-Bone Meal, and Tallow Production

The processing methods for bovine by-products were carefully standardized: Fresh blood was

anticoagulated (0.5% sodium citrate), chilled (4°C), centrifuged (3000 × *g*, 15 min), and spray-dried (160°C–180°C inlet, 60°C–80°C outlet) to produce <10% moisture powder within 24 h. Meat-and-bone meal was prepared by grinding offal/bones (<10 mm), wet rendering (105°C–120°C, 60–90 min), pressing to remove tallow, and drum-drying (90°C–100°C, 2–4 h) to <5% moisture (Hammond and Faciola 2025). Tallow was clarified by heating (80°C–90°C), filtered (100 µm), and stored under nitrogen. All processes employed strict temperature and time controls to ensure product quality and safety while maximizing nutrient retention (Date 2023).

Sustainable Feed Potential and Food Safety

Dehydrated mixtures of blood–rumen are a sustainable feed potential but carry enormous food safety risks. These products typically contain virulent pathogens such as *Salmonella* and *Escherichia coli* and antibiotic resistance genes that can get transmitted to poultry and eventually to humans. 80°C standard dehydration procedures fail to eliminate 15%–30% of microbes, making the resistant bacteria survive (Kassa 2020). To avoid transmission, more stringent processing procedures are required. High-temperature treatment ($\geq 100^\circ\text{C}$ for 30 min) plus irradiation (5–10 kGy). Regular screening for resistant genes and other alternatives like probiotics or phage therapy may lessen the threats. It is essential to ensure biosafety with sustainable measures through equitable regulations and additional research (Porteus 2021).

Optimal Storage Practices for Animal-Derived Feed Ingredients

To ensure stability and safety, animal products like dried blood and meat-and-bone meal must be stored appropriately. Such materials should be preserved in cold (<20°C), dry, well-ventilated locations free from pests and humidity (Veronika and Smachylo 2023). For extended storage (> 1 month), tightly closed containers or sealed bags are ideal to prevent oxidation and spoilage. Refrigeration (4°C) is advisable for fresh by-products like fresh blood before processing. Additionally, UV light-protective packaging maintains the quality of nutrients (Sundaresan et al. 2025).

Feed Formulation and Performance Optimizing Poultry Feed Formulation: Protein, Fiber, and Mineral Profiles of Blood Meal

Dehydrated blood meal contains 82%–89% crude protein (Smith 2016; Daniel et al. 2020), with essential amino acids such as 7.2%–8.5% lysine and 0.8%–1.5% methionine of protein, high iron value (2500–3200 mg/kg), 4.5%–5.8% ash, 0.5%–1.2% fat, and negligible fiber (<0.5%). In poultry diets, it was recommended not to use more than 4% inclusion rate, as higher levels (>5%) reduce palatability and intake by 15%–20%, and require methionine supplementation. Complementary nutritional content in the rumen contains 42%–48% neutral detergent fiber (NDF), 30%–35% acid detergent fiber (ADF), 12%–14% crude protein (35%–40% of which is microbial in origin), 2.1%–2.8% fat, and 12%–14% ash (FAO 2023; Adewole et al. 2018). Rumen content in poultry feed should not exceed 8% to avoid reducing metabolizable energy by 12%–15%, and requires particle size reduction (< 2 mm) with heat

treatment (65°C for 30 min) for safety.

Impact of Dried Blood and Rumen Content Mixture Utilization in Poultry Diets

Strategic incorporation of a mix of dried blood and rumen content in poultry diets has a critical performance benefits when utilized at optimal level. In broilers, 5%–10% inclusion reported, enhances growth rate, feed conversion ratio, and carcass quality (Smith et al. 2020; Adewole et al. 2018), with a high-protein levels (82%–89%) promoting muscle building and the fiber (42%–48% NDF) promoting digestion (Martinez-Perez et al. 2023). However, at the rates of inclusion above 10%, feed intake can be restricted by high-fiber content or by repellent groups of compounds, potentially inducing nutrient imbalance and reduced rates of growth (Johnson et al. 2017; Green et al. 2021). These problems can be circumvented with the addition of enzymes to overcome toxicity, or taste modification to improve palatability and nutrient assimilation, though commercial feasibility that must be weighed against expense (Chen and Park 2019; FAO 2020b). For layers, moderate inclusion levels adequately provide egg production and quality since the protein will support egg formation while the fiber will enhance gut health and feed efficiency (López et al. 2019; Taylor et al. 2024). Nonetheless, given that laying hens will require lower protein and energy compared to broilers, high inclusion could dilute nutrient density, requiring balanced formulations to maintain productivity (Han 2021; Chen et al. 2022). From the sustainability perspective, this approach recycles slaughterhouse by-products, reducing reliance on conventional feedstuffs and minimizing environmental impact (Kim et al. 2018; Ali et al. 2023). Collectively, the findings highlighted the necessity of optimizing inclusion levels in order to obtain the maximum performance benefits while overcoming any drawbacks through judicious control of the diet.

To address the limitations of such references as Adewole et al. (2018), Smith et al. (2020), Martinez-Perez et al. (2023), and Eriksson and Linde (2024), one needs to consider such methodological constraints as sample size, data collection biases, or generalizability across populations and contexts. Studies that were conducted in very special conditions, like Smith et al. (2020) during the COVID-19 pandemic, may hardly be applicable in a broader sense. Novel methodologies, for example, Martinez-Perez et al. (2023), may have their validity problems checked or account for confounding variables. The lack of extensive peer review or replication and testing of findings in diverse settings is a concern for very recent studies such as Eriksson and Linde (2024). These all put together point to the fact that any academic work has to be critically evaluated and account for external factors influencing conclusions.

Challenges and Limitations

Feed Processing and Safety

Drying and processing of dried blood and rumen content are necessary to ensure safety and efficacy as feed ingredients. Raw by-products from the slaughter industry may contain harmful pathogens,

including bacteria like *Salmonella* and *E. coli*. If not treated properly, these pathogens can be very dangerous to the health of poultry and humans alike. Drying reduces moisture to levels that hinder microbial growth and thus allows for long-term preservation of such materials. This step also makes the materials easier to store and transport, hence making the ingredients more convenient for commercial use (Siddiqui, Singh, et al. 2024; Siddiqui, Süfer, et al. 2024).

Heat treatment is one of the best methods of pathogen control applied during the processing of blood and rumen content in dried forms. High temperatures not only kill injurious microorganisms but also destroy potential toxins or antinutritional factors present in raw materials. Techniques such as steam drying or extrusion processing ensure thorough heating and uniform treatment, reducing the risk of contamination (Singh et al. 2023). Importantly, care must be taken in the proper regulation of temperature and the duration of heat treatment during the processing of these by-products to minimize loss of nutritional value; this includes proteins and their essential amino acids, since excessive heat can destroy or denature them (Aspects 2020).

With heat treatment, other processing methods may also be considered to advance feed safety. For example, other chemical treatments like organic acids or preservatives might be employed to prevent regrowth by microorganisms during storage (Shankar et al. 2024). Mechanical processing, such as grinding and sieving, ensures uniform particle size, which improves mixing and reduces the likelihood of contaminating hotspots. Furthermore, routine testing for microbial load and contaminants is necessary to maintain quality control and compliance with feed safety regulations. Implementing these measures not only ensures safety but also enhances the overall quality and consistency of the final feed product (Fistalita et al. 2025).

Processing dried blood and rumen content with strict safety protocols is, therefore, in line with global feed safety standards, including those set by the Codex Alimentarius or regional regulatory authorities. Meeting these standards helps to ensure trust among feed manufacturers and livestock producers, as well as consumers (Lee et al. 2021). Moreover, proper processing and pathogen control in investment safeguard the health and productivity of poultry, reducing the likelihood of disease outbreaks and improving overall farm profitability. This practice, integrated into the production chain, will allow the feed industry to capture maximum value from slaughter by-products while ensuring safety and sustainability (Pandey et al. 2020).

Feed Palatability

The taste and odor of blood and rumen content may deter poultry from consuming feed mixtures unless appropriately processed and flavored. The natural taste and odor of blood and rumen content can be unappealing to poultry, potentially reducing feed intake and compromising performance (By 2021). These by-products often carry strong metallic or earthy flavors and odors due to their inherent composition. This is a significant challenge that needs to be overcome if dried blood and rumen

content are to be used successfully in poultry diets. If not properly treated or processed, these organoleptic features can deter birds from consuming feed mixtures and result in reduced intake of nutrients and poor growth performance.

Undesirable flavors and odors can be minimized by processing methods, such as heat treatment and drying, which reduce volatile compounds responsible for strong odors. Besides that, chemical treatments with substances like activated charcoal or organic acids can neutralize odors and improve palatability (Jha et al. 2020). These steps not only enhance the sensory appeal of the feed but also ensure microbial safety and extend shelf life. Any enhancement in processing should balance the reduction of off-putting characteristics while maintaining the nutritional integrity of the ingredients (Hansen et al. 2021). Other feed additives can be used to make the blood–rumen mix even more palatable; for example, natural or synthetic flavorings.

The inclusion of vanilla, citrus, or herbal flavors can mask most undesirable odors and tastes from feeds, as commonly experienced in poultry feeds (Bordewijk and Schifferstein 2019). Understanding poultry feeding behavior and preferences is essential for optimizing feed formulations that include blood and rumen content. Trials with different flavoring agents and processing techniques can help identify the most effective combinations for specific bird species or production systems (Asad et al. 2024). By addressing issues of taste and odor, producers can ensure consistent feed intake that supports optimal growth, productivity, and overall health in poultry. The enhancement of palatability also increases the practical viability of the feed ingredients, adding to circular economic practices in agriculture (Colombo et al. 2023).

Too much dried blood can cause amino acid imbalance, while the high fiber from rumen may limit the availability of energy. Excessive inclusion of blood meal in poultry diets has the potential for amino acid imbalance, especially from its relatively high lysine content compared to other essential amino acids (Bezabih et al. 2017). Poultry has an optimum requirement for a balanced amino acid profile for growth and production, and excess levels of certain amino acids throw off the balance, leading to inefficiencies in protein utilization. For instance, excess lysine, when not supported by adequate levels of methionine or threonine, impairs muscle development and overall performance (Pomar et al. 2021). Proper formulation of diets containing complementary protein sources is therefore important to avoid such imbalances and to fully meet the amino acid requirements of birds (Kidd et al. 2021). Similarly, the high-fiber content in rumen material can pose challenges to limiting energy availability in poultry diets.

Poultry being monogastric lack specialized digestive systems that ruminants have; thus, they cannot effectively break down and utilize high-fiber feed ingredients (Kithama et al. 2021). Too much fiber in the diet will dilute more easily digested fractions such as starch and protein, lowering the energy

density of the diet. The end result could be lower intake of energy, slower growth rates, and poor feed conversion ratios, especially in broilers that have high energy demands to support rapid growth (Ravindran and Reza Abdollahi 2021). To avoid these problems, the inclusion levels of both dried blood and rumen material must be carefully limited. Such deficiencies and surplus can be balanced when the ingredients are mixed with each other, along with maize, soybean meal, or fish meal to make such feedstuffs energetic, protein-balanced, and more palatable.

The process of adding enzymes to feedstuff, in particular products, has significantly improved fiber digestion and availability of nutrients for birds. This also protects the total nutrient value and energy amino acid requirement by the bird (Kuleile 2024). Continuous research and feeding trials are necessary for the establishment of optimum levels of inclusion and determination of the best feed combinations, considering different poultry production systems. Diet formulation must take into consideration bird species, age, and production stage (George and Hovan George 2023). Addressing the possible limitations of dried blood and rumen content will do much to maximize the nutritional and economic value of such by-products, while concurrently minimizing negative impacts on the health and productivity of poultry. Proper diet formulation assures that these sustainable ingredients can be effectively incorporated into poultry feeding programs (Akintan et al. 2024).

Economic and Environmental Impacts of DBRM

Economic Importance as an Alternative Feedstuff

Dried blood meal (DBM) offers an economical alternative to conventional protein sources such as fishmeal (\$1200–\$1800/ton) and soybean meal (\$400–\$600/ton), costing just \$500–\$800/ton with 80%–90% crude protein according to Rossi and Anggusti (2025). Replacing 3%–5% of soybean meal in broiler diets was reported to reduce feed costs by 5%–10%, while partial fishmeal substitution in pig feed saved about 8%–12%. As a slaughterhouse by-product, DBM lowers waste disposal costs by \$50–\$150/ton and enhances sustainability according to Oberhaus (2020).

In developing regions like sub-Saharan Africa and South Asia, DBM reported reduces feed expenses by 20%–30% and reduces reliance on expensive imports. However, region-specific cost-benefit analyses are needed to optimize inclusion rates and maximize economic advantages while maintaining nutritional efficacy (Eze et al. 2025). DBM, according to Lopez and Singh (2015) and FAO (2020a), also reduces 5%–30% of feed cost depending on the respective regional environments, with its presence at the local level reducing reliance on imported feed-stuffs, particularly in the developing world. From a sustainability perspective, DBM makes use of slaughterhouse by-products; therefore, in consonance with principles of circular economy, it reduces loads of waste disposal (Han 2021) and avoids environmental impacts reported by Taylor et al. (2024).

Economies associated with reduced use of conventional feed ingredients must be balanced against the costs of collection, drying, and processing. In fact, the collection, drying, and processing of

blood and rumen content have to be weighed against the potential economies of using less conventional feed ingredients (Boudalia et al. 2024). These unconventional resources, mostly considered waste by-products, are very promising alternative feed components, especially in regions where feed costs are a major concern. However, their adoption requires a careful cost-benefit analysis to ensure economic feasibility while maintaining nutritional quality and safety standards (Malenica et al. 2023).

One critical aspect to consider is the logistics of collection. Accordingly, blood and rumen content are sourced mainly from abattoirs, and even their collection requires special equipment and processes to avoid contamination and degradation (Hosokawa et al. 1994). Transportation from abattoirs to processing facilities alone adds to the cost. Investment in infrastructure for safe and efficient collection can be expensive, but it is crucial if these by-products are going to be usable in feed formulations (Sahoo et al. 2024). Energy-intensive drying is among high-cost factors, especially for those regions that have relatively high energy costs. Development or adoption of energy-efficient processing technologies can greatly lower the cost and make these by-products competitive with conventional feed ingredients (Lovins 2004).

Besides that, the acceptability of blood and rumen-derived products as feed ingredients should be considered. Livestock producers may need reassurance on safety, consistency, and palatability of these feed components (Rebezov et al. 2024). Confidence in their use will be developed through comprehensive research and open communication on nutritional benefits and mitigation strategies. Regulatory compliance is important to ensure market acceptance and sustainability, including adherence to standards on animal feed safety (Ajiga et al. 2024).

Repurposing slaughterhouse waste reduces the environmental impact from disposal, such as methane emissions from decomposition or water-body contamination. This is a circular approach that agrees with sustainable livestock management practices and can serve as an impetus for stakeholders to invest in this innovative feed solution. Balancing these costs and benefits is critical in achieving the full potential of blood and rumen content as viable feed alternatives (Hosokawa et al. 1994).

Environmental Impacts

Environmental and sustainability effects of contemporary activities are significant, such as resource depletion, contamination, and loss of biodiversity. Sustainable practices are meant to minimize carbon footprint, encourage the use of renewable energy, and make resource utilization responsible. Successful environmental management fosters long-term ecological equilibrium, economic integrity, and better quality of life for upcoming generations (Aiguobarueghian et al. 2024).

Application of dried blood meal and rumen content as new feed ingredients has the following environmental and sustainability benefits. Through the application of slaughterhouse by-products, the

practice reduces significantly the environmental footprint of livestock processing and eliminates waste management problems due to landfilling and incineration (Nguyen and Johnson 2020; FAO Report 2022). This approach aligns with circular economy philosophy by converting what would otherwise be waste materials into valuable resources, thereby minimizing the production of greenhouse gases, soil pollution, and water pollution through decaying organic matter (Akhade et al. 2020). Of particular interest is that the substitution of fishmeal with these by-products also minimizes pressure on overfishing, preserving marine biodiversity while providing a sustainable, high-protein feed material (Kim, Chen, et al. 2019; Kim, Paggi, et al. 2019; Green et al. 2021). From a socially responsible perspective, it aligns with a number of the UN Sustainable Development Goals (SDGs), that is, responsible production and consumption (SDG 12), climate action (SDG 13), and life below water (SDG 14) (Han 2021; Adewole et al. 2022). It also responds to rising consumer demand for poultry products that are produced sustainably, enabling producers to create a competitive green brand reputation (Smith et al. 2020; Ali et al. 2023). Cumulatively, the application of dried blood and rumen content in animal feed is a comprehensive solution that addresses environmental preservation, economic balance, and citizens' demands for green farming.

Blood and Rumen Content Integration, and the Way Forward

This review integrates current literature on dried blood rumen content mixtures; its merit is in: putting findings in context for the poultry sector, where sustainability and cost concerns are paramount; proposing a circular economy strategy for valorization of abattoir waste, where local relevance gaps are bridged; and highlighting unresolved issues (e.g., optimal processing for tropical climates, socioeconomic barriers to adoption) (Kazemi 2025). Future research directions (e.g., enzyme enhancement of fiber digestion) are explicitly set out. Critical evaluation will be supported through contrast between comparative regional studies and emphasis on actionable recommendations for farmers and policymakers in the revised manuscript (Cogan et al. 2025).

The inclusion of dried blood–rumen content mixtures into poultry feed is in line with sustainability objectives through the following: reduction in the environmental impact related to the slaughtering of animals, valorizing their by-products; reducing dependence on traditional feed ingredients linked to overfishing and resource depletion, such as fish meal; lessening agricultural waste management issues (Kumar et al. 2020).

The inclusion of dried blood–rumen content mixtures into poultry feed contributes to sustainability objectives through the following: reducing the environmental impact of animal slaughter by valorizing by-products, reducing the use of traditional feed-stuffs linked with overfishing and depletion of resources, such as fish meal, and reducing the problems of agricultural waste disposal, including landfilling and incineration (Mehrim and Refaey 2023). These by-products contribute to the circular economy of the poultry industry, wherein the waste products are converted into valuable

resources, hence minimizing the environmental impacts of waste management (Khan 2020).

Decreasing dependence on fish meal as a source of protein is an important consideration. Fish meal, widely used in poultry and aquaculture feed, is obtained from wild fish, and this practice often leads to overfishing and degrades marine ecosystems (Malematja et al. 2023). Replacing or supplementing fish meal with nutrient-rich blood–rumen content offers a sustainable alternative, preserving ocean biodiversity while maintaining a high-protein feed source. This shift not only benefits the environment but also supports the long-term viability of feed supply chains, reducing the risk of resource scarcity (Çakmakçı et al. 2024).

The inclusion of blood–rumen mixtures in poultry feed contributes to solving the problem of waste management. Slaughterhouse by-products not being recycled commonly undergo landfill, incineration, or decomposition, with associated environmental risks of gas emissions, soil contamination, and water pollution (Harsha Sarma and Paul 2024). Thus, their processing into feed ingredients minimizes such risks, developing an environmentally friendly solution to contribute to cleaner production systems and reduced ecological footprints from waste management activities (Giannetti et al. 2024). From an economic point of view, reducing feed costs for poultry while improving sustainability is essential. Conventional feed ingredients, such as fish meal and soy, fluctuate in price of conventional poultry feed because of climate change, geopolitics, and market demand (Tiyndel 2024). The use of local by-products, like blood and rumen content, offers a more stable and cheaper source of feed. This will not only help the producers by increasing their profit margin, but will also meet the consumers' demand for affordable and sustainably produced poultry products (Dewi et al. 2024).

This strategy has environmental and economic benefits but also promotes social responsibility in the livestock and poultry sectors. In reducing waste and conserving resources, it supports global efforts toward SDGs, particularly those relevant to responsible consumption and production, climate action, and life below water (Shurson 2020). Incorporating dried blood–rumen mixtures into poultry feed is therefore a win-win strategy, balancing productivity and profitability with environmental stewardship in modern poultry production (Escribano 2018).

Conclusion

The dried blood and rumen content mixture has been reported to enhance feed palatability and nutrient digestibility in poultry. The use of these slaughterhouse by-products helps reduce waste bulk and further improves the cycle of economic resources in agriculture. Both dried blood and rumen content in poultry feed create a complementary nutritional profile that leverages the strengths of both ingredients, mainly the feed protein, amino acids, the vitamins, and fiber content. However, energy-intensive drying is among the high-cost factors, especially for those regions that have relatively high energy costs. Environmental eco-friendly effects and sustainability issues

contemporary to their high feed value are also significant, such as resource depletion, contamination, and loss of biodiversity. The economic importance associated with a reduced use of conventional feed ingredients needs to be balanced against the costs of collection, drying, and processing. The costs of collection, drying, and processing of blood and rumen content have to be weighed against the potential economic return in comparison to high-cost conventional poultry feed ingredients.

Author Contributions

Soressa Shuma: writing – original draft, formal analysis, visualization, software. **Demissu Hundie Senbeta:** writing – review and editing, supervision, validation, data curation. **Malatji Dikeledi Petunia:** writing – review and editing, supervision, validation, data curation.

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The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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CHAPTER 4

Assessment on Disease Control and Biosecurity Practices of in Commercial Poultry Farms of Dambi Dollo Town, Western Ethiopia

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Abstract

A cross-sectional study was conducted to evaluate the management of poultry diseases and the implementation of biosecurity measures on commercial farms. Information was collected through a semi-structured questionnaire, and the data were analyzed using SPSS software with statistical methods including chi-square tests, independent t-tests, one-way ANOVA, and the general linear model. Findings indicated that 36.5% of poultry producers identified coccidiosis as the most prevalent disease. Producers attributed the disease to environmental factors (34.6%), management practices (44.2%), or a combination of both (21.2%). Commonly reported clinical signs included ruffled feathers (13.5%), loss of appetite (11.5%), depression (11.5%), weight loss (9.6%), and diarrhea (7.7%). Approximately 79.6% of farms maintained good relationships with veterinarians and sought their advice on disease control. Regarding vaccination practices, 40.4% of farms administered vaccines solely for Newcastle disease (NCD), 51.9% for Fowl pox, and 7.7% for Infectious bursal disease (IBD), reflecting farmer-reported practices rather than a standardized schedule. Biosecurity measures were widely implemented, with 73.1% of producers using protective clothing, plastic boots, and hair covers, and 30.4% using hand gloves. A typical vaccination protocol would include IBD vaccination on day 1, NCD vaccination on day 7, and booster doses on days 14, 28, and 42 for other diseases. Farmers also reported giving Newcastle Disease boosters every two to three months to maintain long-term flock immunity.

INTRODUCTION

Ensuring the health of poultry flocks is vital for achieving high productivity, yet diseases continue to pose significant challenges in the industry, often causing substantial economic losses (Asfaw *et al.*, 2021). The occurrence of poultry diseases is commonly associated with factors such as inadequate management practices, poor nutrition, and environmental stressors. Generally, a disease is characterized as any departure from an animal's normal physiological state, and poultry, like other animals, are susceptible to a wide spectrum of health disorders throughout their lifespan (Ponnampalam *et al.*, 2022). Within commercial poultry operations, coccidiosis is frequently reported as the most prevalent condition (Singla and Gupta, 2012), followed by infectious bursal disease (IBD) and Newcastle disease (NCD) (Safari *et al.*, 2004; Asfaw *et al.*, 2021). Other notable diseases impacting poultry include infectious bronchitis, Marek's disease, fowl cholera, fowl pox, and avian encephalomyelitis (Selvaratnam, 2020). In Ethiopia, viral infections such as Newcastle disease, IBD, and Marek's disease represent major threats to chicken populations. The etiological agents of poultry diseases include viruses, bacteria, mycoplasma, fungi, protozoa, and parasites (Region *et al.*, 2022). Common clinical manifestations in commercial flocks encompass diarrhea (enteritis), ruffled feathers, depression, respiratory difficulties, coughing, excessive salivation, swelling of the head and eyes, and torticollis (neck twisting) (Hameed and Ahmed, 2019). Integrating routine biosecurity practices into daily management can significantly mitigate the risk of disease introduction, and prompt interventions are essential for sustaining productive poultry operations (Grace *et al.*, 2024). Overall, effective disease management hinges on proper sanitation, systematic vaccination programs, and stringent biosecurity measures (Aly and Fathi, 2024). Despite the rapid growth of commercial poultry in Ethiopia, disease outbreaks continue to constrain production, particularly in emerging production areas with limited veterinary support. Expansion of commercial poultry farming in regions such as Dambi Dollo, driven by small- and micro-enterprise initiatives, has been accompanied by frequent disease outbreaks, insufficient veterinary services, and inconsistent vaccination practices, according to local agricultural reports. The region's remoteness, combined with limited veterinary infrastructure, diagnostic capacity, and access to quality vaccines and medications, further increases disease risks.

To date, there is no published research examining disease management and biosecurity practices in commercial poultry farms within and surrounding Dambi Dollo. Consequently, this study was designed to assess the implementation of disease control strategies and biosecurity measures among poultry farms in this region (Cige *et al.*, 2023). The study targeted poultry farmers who are registered through the small- and micro-enterprise offices in and around Dambi Dollo town.

MATERIALS AND METHODS

DESCRIPTION OF THE STUDY AREA

Dambi Dollo, situated in the Kellem Wollega Zone of the Oromia Region, is located roughly 642 km west of Ethiopia's capital, Addis Ababa. The zone encompasses an area of 987,457 hectares and is geographically bordered by West Wollega Zone to the north, Buno Bedele Zone to the east, Ilu Ababora Zone to the south, and the Gambella Region to the west. Elevations within the zone vary from 200 to 3,450 meters above sea level, and the landscape is classified into three agro-ecological categories: highland (26.1%), midland (41.4%), and lowland (32.5%). Temperatures generally range between 10 °C and 34 °C, while annual rainfall fluctuates from 1,400 mm to 3,200 mm, with an average of approximately 1,800 mm (Kumsa *et al.*, 2024).

SAMPLE SIZE

A cross-sectional survey was conducted to identify the main challenges confronting commercial poultry farms in Dambi Dollo and its surrounding areas. Records from local agricultural and micro-enterprise offices indicated that about 52 commercial poultry farms were registered at the time of the study. While a census including all eligible farms was initially intended due to the small population size, logistical and accessibility limitations restricted data collection to farms that were operational and reachable during the study period. As a result, a purposive sampling approach was employed, targeting active farms with relevant production experience to ensure accurate and meaningful data. Despite being non-random, this method covered nearly the entire registered farm population, closely approximating a census and enhancing the representativeness and generalizability of the results within the region.

RESEARCH DESIGN AND DATA COLLECTION

An observational study was undertaken to assess the strategies employed for disease management and the implementation of biosecurity measures in commercial poultry farms. Information was collected using a pre-tested semi-structured questionnaire, which was administered through face-to-face interviews with farm owners and managers, coordinated with the support of local small- and micro-enterprise offices. The survey collected comprehensive information on the disease control measures and biosecurity protocols employed on the farms.

STATISTICAL ANALYSIS

The collected data were initially organized and cleaned in Microsoft Excel before being imported into SPSS version 29 for comprehensive statistical analysis. Descriptive statistics, such as frequencies, percentages, and means, were computed to summarize the dataset. For parametric analyses, independent samples t-tests were applied to compare two group means, while one-way Analysis of Variance (ANOVA) with post-hoc tests (e.g., Tukey's HSD) was used for comparisons across multiple groups. Relationships between categorical variables were assessed using Pearson's chi-square (χ^2) test. The assumptions of normality and homogeneity of variance were evaluated using the Shapiro-Wilk and Levene's tests, respectively, and a significance level of $p < 0.05$ was considered statistically significant.

RESULTS

SOCIO DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

Table 1 presents a summary of the sociodemographic characteristics of commercial poultry farmers in Dambi Dollo and its surrounding areas. The findings indicate that poultry farming in the area is predominantly male dominated, with 73.1% of respondents being men and 26.9% women. Participation of young farmers was considerable, as 53.8% of respondents were aged between 15 and 30 years, whereas only 11.5% were in the 46–60 age bracket. Most farmers (75%) were married, highlighting the involvement of household heads in poultry production. Regarding experience, most respondents (approximately 60%) had 1–3 years of involvement in poultry farming, while less than 8% had more than six years of experience, suggesting that the sector is relatively young and emerging. In terms of educational background, 38.5% of farmers had

Table 1: Sociodemographic characteristics of commercial chicken farmers in and around Dambi Dollo.

Variable	Category	N	%	X ²	P-value
Sex of respondents	M	38	73.1	11.077 ^a	.001
	F	14	26.9		
Age of respondents	<15	3	5.8	29.077 ^b	.001
	15-30	28	53.8		
	31-45	15	28.8		
	46-60	6	11.5		
Marital status of Commercial producers	Married	39	75.0	70.154 ^b	.001
	Single	7	13.5		
	Divorced	3	5.8		
Occupation of commercial producers	Widowed	3	5.8	24.269 ^c	.001
	Farmers	32	61.5		
	Private job	17	32.7		
Family size	Govt. Employers	3	5.8	23.692 ^b	.001
	1-3	26	50.0		
	4-6	16	30.8		
	More than 6	10	19.2		
Experience in year	<3	31	59.6	21.038 ^c	.001
	3-6	17	32.7		
	More than 6	4	7.7		
Educational level	Illiterate	4	7.7	27.692 ^d	.001
	Read and write	5	9.6		
	Grade 1-4	3	5.8		
	Grade 5-8	9	17.3		
	High school	5	21.1		
	College and university	20	38.5		

*Significant effect at $P < 0.05$.

Attained college or university-level education, representing the highest educational category. Household size distribution revealed that half of the respondents (50%) had small families of 1–3 members. Additionally, 61.5% of farmers relied entirely on poultry farming as their primary source of livelihood, while the remainder engaged in mixed economic activities.

FLOCK SIZE OF CHICKS IN COMMERCIAL POULTRY FARMS IN AND AROUND DAMBI DOLLO

Table 2 provides an overview of flock sizes and breed

composition across 52 commercial poultry farms in the Dambi Dollo area. The mean flock size was 734.6 ± 20.9 birds. Female chicks (654.8 ± 24.5) outnumbered male chicks (569.2 ± 32.7), indicating a production system skewed toward females. Regarding breed distribution, Bovans Brown was the most prevalent, accounting for 55.8% (905.77 birds) of the total population, followed by Sasso T44 at 23.1% (554.62 birds) and mixed breeds at 21.2% (589.62 birds). Statistical analysis showed significant variation in flock sizes among the different breeds ($P < 0.05$), highlighting a clear preference among farmers for Bovans Brown in this region.

Table 2: Flock sizes and breed composition of commercial poultry farms in and around Dambi Dollo.

Variables		N (%)	Mean (SEM)
Flock Size		52(100%)	734.6154 (20.89343)
Sex	Female chicks	52(100%)	654.83 (24.499)
	Male chicks	18(34.6%)	569.23 (32.700)
Breed	Bovans brown (egg type)	29 (55.8%)	905.7692 (17.24053)
	Saso T44	12 (23.1%)	554.6154 (15.07513)
	Mixed	11 (21.2%)	589.6154 (12.89814)

Note: N (%) represents the number and percentage of producers; SEM denotes the standard error of the mean. Means in the same column with different superscript letters differ significantly ($P < 0.05$).

DISEASES AND SIGNS IN COMMERCIAL POULTRY FARMS

Figure 1 Shows that symptoms seen in commercial poultry farms in and around Dambi Dollo clinical signs observed in affected poultry included ruffled feathers (13.5%), appetite loss (11.5%), depression (11.5%), weight loss (9.6%), and diarrhea (7.7%). Most farmers (65.4%) reported little to no experience in managing disease outbreaks, which raises concerns regarding timely intervention. However, the study found that 98.1% of respondents maintained close contact with veterinarians for disease management.

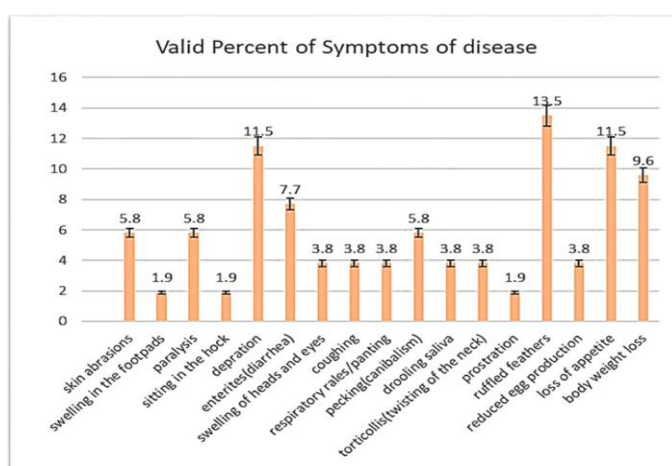


Figure 1: Symptoms seen in commercial chicken farms in and around Dambi Dollo.

DISEASE MANAGEMENT AND VETERINARY SERVICES

Table 3 illustrates the disease management practices of commercial chicken farmers in and around Dambi Dollo. Most farmers (78.8%) implemented quarantine for affected birds, and 90.4% reported experiencing disease outbreaks.

Although 98.1% of farmers reported having access to veterinarians and consulting them in case of emerging health problems, the persistence of limited disease recognition (63.5% unable to name major diseases) suggests that the farmer–veterinarian interaction is largely reactive and treatment-oriented, rather than preventive or knowledge-building. In that context, farmers often rely heavily on veterinary specialists for diagnosis and treatment rather than being actively engaged in learning about diseases, symptoms, and early identification. This is quite a common pattern in developing poultry systems, where the structure of a veterinary visit often focuses on clinical interventions and the distribution of medicines rather than structured farmer training or continuous advisory support. Hence, the high veterinary contact rate likely reflects access to services for acute care rather than effective extension-style engagement. Strengthening advisory roles, routine on-farm training, and preventive education programs should be emphasized in enhancing farmers’ disease literacy and ensuring better long-term resilience of poultry health management systems. In most cases, 80.8% of birds recovered within 1–3 days of treatment, suggesting generally effective health-care practices; this rapid recovery was primarily associated with commonly used interventions such as broad-spectrum antibiotics, anticoccidials, and supportive therapies, including vitamins and electrolytes. This may suggest that these treatments are timely and appropriate responses; however, it further points to the need for improved antimicrobial stewardship and more transparent treatment practices to make sure diseases are managed responsibly.

Table 3: Veterinary engagement and treatment in commercial chicken farms in and around Dambi Dollo.

Variables	Responses	N	%	X ²	P-value
Close relation with veterinarian	Yes	51	98.1	48.077a	0.001
	No	1	1.9		
Skilled in vaccine/treatment dissemination protocols	Yes	49	94.2	40.692a	0.001
	No	3	5.8		
Time of recovery after treatment	1-3 days	42	80.8	54.500b	0.001
	4-6 days	9	17.3		
	No recovery	1	1.9		
When do you call a veterinarian	At sickness	47	90.4	33.923a	0.001
	At death (>1 chick)	5	9.6		
Accustomed to treat chicks yourself	Yes	47	90.4	33.923a	0.001
	No	5	9.6		
Presence of isolation room	Yes	40	76.9	15.077a	0.001

Variables	Responses	N	%	X ²	P-value
	No	12	23.1		

Table 4: Vaccination practices in commercial poultry farms in and around Dambi Dollo.

Variables	Responses	N	%	X ²	P-value
Do you vaccinate your chicken	Yes	50	96.2	44.308a	0.001
	No	2	3.8		
Vaccination of the disease	NCD	21	40.4	16.423b	0.001
	Fowl pox	27	51.9		
	IBD	4	7.7		
Frequency of vaccination	Once	6	11.5	22.308c	0.001
	Twice	4	7.7		
	Thrice	17	32.7		
	Four times	25	48.1		
Adherence to vaccination schedule	Adhered	45	86.5	66.269b	0.001
	Non-adhered	7	14.5		
Do you know the name of vaccine?	Yes	39	75.0	13.000a	0.001
	No	19	25.0		

VACCINATION IN COMMERCIAL POULTRY FARMS

Table 4 shows that vaccination practices among commercial poultry farms in and around Dambi Dollo. The study recorded very high vaccination uptake, with 96.2% of farmers vaccinating their birds ($X^2 = 44.308$, $p < 0.001$), reflecting strong awareness of preventive health practices. Contrary to expected patterns in commercial poultry systems, Fowl Pox vaccination was more common than NCD vaccination (51.9% vs. 40.4%, respectively). This is notable, considering that NCD is widely recognized as one of the most devastating poultry diseases. Farmers indicated prioritizing Fowl Pox vaccination mainly because its clinical signs are visible and it is frequent in the area, coupled with reportedly stronger local promotion by veterinary extension agents during vaccination campaigns. On the other hand, some farmers may have perceived NCD vaccines as less available, or assumed routine government-driven vaccinations were enough to neutralize the risk of this disease. These findings suggest that vaccine prioritization in the study area may be dictated by perceived local disease pressure, vaccine availability, and advisory guidance rather than global risk profiles,

emphasizing the need for an education that is going to boost farmers’ awareness on the critical position of NCD in poultry management programs.

The highest proportion of respondents practiced fowl pox vaccination, 51.9%, followed by Newcastle Disease, 40.4%, and Infectious Bursal Disease was the least considered, at 7.7%. Although these figures indicate significant differences in vaccine adoption, deeper interpretation points toward very important behavioral and management drivers. Farmers very often mentioned prioritizing fowl pox vaccination because of the presence of clinical signs and perceived long-term impact on production, while Newcastle Disease vaccination, despite its well-recognized severity, was occasionally delayed or incompletely applied due to managerial challenges of handling the vaccine, incomplete cold-chain systems, and uncertainty about proper revaccination schedules. The lowest level of Infectious Bursal Disease vaccination has reflected both poor awareness of its economic importance and poor local availability of the vaccine. These data underscore the need for enhanced farmers’ education and adequate systems of vaccine distribution to ensure balanced and efficient strategies of disease prevention.

FARM MANAGEMENT, DISEASE CONTROL AND PREVENTIVE STRATEGIES IN COMMERCIAL POULTRY

Table 5 presents farm management practices and reporting among commercial poultry farms in and around Dambi Dollo. The survey revealed that coccidiosis was the most common disease, affecting 36.5% of the farms. However, 63.5% of producers were unable to identify the specific diseases present in their flocks, indicating a lack of disease awareness and diagnostic skills. The study also found that 65.4% of producers lacked experience in managing or reporting disease outbreaks, reflecting limited preparedness and access to veterinary extension services

Most farmers (90.4%) administered treatments themselves but sought veterinary consultation when birds became seriously ill. Record-keeping was strong, with 86.5% maintaining farm records.

SEASONAL TRENDS AND COST CONSIDERATIONS IN COMMERCIAL POULTRY FARMS

Seasonal loss patterns and cost perceptions among poultry producers in and around Dambi Dollo revealed that mortality peaks occurred during the long rainy season (32.7%), although this trend was not statistically significant ($p = 0.511$). Most farmers (69.2%) considered vaccines affordable, while 23.1% perceived them as costly. Additionally, a strong preference for prevention over treatment was observed, with 92.3% prioritizing preventive measures, indicating good awareness of cost-effective disease control practices.

Table 5: Farm management and reporting in commercial poultry farms in and around Dambi Dollo.

Variables	Responses	N	%	X ²	P-value
Immediate measure for sick birds	Isolation + follow-up	41	78.8	17.308a	0.001
	Isolation + treat	11	21.2		
Experiences for disease outbreak	Yes	18	34.6	4.923a	0.027

Variables	Responses	N	%	X ²	P-value
Reporting of disease outbreak	No	34	65.4	33.923a	0.001
	Yes	47	90.4		
Type of disease frequently occurred	No	5	9.6	3.769a	0.052
	Coccidiosis	19	36.5		
	Don't know	33	63.5		
Accustomed to record the disease	Yes	45	86.5	27.769a	0.001
	No	7	13.5		

Table 6: Mortality and risk factors in commercial poultry farms in and around Dambi Dollo.

Variables	Responses	N	%	X ²	P-value
Major disease control measures	Prevention	48	92.3	37.231a	0.001
	Treatment	4	7.7		
High mortality age	1-3 weeks	31	59.6	17.577b	0.001
	4-6 weeks	14	26.9		
	>6 weeks (adult)	7	13.5		
Season of high loss	Long dry (Oct-Jan)	10	19.2	2.308c	0.511
	Short rainy (Feb-Mar)	11	21.2		
	Short dry (Apr-May)	14	26.9		
	Long rainy (Jun-Sep)	17	32.7		
Reason for mortality	Transportation stress	25	44.6	22.769b	0.001
	Overcrowding	17	30.4		
	Cannibalism	7	12.5		

Variables	Responses	N	%	X ²	P-value
Type of mortality	Unclear	3	5.4	25.077b	0.001
	Sudden death	34	65.4		
	Sporadic	18	34.6		
Mortality rate	Reported	4	7.7	-	-
Survival rate	Reported	48	92.3	-	

MORTALITY IN COMMERCIAL POULTRY FARMS

Table 6 shows the mortality profile of commercial poultry farms in and around Dambi Dollo. Mortality was greatest in (1-3 weeks: 59.6%), and sudden death was most frequent (65.4%). Transport stress (44.6%) and overcrowding (30.4%) were prominent causes of mortality, indicating areas where management may be improved. Most chicks within the study area originate from far regional hatcheries; thus, they need many hours to travel under fluctuating handling and temperature conditions. This may seriously increase the level of stress and predisposition to early mortality. Improving transport through proper ventilation, temperature control, shorter delivery intervals, and using trained handlers, coupled with encouraging the establishment of nearer hatchery supply points, would significantly help reduce the losses in transportation.

BIOSECURITY ON COMMERCIAL POULTRY FARMS

Table 7 illustrates the biosecurity practices implemented by commercial poultry farms in and around Dambi Dollo. The findings reveal that poultry farmers generally maintained a fairly high compliance with key biosecurity protocols. The use of protective clothing was fully complied with by 73.1% of the respondents ($X^2 = 11.077$, $p < 0.001$), followed by foot baths and boots, both 67.3% ($X^2 = 6.231$, $p = 0.013$), while gloves were used by only 30.4% of farmers. In discussions, many farmers did not consider gloves to be as critical for everyday handling of birds, and some farmers reported discomfort and limited availability. Gloves seem to be perceived as secondary or only necessary in cases of outbreaks, whereas boots or overalls have been adopted as an integral part of everyday farm activities.

Table 7: Biosecurity practices in commercial poultry farms in and around Dambi Dollo.

Variables		N	%	X ²	Value
Presence of foot bath	Yes	35	67.3	6.231a	0.013
	No	17	32.5		
Wearing protective clothes	Yes	38	73.1	11.077a	0.001
	No	14	26.9		
Using hand gloves	Yes	17	30.4	6.231a	0.013
	No	35	62.5		
Wearing boots	Yes	35	67.3	6.231a	0.013
	No	17	32.7		

Most farms reported using formalin or berkina disinfectant in foot baths, typically prepared at an estimated concentration of about 2–5% based on farmer responses. Solutions were generally replaced every 2–7 days, depending on farm activity and resource availability. While these practices reflect a willingness to maintain hygiene, variability in concentration and replacement frequency suggests that some farms may have suboptimal foot bath efficacy. Strengthening farmers' knowledge of appropriate disinfectant concentration and regular changing schedules is therefore imperative, given that poorly maintained foot baths can compromise biosecurity and increase disease transmission risk. The study revealed that commercial poultry farmers in Dambi Dollo face several challenges, including limited knowledge of poultry diseases, insufficient disease management and reporting, and gaps in biosecurity practices. Among biosecurity measures, 73.1% of producers used protective clothing (tuta), 30.4% used gloves, and 67.3% used boots. Footbaths were widely implemented, with 77.6% of farmers applying disinfectants such as formalin or berekina at farm entrances. Small-scale farms were observed to have comparatively weaker biosecurity practices. Additionally, vaccination coverage was generally high, but some gaps remained, particularly regarding low-coverage vaccines like Infectious Bursal Disease.

DISCUSSION

The predominance of male respondents in this study is consistent with prior research highlighting male dominance in agricultural enterprises across Africa (Awoke *et al.*, 2024). This trend may be attributed to cultural norms, disparities in asset ownership, and gender-specific labor divisions. Additionally, the high participation of youth (53.8%) aligns with findings by Ipara *et al.* (2023), suggesting an increasing interest among younger populations in poultry agribusiness as a viable livelihood and income-generating option. Limited involvement of older individuals may be associated with the physically demanding nature of poultry management or a preference for less labor-intensive occupations.

The observation that 75% of respondents were married indicates greater engagement of household heads in commercial poultry ventures. Marriage may provide advantages such as shared labor, financial stability, and family support systems, comparable to findings reported by Rietveld *et al.* (2023) and Naidoo and Kodjo (2023). Most respondents had only 1–3 years of experience in poultry farming, suggesting that the sector is still developing in the region. This may reflect growing market opportunities and recent policy attention, yet may also highlight challenges such as disease burden, input constraints, and market volatility leading to high turnover rates. Therefore, strengthening capacity-building initiatives, including technical training and extension support, remains essential. The relatively high proportion of educated respondents (38.5% with tertiary education) underscores the role of formal education in facilitating adoption of improved production and management technologies, consistent with reports from the Ministry of Agriculture (2022) and Nwobodo *et al.* (2023). Likewise, small household sizes and the reliance of 61.5% of respondents solely on farming suggest increased specialization in poultry production, in line with observations by Awoke *et al.* (2024) and Gonta (2023). Overall, the sociodemographic attributes gender, age, marital status, education, and farming experience were significant determinants of participation and performance in poultry production ($p < 0.001$). These findings reinforce the importance of youth-focused support programs, gender-responsive interventions, and strengthened training systems to foster sustainable commercial poultry development in Ethiopia, consistent with recommendations from Mohd Suib *et al.* (2023).

Furthermore, the predominance of female chicks reflects typical commercial poultry production practices where female birds are prioritized for egg-laying purposes. This trend aligns with national statistics indicating that female poultry make up approximately 68–72% of the total flock in Ethiopia (Muriithi, 2023) and corresponds with observations by Sinclair *et al.* (2022).

The preference for Bovans Brown (55.8%) reflects its popularity in commercial egg production due to its high laying performance, adaptability, and productivity. This aligns with national reports indicating 58–62% adoption of Bovans Brown strains in Ethiopian commercial poultry farms (Vlaicu *et al.*, 2024). The significant influence of breed type on flock size suggests that producers strategically select high-performing breeds to enhance productivity and profitability.

The high occurrence of coccidiosis aligns with literature identifying it as a major poultry disease in intensive systems, often associated with hygiene and litter challenges (Cornell, 2020). The large proportion of farmers unable to

diagnose diseases highlights a significant knowledge gap, like the findings of (Billy and Nairobi 2019), and underscores a risk to effective disease control. The absence of record-keeping further hinders timely and targeted interventions, consistent with Mohsin and Mehak (2024) who emphasize the importance of documentation for health monitoring. Producers' attribution of disease to environmental and management-related factors supports the notion that poultry health challenges are multifactorial, in agreement with (Grace *et al.* 2024). The limited disease management experience (65.4%) highlights inadequate veterinary support systems, which could delay response to outbreaks and increase economic loss, as noted by Tao *et al.* (2021). These results emphasize the need to strengthen farmer training, biosecurity practices, and veterinary extension services. The clinical signs recorded in this study correspond with those reported by (Bezabih *et al.*, 2017). The limited experience in dealing with disease outbreaks mirrors findings from Kaduna, Nigeria, where farmers did not frequently report disease cases due to limited management knowledge (Analysis of Farm Enterprise Combinations Under Risk, 2021). However, unlike the Nigerian case where veterinary support was limited (Nu'man, 2023), the high level of veterinary consultation (98.1%) among Dambi Dollo producers indicates a positive trend toward improved disease surveillance and control. This underscores the importance of veterinary access in reducing poultry health risks and improving production outcomes.

The high rate of quarantine practice (78.8%) exceeds reported levels in Nigeria and Tanzania (60–65%) as noted by Ekiri *et al.* (2025) and Lai *et al.* (2023), indicating stronger biosecurity awareness in Dambi Dollo farms. Similarly, the outbreak reporting rate of 90.4% surpasses the 55–70% reported in other Ethiopian production systems (Phonde, 2004), reflecting improved transparency and disease surveillance. Veterinary contact rates (98.1%) were substantially higher than Kenya's 82% (Bahta *et al.*, 2023) and Uganda's 75% (Deiana *et al.*, 2024), suggesting better access to veterinary support in the study area. However, knowledge gaps persist, with 63.5% unable to identify common poultry diseases consistent with observations in Ghana (Boansi *et al.*, 2024) and India (Sharma *et al.*, 2022). The rapid recovery rate (80.8%) aligns with reports from South African commercial poultry farms (85–90%) (Moeletsi *et al.*, 2023), indicating effective treatment response. Collectively, these findings highlight strong veterinary engagement but emphasize the need for enhanced farmer training in disease recognition and preventive health management.

The high vaccination coverage (96.2%; $X^2 = 44.308$, $p < 0.001$) in Dambi Dollo exceeds the reported range of 72–85% in other Ethiopian regions (Asfaw *et al.*, 2021) and surpasses neighboring countries where vaccination rates range from 65–80% (Ababa, 2023). Prioritization of Fowl pox (51.9%) over Newcastle Disease (40.4%) contrasts with global patterns that rank NCD vaccination at 60–75% (Oie, 2023). The very low coverage of Infectious Bursal Disease vaccination (7.7%) aligns with findings from the Amhara region (Alemu *et al.*, 2024), highlighting a national consistency in low IBD prevention. These results also mirror findings from Nigeria, where farmers practice routine multiple vaccination, particularly against Gumboro, NCD, and Fowl pox (Negash *et al.*, 2022). However, the lower vaccination rates reported in Bahir Dar (Bereket *et al.*, 2022) show regional disparities in vaccine use. Although Dambi Dollo demonstrates strong vaccination commitment, improving access and awareness for under-prioritized vaccines like IBD remains critical to strengthening overall poultry health security.

The high rate of farmer-led treatment (90.4%) aligns closely with findings from Tanzania (88%) and Kenya (85%), where smallholder and semi-commercial farmers similarly prefer first-line self-treatment before veterinary engagement (Ouma *et al.*, 2023). The adoption of isolation units in Dambi Dollo (76.9%) surpasses Nigeria's 62% (Entsua-Mensah *et al.*, 2022), suggesting better awareness of disease containment. Chick mortality in the first 1–3 weeks (59.6%) is consistent with global trends reported by (Rana *et al.* 2023), emphasizing universal vulnerability of young birds. However, transport-related mortality (44.6%) was notably higher than Uganda's 35% (Applestein *et al.*, 2021), suggesting logistical and handling constraints in the local supply chain. These findings reflect generally good management practices but point to opportunities for improvement, particularly in chick transport systems, brooding management, and reducing overcrowding-related losses.

The rainy-season mortality peak (32.7%) closely matches the 35% reported in Zambia (Oduma *et al.*, 2023), but contrasts with Sudan's dry-season mortality pattern (Ahmed *et al.*, 2025), highlighting regional climatic influences on disease dynamics. Farmer perception of vaccine affordability (69.2%) is higher than the 55% reported in Ghana (Donkor *et al.*, 2025), suggesting better access or pricing in the study area. Moreover, the strong focus on prevention (92.3%) exceeds reported rates in Nigeria (78%; Tesfaye and Mohammed, 2023), indicating higher awareness and adoption of proactive biosecurity measures among Ethiopian poultry farmers. Collectively, these trends imply positive economic awareness regarding disease prevention despite seasonal vulnerability.

The observed chick mortality (13.5%) exceeds the recommended threshold of $\leq 5\%$ by the third week (Hameed and Ahmed, 2019), indicating areas for improvement in early chick care and transport management. The seasonal mortality peak during the rainy period aligns with weather-associated challenges documented in other regions. Risk factors such as transport stress and overcrowding correspond with previous findings from (Matebie *et al.*, 2023) and Mangan and Siwek (2024), who also reported management stressors as leading contributors to early poultry mortality. Thus, despite overall manageable mortality rates, targeted interventions for chick transport practices, brooding management, and density control are necessary to further reduce losses.

The level of protective clothing usage in Dambi Dollo (73.1%) surpasses that reported in Nigeria (58%; Ekakoro *et al.*, 2025), highlighting stronger compliance in this study area. Footbath utilization (67.3%) also exceeds rates recorded in Tanzania (52%; Ouma *et al.*, 2023), suggesting a higher level of awareness regarding contamination control. However, glove use (30.4%) remains low, reflecting similar gaps noted in other African poultry systems (Getso and Hassan, 2020). Footbaths and protective clothing play crucial roles in limiting pathogen entry, and widespread use in Dambi Dollo demonstrates positive commitment toward disease prevention. Nonetheless, comprehensive biosecurity demands integrated practices beyond personal protective equipment, including proper facility hygiene, movement control, waste disposal, and effective communication between farms. Strengthening glove use and reinforcing full-spectrum biosecurity. The results underscore the critical need for farmer training and awareness programs to improve disease recognition, reporting, and management. Comparisons with other studies indicate similar patterns: Nusirat *et al.* (2012) reported that 35.1% of respondents did not use protective clothing, and 18.9% used gloves, while Getso and Hassan (2020) and Birhanu *et al.* (2015) observed high adoption of protective clothing and foot baths in Ethiopian farms.

The use of footbaths (77.6%) aligns with findings in Mekelle, where 80% of farms practiced entrance disinfection (Tadesse *et al.*, 2024). Nevertheless, small-scale farms remain at risk due to weak biosecurity, which can facilitate the introduction of infectious agents (Olakiumide, 2021; Kithome *et al.*, 2022). Enhancing disease control, vaccination adherence, and comprehensive biosecurity practices is essential for reducing losses and improving productivity. Targeted farmer training, better access to veterinary services, and robust preventive measures will contribute to more sustainable commercial poultry farming systems in the region (Grace *et al.*, 2024).

CONCLUSION

A study in Dambi Dollo, Ethiopia, recognized the major shortcomings in poultry disease management, including low disease awareness in 63.5% of farmers, infrequent biosecurity with only 30.4% glove use, high early chick mortality of 59.6%, and seasonal outbreaks with 32.7% rainy-season mortality. The other problems were transport stress at 44.6%, vaccine effectiveness concerns despite 96.2% coverage, and inadequate veterinary coordination. To tackle these issues effectively, a multi-sectoral approach involving government departments, veterinary department, and poultry farmers' associations is required. Solutions proposed include the establishment of farmer training to improve knowledge on diseases, mandating better biosecurity measures, better brooding, and implementing climate-adapted practices. Furthermore, implementing quality control on vaccine handling, improving transport conditions, and strengthening veterinary collaboration via mobile clinics or extension services would also weaken disease pressures and mortality. Marrying such targeted interventions with infrastructural investments like climate-controlled poultry houses would allow the poultry industry in Dambi Dollo to achieve sustainable flock health improvements and overall productivity.

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NOVELTY STATEMENT

This is a first-of-its-kind study to assess the effectiveness of disease control measures and biosecurity in the poultry farms of the region: namely, the town of Dambi Dollo in Western Ethiopia, pointing out the important gaps that exist in this regard.

AUTHOR CONTRIBUTION

All authors equally contributed to the study design, data interpretation, manuscript writing, and review.

DATA AVAILABILITY

The datasets generated and analyzed during the current study are available from the corresponding authors upon reasonable request.

ETHICS STATEMENT

All procedures involving animals were reviewed and approved by the Animal Use and Ethics Committee, South Africa University, College of Environmental Sciences – Animal REC (Approval No. 2024/CAES_AREC/5937).

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CHAPTER 5

.: “Assessment of housing, management, and biosecurity practices in commercial poultry farms around Dambi Dollo Town, Western Ethiopia.

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Abstract

This study evaluated housing systems, management practices, and biosecurity measures implemented in commercial poultry farms located in and around Dambi Dollo town, situated in the Kellem Wollega Zone of Western Oromia, Ethiopia. The study was undertaken using a semi-structured questionnaire data collection from 52 commercial poultry farmers, as well as observational data. The study revealed that commercial farmers in the present study were predominantly male (73.1%), within the age range between 15–30 (53.8%), and experienced poultry farmers (75%). Most of the farms had intensive production systems 94.5 with deep litter housing (73.1%). Flock size varied with a mean of 734 birds, of which the majority were Bovans Brown layers. Hygiene and biosecurity measures varied significantly between farms. While 80.8% farms were using commercial feed and 75% farms had proper storage facilities, however, rodents' infestation (96.2%) and predators (94.2%) were among the major constraints identified. Quality Ventilation, cleaning frequency, litter renewal, and the use of disinfectants were strongly associated with farm cleanliness. Interestingly, 78.8% of farmers were practicing bird culling primarily due to stunted growth or deformities, that most of the culled birds were being sold. The study highlights the need for stepped-up farmer training, improved predator control, and coordinated biosecurity practices to enhance poultry productivity and health. The findings form a platform for targeted interventions and policy formulation to boost the commercial poultry sector in the region.

Key Words: Commercial- Poultry, Farming, Housing, Management

Introduction

Poultry production is a significant component of rural agricultural economies in developing countries, among the major in providing animal protein and a source of income for many people (Erdaw and Beyene 2022). In Ethiopia, the sector is mostly controlled by backyard production systems, yet with commercialization fueled by growing consumer demand, there is significant and expanding commercialization. This trend is crucial for enhancing food safety, poverty reduction, and rural economic development (Giller et al. 2021).

Increase in poultry production is considerably dependent on the acceptance of appropriate housing systems and sound management practices (Aslam et al. 2020). Key factors such as design of house, biosecurity level, feed and water management, veterinary medicine, and effective marketing outlets are critical factors of productivity, profitability, and overall farm sustainability (Aslam et al. 2020). Absence or insufficiency of any of the above may lead to a colossal loss due to the outbreak of disease, poor feed conversion, and high mortality, thereby undermining the viability of the venture.

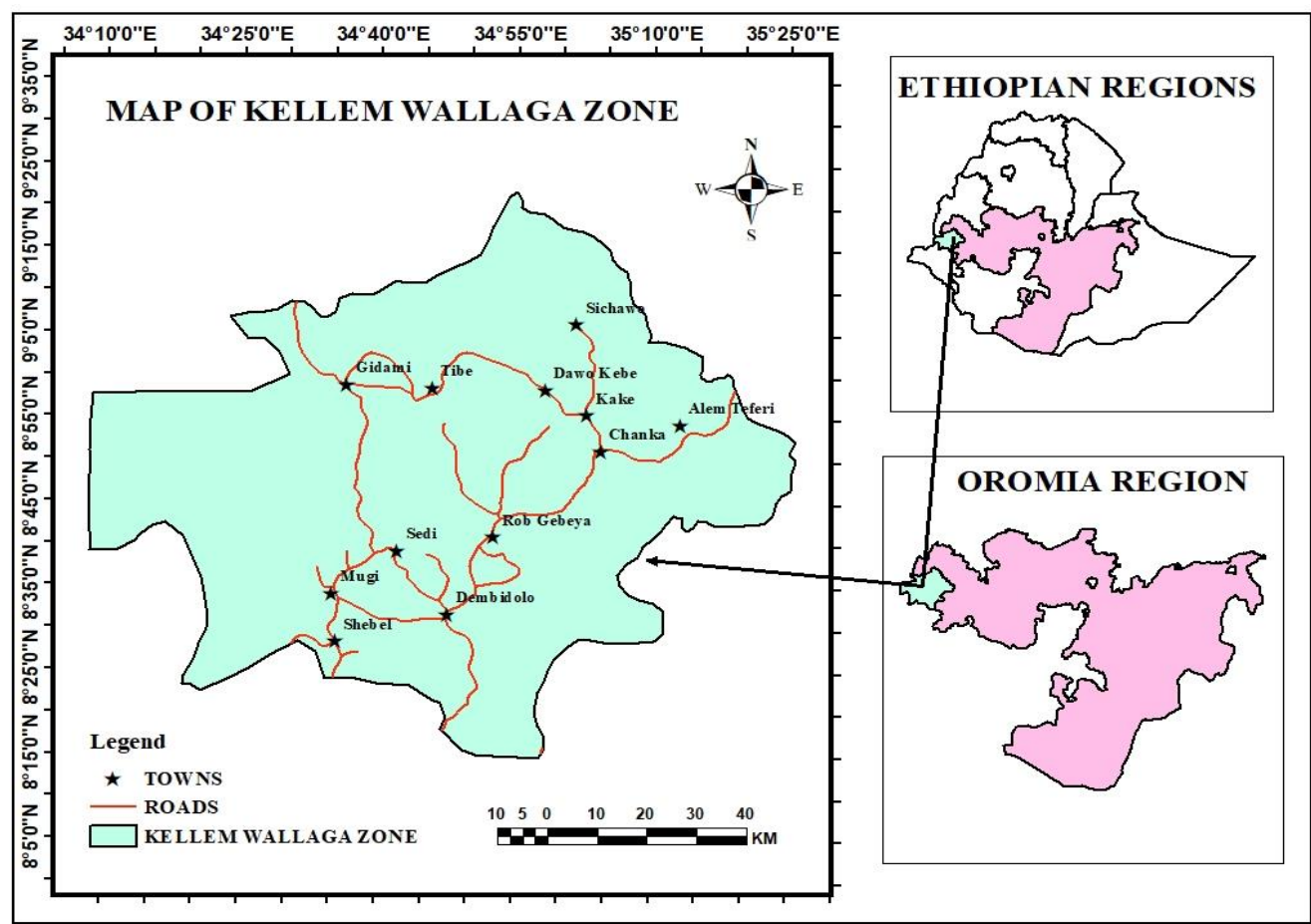
Although the industry is expected to face multi-faceted challenges, commercial poultry production in western regions of Ethiopia, e.g., the Kellem Wollega Zone, is suspected to be hampered by inadequate capital and quality input supply, infrastructure, and pervasive disease and pest pressure (Degefa, Biru, and Abebe 2020). However, a scientific assessment of the prevailing housing and management systems in this specific region has been lacking. Such a study is critical to establish current strengths, to flag major constraints, and to inform the development of well-focused interventions (Wolfgring and Peverini 2024).

Therefore, this study was set out to assess commercial poultry housing and management within and around Dambi Dollo town, western Ethiopia. It aims to determine a general benchmark evaluation of socio-demographic factors, bird types, housing systems, feeding and watering management, financial resources, record-keeping, and the general problems of predators and pests (FAO 2020). The findings are expected to help policymakers, extension agents, and investors in designing plans for improving productivity and ensuring the sustained development of the commercial poultry industry in the region. Specifically, the study aimed **(i) to evaluate the socio-demographic characteristics of poultry farm owners, (ii) to identify the types of poultry breeds and housing systems practiced, (iii) to assess feeding, watering, and health management practices, (iv) to examine financial management and record-keeping systems, and (v) to identify the major constraints such as predators, pests, and disease challenges affecting poultry production.** The findings of this study will provide valuable information for policymakers, extension workers, and investors to design effective intervention strategies for improving poultry productivity and ensuring sustainable development of the poultry sector in the region.

Materials and Method

The ethical clearance for this study was approved in general mainly for the experimental study employed on live animals (specifically, Sasso-C44 broilers). Of course, not particular to the methodology in each chapter.

Description of the Study Area



Study area map

Dambi Dollo is situated in the Kellem Wollega Zone of the Oromia Region, approximately 642 km west of Ethiopia’s capital, Addis Ababa. The zone encompasses an estimated landmass of 987,457 ha and shares its boundaries with West Wollega to the north, Buno Bedele to the east, Ilu Aba Bora to the south, and the Gambella Region to the west. Elevation within the zone varies widely, ranging from 200 to 3,450 meters above sea level. Ecologically, the area is divided into three major agro-ecological zones: highland (26.1%), midland (41.4%), and lowland (32.5%). The climate is characterized by temperatures fluctuating between 10°C and 34°C, with an annual rainfall distribution ranging from 1,400 mm at the lower end to as high as 3,200 mm (Kumsa et al., 2024).

Research Design and Data Collection Method

A structured survey complemented by direct field observations was conducted to assess housing conditions and management practices among commercial poultry producers. Information was obtained using a pre-tested,

semi-structured questionnaire administered through face-to-face interviews with farm managers and supervisors. The study focused on gathering detailed insights regarding disease management strategies and the biosecurity measures implemented across commercial poultry operations.

Statistical Analysis

The data collected were initially organized and cleaned up using Microsoft Excel, after which they were transferred to SPSS version 29 for detailed statistical analysis. Descriptive statistics, including frequencies, percentages, and means, were generated to summarize key findings. Inferential analyses employed parametric techniques, with independent sample t-tests used to compare mean differences between two groups and one-way ANOVA applied for comparisons involving more than two groups, followed by appropriate post-hoc procedures such as Tukey’s HSD. Associations between categorical variables were assessed using Pearson’s chi-square (χ^2) test. Before conducting parametric tests, data were evaluated for normality using the Shapiro–Wilk test and for homogeneity of variance using Levene’s test. Statistical significance was established at a threshold of $p < 0.05$.

Results

Socio-demographic characteristics

Table 1 outlines the socio-demographic profile of commercial poultry producers operating in and around Dambi Dollo. The results highlighted distinct demographic trends: most of the respondents were male (73.1%) and predominantly young, with 53.8% falling between 15 and 30 years of age. Moreover, 75% of participants were married. In terms of occupation, most respondents identified primarily as farmers (61.5%), while 50% reported being household members. Poultry farming experience was generally modest; 75% had previous experience, and among them, 59.6% had been engaged in the activity for 1–3 years.

Educational attainment showed that 38.5% of respondents held a college or university degree. Household sizes were also relatively small, with 50% comprising 1–3 members. Occupational engagement further demonstrated that 61.5% relied exclusively on agriculture, 32.7% combined farming with trading activities, and 5.8% reported other secondary occupations. Chi-square analysis revealed statistically significant differences across all socio-demographic variables ($p < 0.001$). Notably, gender, marital status, and educational level each exerted a significant influence ($p < 0.05$) on commercial poultry farming participation and practices.

Table 1. Socio-demographic characteristics of commercial poultry farms in and around Dambi Dollo.

Variable	Category	N	%	X ² (Chi-square)	P-value
Sex of respondents	M	38	73.1	11.077 ^a	.001
	F	14	26.9		
Age of respondents	<15	3	5.8	29.077 ^b	.001
	15-30	28	53.8		

Marital status of Commercial producers	31-45	15	28.8	70.154b	.001
	46-60	6	11.5		
	Married	39	75.0		
	Single	7	13.5		
Occupation of commercial producers	Divorced	3	5.8	24.269c	.001
	Widowed	3	5.8		
	Farmers	32	61.5		
	Private job	17	32.7		
	Govt. Employers	3	5.8		
Family size	1-3	26	50.0	23.692b	.001
	4-6	16	30.8		
	More than 6	10	19.2		
Experience in year	<3	31	59.6	21.038c	.001
	3-6	17	32.7		
	More than 6	4	7.7		
Educational level	Illiterate	4	7.7	27.692d	.001
	Read and write	5	9.6		
	Grade 1-4	3	5.8		
	Grade 5-8	9	17.3		
	High school	5	21.1		
	College and university	20	38.5		

Flock size of chicks in commercial poultry farms in and around Dambi Dollo

As summarized in Table 2, flock size and breed distribution were assessed across 52 commercial poultry farms located in and around Dambi Dollo town. The findings indicated an average flock size of 734.6 ± 20.9 birds. Female chicks (654.8 ± 24.5) were kept in noticeably higher numbers compared to male chicks (569.2 ± 32.7). With respect to breed composition, Bovans-Brown birds were the most prevalent, accounting for 55.8% of the flocks (mean = 905.8 birds). This was followed by Saso-T44 (23.1%, mean = 554.6 birds) and mixed genetic stock (21.2%, mean = 589.6 birds). Despite variations in breed distribution, statistical analysis showed that breed type did not significantly affect mean flock size ($P > 0.05$).

Table 2. Flock size and chick breeds in commercial poultry farms in and around Dambi Dollo town

Variables		N (%)	Mean (SEM)
Flock Size		52(100)	734.6154 (20.893)
Sex	Female chicks	52(100%)	654.83 (24.499)
	Male chicks	18(34.6%)	569.23 (32.700)
Breed	Bovans brown (egg type)	29(55.8%)	905.7692 (17.240)
	Saso T44	12(23.1)	554.6154 (15.07)
	Mixed	11(21.2)	589.6154(12.898)

N= number of respondents

Housing Management Practices in Commercial Poultry Production

Table 3 depicts Housing Management Characteristics in Commercial Poultry Farms. An evaluation of various housing and management practices in poultry farms revealed a strong preference for intensive management systems, which were used by a significant majority of farms (94.2%) compared to semi-intensive systems (5.8%) ($\chi^2 = 49.692$, $p = 0.001$). Furthermore, regarding the type of house, a deep litter system was the most widely used method (73.1%), as a significant finding ($\chi^2 = 11.007$, $p = 0.001$) over cages (26.9%).

However, the specific floor type within the deep litter system was not significantly related to farmer preference ($\chi^2 = 1.231$, $p = 0.267$), Concrete deep litter (57.7%) and soiled deep litter (42.3%) were the main litter materials used; however, the difference was not statistically significant ($P > 0.05$). Similarly, neither house orientation (East-West: 55.8%, North-South: 44.2%) nor the primary construction material (full cement: 55.8%, partial cement: 44.2%) showed a significant difference ($\chi^2 = 0.692$, $p = 0.405$).

Table 3 Housing Management Characteristics in Commercial Poultry Farms

Category	system	N	%	χ^2	(p-value)
Management System	Intensive	49	94.2	49.692	0.001
	Semi Intensive	3	5.8		
Housing Type	Deep litter	38	73.1	11.007	0.001
	Cage system	14	26.9		
Floor Type	Concrete deep litter	30	57.7	1.231	0.267
	Soiled deep litter	22	42.3		
House Orientation	East-West	29	55.8	0.692	0.405
	North-South	23	44.2		
Construction Material	Full cement	29	55.8	0.692	0.405
	Partial cement	23	44.2		
Bedding Material	Straw	17	32.7	6.231	0.013

Category	system	N	%	χ^2	(p-value)
Cleaning Frequency	Wood shavings	35	67.3	16.423	0.001
	Weekly	21	40.4		
	Monthly	27	51.9		
	Per production cycle	4	7.7		
Disinfectant Use	Formalin only	15	28.8	9.308	0.002
	Formalin+Berekina	37	71.2		
Stocking System	All-in-all-out	44	84.6	19.692	0.001
	Continuous	8	15.4		
Ventilation Quality	Good	3	5.8	18.38	0.001
	V Good	21	40.4		
	Excellent	28	53.8		

N = number of respondents

Meanwhile, substantial variations were observed in the bed material used ($\chi^2 = 6.231$, $p = 0.013$), with wood shavings (67.3%) being significantly more common than straw (32.7%). Additionally, cleaning frequency was highly divergent and significantly associated ($\chi^2 = 16.423$, $p = 0.001$); monthly cleaning was the most common practice (51.9%), followed by weekly cleaning (40.4%), while cleaning only per production cycle was the least common (7.7%). Consequently, in line with these cleaning routines, the application of disinfectants also showed a statistically significant difference ($\chi^2 = 9.308$, $p = 0.002$), as 71.2% of farms used a combination of formalin and Bere kina (sodium hypochlorite), whereas 28.8% used formalin alone. The stocking method was inclined towards the all-in-all-out system (84.6%) over continuous stocking (15.4%) ($\chi^2 = 19.692$, $p = 0.001$). Lastly, the quality of ventilation varied significantly across the farms ($\chi^2 = 18.38$, $p = 0.001$), with most reporting good ventilation (53.8%), followed by very good (40.4%), and a few indicating poor ventilation (5.8%).

Feeding Management Practices of Commercial Poultry Farms in the Study Area

Table 4 depicted feed management practices on commercial poultry farms where most farms (80.8%) utilized commercial feed, while only 19.2% did not ($\chi^2 = 19.692$, $p = 0.001$). Furthermore, regarding the specific origin of the feed, a combination of commercial and farm-made feed was the most prevalent practice (51.9%). The majority of poultry producers used mixed feeding practices, while 46.2% relied exclusively on commercial feed. The use of homemade feed was minimal (1.9%), showing a statistically significant difference among feeding practices ($\chi^2 = 23.346$, $p = 0.001$). However, the direct source for procuring this feed was diverse and not statistically different ($\chi^2 = 5.692$, $p = 0.058$), nevertheless, it showed a moderate reliance on intermediaries, with 46.2% of farms obtaining feed from retailers, 34.6% from feed mills, and 19.2% directly from factories. Additionally, the study found that most respondents (76.9%) knew feed nutrient composition, a statistically significant finding ($\chi^2 = 15.077$, $p = 0.001$). Similarly, a significant majority (80.8%) were aware of the amount of feed provided per bird ($\chi^2 = 15.077$, $p = 0.001$). Consequently, the frequency of feeding also showed differences, with twice-daily feeding being the standard practice for most farms (71.2%), followed by once a day (15.4%) and three times a day (13.5%) ($\chi^2 = 24.923$, $p = 0.001$). In addition, a large proportion of farms (75%) possessed special storage facilities for feed, result ($\chi^2 = 13.00$, $p = 0.001$). Meanwhile, for storage duration, there was a strong association ($\chi^2 = 19.692$, $p = 0.001$) showing that short-term storage of 1–4 months was very common (80.8%) , while only 19.2% kept feed for 5–8 months.

Table 4. Feed Management Practices in Commercial Poultry Farms

Attribute	Category	N	%	χ^2	(p-value)
Commercial Feed Use	Yes	42	80.8	19.692	0.001
	No	10	19.2		
Feed Type	Commercial only	24	46.2	23.346	0.001
	Farm-produced only	1	1.9		
	Mixed	27	51.9		
Feed Source	Factories	10	19.2	5.692	0.058
	Retailers	24	46.2		
	Feed mills	18	34.6		

Attribute	Category	N	%	χ^2	(p-value)
Nutrient Awareness	Know composition	40	76.9	15.077	0.001
	Unaware	12	23.1		
Feed Quantity	Know amount/bird	42	80.8	15.077	0.001
	Unaware	10	19.2		b
Feeding Frequency	Once	8	15.4	24.923	0.001
	Twice	37	71.2		
	Trice	7	13.5		
Feed Storage	Have storage	39	75	13.00	0.001
	No storage	13	25		
Storage Duration	1-4 months	42	80.8	19.692	0.001
	5-8 months	10	19.2		

Water Supply and Management Practices of Commercial Poultry Operations

Table 5 summarizes water provision and management practices in commercial poultry farms.

An assessment of water availability and management practices in commercial poultry farms, analyzed via Chi-square tests, revealed significant universal provision of water, with 98.1% of farms reporting availability and 1.9% having none ($\chi^2 = 48.077$, $p = 0.001$). Furthermore, regarding monitoring, 69.8% of respondents were significantly ($\chi^2 = 9.308$, $p = 0.002$) aware of the amount of water provided per bird, while 28.3% were not. Additionally, the sources of water varied across farms. The frequency of sources was significant ($\chi^2 = 4.923$, $p = 0.027$), with piped water being the most common (48.1%); however, a substantial proportion of farms still relied on groundwater sources, including wells (36.5%) and boreholes (15.4%). Consequently, the frequency of watering also differed significantly ($\chi^2 = 26.923$, $p = 0.001$). Most farms (65.4%) provide water, and (always available),. Meanwhile, others provided water three times a day (26.9%) or twice a day (7.7%), practices that are nevertheless less common than the optimal method.

Table 5. Water Provision and Management in Commercial Poultry Farms

Attributes	Category	N	%	χ^2	(p-value)
Water Access	Available	51	98.1	48.077	0.001
	Not available	1	1.9		
Quantity Awareness	Know amount	37	69.8	9.308	0.002
	Unaware	15	28.3		
Water Source	Pipe water	25	48.1	4.923	0.027
	Borehole	8	15.4		
	Well water	19	36.5		
Watering Frequency	Ad libitum	34	65.4	26.923	0.001
	Twice daily	4	7.7		
	Thrice daily	14	26.9		

N; Number of respondents

Poultry Marketing Channels and Challenges in Commercial Poultry Farms

A study exploring the marketing practices and challenges of commercial poultry farmers utilized Chi-square tests to analyze significant differences among various factors. The findings revealed that retailers were the predominant purchasers ($\chi^2 = 6.231$, $p = 0.013$), accounting for 67.3% of sales, compared to 32.7% from town residents.

Table 6. Marketing Practices, Distribution Channels, and Challenges in Commercial Poultry Production

Category	Subcategory	N	%	χ^2	(p-value)
Buyer Type	Retailers	35	67.3	6.231	0.013
	Town dwellers	17	32.7		
Sales Location	Hotel/Restaurants	32	61.5	38.615	0.001

Category	Subcategory	N	%	χ^2	(p-value)
	Farm gate	8	15.4		
	Local markets	3	5.8		
	Combined channels	9	17.3		
Price Determinants	Weight	25	48.1	8.577	0.014
	Age	19	36.5		
	Breed	8	15.4		
Transport Method	Vehicle	39	75	13.00	0.001
	Manual/Sack	13	25		
Market Distance (km)	<5 km	38	73.1	11.077	0.001
	5-10 km	14	26.9		
Marketing Challenges	Price fluctuations	15	28.8	15.731	0.001
	Poor infrastructure	30	57.7		
	Market access	7	13.5		

Furthermore, sales channels were highly diverse and significantly different ($\chi^2 = 38.615$, $p = 0.001$). Most sales were made to hotels/restaurants (61.5%). Additionally, sales occurred through composite channels (17.3%), at the farm gate (15.4%), and in local markets (5.8%). Regarding price determinants, difference was observed ($\chi^2 = 8.577$, $p = 0.014$). Live weight was the most cited factor (48.1%), followed by age (36.5%) and breed (15.4%). Consequently, for the means of transport, a significant majority of farmers (75%) used vehicles, while 25% relied on manual or sack methods a finding that underscores the importance of transport infrastructure in commercial marketing.

Meanwhile, market distance also showed significant variation ($\chi^2 = 11.077$, $p = 0.001$). Most farmers (73.1%) sold their products within a 5 km radius, while 26.9% served markets 5–10 km away; . Nevertheless, farmers face several marketing constraints, which were well distributed and significant ($\chi^2 = 15.731$, $p = 0.001$). Poor

infrastructure was the most prominent challenge (57.7%), followed by unstable prices (28.8%) and poor market access (13.5%).

Financial Sources and Credit Use in Commercial Poultry Farms

This section discusses the financial arrangements supporting poultry farming, including sources of finance, credit availability, and spending priorities, with Chi-square tests used to assess the statistical significance of differences between categories Table 6. Depicted marketing Practices, Distribution Channels, and Challenges in Commercial Poultry Production.

The results for the primary source of financing indicated high variation ($\chi^2 = 12.615$, $p = 0.006$). Own saving was the most prominent source (44.2%), followed by cooperative credit (36.5%) and bank loans (19.2%); Furthermore, most farmers (57.7%) reported that credit was out of reach, while only 42.3% had access to credit facilities ($\chi^2 = 1.231$, $p = 0.267$). Additionally, perceived interest levels on credit did not show a difference ($\chi^2 = 0.077$, $p = 0.782$). Over half (51.9%) of the farmer’s felt rates were high (>15%), while the remaining 48.1% felt they were medium (8–15%),. Meanwhile, in the assessment of expenditure priorities, no difference was found ($\chi^2 = 1.529$, $p = 0.465$). The highest priority was bird replacement (41.2%), followed by the acquisition of feeds (31.4%) and health inputs (27.5%).

Table 7. Sources of Financial Resources and Credit Utilization in Commercial Poultry Production

Category	Subcategory	N	%	χ^2	(p-value)
Primary Funding Source	Own savings	23	44.2	12.615	0.006
	Bank loans	10	19.2		
	Cooperative credit	19	36.5		
Credit Access	Available	22	42.3	1.231	0.267
	Not available	30	57.7		
Interest Rate Level	High (>15%)	27	51.9	0.077	0.782
	Medium (8-15%)	15	48.1		
Expenditure Priority	Feed purchases	16	31.4	1.529	0.465
	Health inputs	14	27.5		
	Bird replacement	21	41.2		

Farm Record-Keeping Practices and Monitored Parameters in Commercial Poultry Farms:

A descriptive analysis of record-keeping practices on poultry farms revealed a high level of importance attached to monitoring key production and health parameters. Table 7. illustrate that Sources of Financial Resources and Credit Utilization in Commercial Poultry Production. Most respondents (84.6%) reported practicing record keeping in their poultry farms, whereas 15.4% did not. This difference was statistically significant ($\chi^2 = 24.923$, $p = 0.001$).

Table 8. Record-Keeping Practices and Types of Production Parameters Monitored by Commercial Poultry Farms in and Around Dambi Dollo Town, Western Ethiopia.

Category	Subcategory	N	%	χ^2	(p-value)
Record Keeping	Yes	44	84.6	24.923	0.001
	No	8	15.4		
Mortality records	Yes	45	86.5	66.962	0.001
	No	7	13.5		
Feed costs	Yes	49	94.2	40.692	0.001
	No	3	5.8		
Weight gain	Yes	47	90.4	33.923	0.001
	No	5	9.6		
Medical history	Yes	50	96.2	44.308	0.001
	No	2	3.8		

Furthermore, when examining specific records, highly significant results were observed across all categories. Death records were maintained by 86.5% of farms, while only 13.5% did not keep them ($\chi^2 = 66.962$, $p = 0.001$). Additionally, feed expenditure was the most frequently maintained record, with 94.2% of farms tracking it compared 5.8% that did not ($\chi^2 = 40.692$, $p = 0.001$).

Meanwhile, weight gain monitoring was performed by 90.4% of farms, whereas 9.6% did not monitor it ($\chi^2 = 33.923$, $p = 0.001$). Moreover, an overwhelming 96.2% of farms kept medical history records, and only 3.8% did not ($\chi^2 = 44.308$, $p = 0.001$).

Rodent and Predator Presence in Poultry Farms:

This sub-section analyzes the presence of pest and predator hazards in commercial poultry farms, utilizing Chi-square tests to determine the significance of the observed distributions. Table 9. Illustrate that Prevalence of Rodents and Predators and Their Impact on Commercial Poultry Farms in and Around Dambi Dollo Town, Western Ethiopia. The survey suggested an extremely high ($\chi^2 = 44.308$, $p = 0.001$) prevalence of rodent infestation, as 96.2% of farms confirmed their presence. Similarly, predators were reported ($\chi^2 = 30.769$, $p = 0.001$) by 94.2% of farms, with 5.8% reporting no infestation. Additionally, for those farms reporting predators, the types varied significantly ($\chi^2 = 28.423$, $p = 0.001$). Cats were the most identified predator (67.3%), followed by farms reporting both cats and weasels (23.1%), and weasels alone (9.6%).

Table 9. Prevalence of Rodents and Predators and Their Impact on Commercial Poultry Farms in and Around Dambi Dollo Town, Western Ethiopia

Category	Subcategory	N	%	χ^2	(p-value)
Presence of rodents	Yes	50	96.2	44.308	0.001
	No	2	3.8		
Presence of predators	Yes	49	94.2	30.769	0.001
	No	3	5.8		
Name of predators	Cat	35	67.3	28.423	0.001
	Weasel	5	9.6		
	Both	12	23.1		

Training and Extension Services in Poultry Farms

This section assesses the extent of training and extension service delivery to commercial poultry farmers, focusing on the source, frequency, and content of such services, with Chi-square tests used to ascertain statistical significance. Table 10. Availability and utilization of training and extension services in commercial poultry farms in the study area

Furthermore, among those trained, government institutions were the major ($\chi^2 = 13.00$, $p = 0.001$) providers, responsible for 75% of training compared to 25% by non-governmental organizations. However, the frequency of training received showed no definite trend, as 46.2% had been trained once, 28.8% twice, and 25% three times, a distribution that was not statistically significant ($\chi^2 = 3.962$, $p = 0.138$). Additionally, the type of training provided was significant ($\chi^2 = 29.346$, $p = 0.001$). A strong preference for knowledge-based instruction was evident, with 64.8% of farmers receiving theoretical training only, 25% receiving both theoretical and practical, and a mere 7.4% receiving practical training. Meanwhile, concerning access to extension services, 76.9% of farmers had access while 23.1% did not a statistically significant variation ($\chi^2 = 15.077$, $p = 0.001$). Moreover, the types of services received varied ($\chi^2 = 10.885$, $p = 0.004$), with technical advice being the most common (53.8%), followed by full package services (28.8%) and input provision support (17.3%). Nevertheless, the frequency of extension contact had a significant distribution ($\chi^2 = 18.615$, $p =$

0.001). Most respondents (61.5%) accessed services only once, while 19.2% received them twice and another 19.2% thrice.

Table 10. Availability and Utilization of Training and Extension Services in Commercial Poultry Farms in the Study Area

Attribute	category	N	%	χ^2	(p-value)
Training taken	Yes	43	82.7	22.231	0.001
Training given by	No	9	17.3	13.00	0.001
	Government	39	75		
	Non Government	13	25		
Frequency of training	Once	24	46.2	3.962	0.138
	Twice	15	28.8		
	Trice	13	25		
Type of training	Theoretical	35	64.8	29.346	0.001
	Practical	4	7.4		
	Both	13	25		
Presence of extension services	Yes	40	76.9	15.077	0.001
Type of extension services	No	12	23.1	10.885	0.004
	Technical advice	28	53.8		
	Provision	9	17.3		
Frequency of extension services	Complete package	15	28.8	18.615	0.001
	Once	32	61.5		
	Twice	10	19.2		
	Trice	10	19.2		

Hygiene and Sanitation Practices on Poultry Farms

A study comparing cleaning routines, litter management, and waste disposal on commercial chicken farms utilized Chi-square tests to evaluate the significance of differences in these practices. Table 11 illustrate that hygiene and sanitation practices on poultry farms. Regarding feeding and watering equipment hygiene, the frequency of washing feeders differed ($\chi^2 = 8.346$, $p = 0.015$), with 50% of farms washing weekly, 32.7% twice a week, and 17.3% three times a week; . Furthermore, the frequency of waterer cleaning was different ($\chi^2 = 51.654$, $p = 0.001$), as the majority (59.6%) cleaned daily, while smaller percentages washed weekly (13.5%), three times weekly (11.5%), or monthly (7.7%).

Table 11. Hygiene and Sanitation Practices on Poultry Farms

Category	system	N	%	χ^2	(p-value)
Feeder Cleaning	Once per week	26	50	8.346	0.015
	Twice per week	17	32.7		
	Trice per week	9	17.3		
Waterer Cleaning	Daily	31	59.6	51.654	0.001

Room Cleaning	Once per week	7	13.5	12.808	0.012
	Trice per week	6	11.5		
	Trice per week	4	7.7		
	Monthly	4	7.7		
	Daily	18	34.6		
	Once per week	15	28.8		
	Trice per week	8	15.4		
	Trice per week	6	11.5		
Type of litter material	Monthly	5	9.6	33.923	0.001
	Teff straw	47	90.4		
	Saw dust	5	9.6		
Frequency of changing litter material	Once per month	35	67.3	27.038	0.001
	Twice per month	9	17.3		
Wast Disposal	Trice per month	8	15.4	12.615	0.006
	Burning	31	59.6		
	Burying	21	40.4		
Disposal of dead birds	Spread on the earth	32	61.5	2.769	0.096
	Burying	20	38.5		

Additionally, the frequency of cleaning poultry houses also differed ($\chi^2 = 12.808$, $p = 0.012$). Daily cleaning was done by 34.6% of farms, while others cleaned weekly (28.8%), three times a week (15.4%), twice a week (11.5%), or monthly (9.6

Meanwhile, in litter management, Teff straw was the most frequently employed material, utilized by 90.4% of farms, with only 9.6% using sawdust. Moreover, the frequency of litter replacement varied ($\chi^2 = 27.038$, $p = 0.001$); most farms (67.3%) replaced litter monthly, while 17.3% did so every two months and 15.4% every three months. In addition, waste disposal methods showed a division ($\chi^2 = 12.615$, $p = 0.006$), with 59.6% of farms using burning and 40.4% burying waste. However, for dead bird disposal, the variation was not significant ($\chi^2 = 2.769$, $p = 0.096$); nevertheless, the widespread use of ground spreading (61.5%) compared to burial (38.5%) could have serious biosecurity consequences, including disease spread and environmental contamination.

Culling Practices and Utilization of Culled Birds in Commercial Poultry Farms

This section examines the frequency, underlying causes, and subsequent handling of culled birds within commercial poultry operations. Table 12. Depicted that culling practices and application of culled birds in poultry farms. Comparative analysis is carried out to identify patterns in culling behavior and post-culling applications, with Chi-square tests employed to determine the significance of observed differences in culling motives and outcomes. A significant majority of farms (78.8%) reported intentionally culling birds, while 21.2% did not ($\chi^2 = 17.308$, $p = 0.001$). Furthermore, among farms that culled, the principal reasons varied significantly ($\chi^2 = 14.000$, $p = 0.001$). The most common reason cited was small size (57.7%), followed by a

combination of small size and deformity (23.1%), and deformity alone (19.2%); these findings suggest that physical deformities and improper growth are major stimuli for culling, underscoring the role of visual and performance evaluation in flock management. Regarding the disposal of culled birds, a significant variation was observed ($\chi^2 = 7.692$, $p = 0.006$). The majority (69.2%) sold culled birds, while 30.8% used them at home, demonstrating that culled birds are commonly monetized due to their retained economic value despite removal from the productive flock. Overall, the results highlight that culling is a common and deliberate operation on commercial chicken farms, driven by clear economic and managerial necessities. Nevertheless, the criteria for culling and the resultant usage suggest potential avenues for optimizing flock uniformity and minimizing losses through early detection and nutritional supplementation.

Table 12. Culling Practices and Application of Culled Birds in Poultry Farms

Category			Subcategory	N	%	χ^2	(p-value)
Culling of birds purposely			Yes	41	78.8	17.308	0.001
			No	11	21.2		
Reason of culling			Small size	30	57.7	14.00	0.001
			Deformed shape	10	19.2		
			Both	12	23.1		
Use of culled birds			Sell	36	69.2	7.692	0.006
			Use of home consumption	16	30.8		

Discussion

The predominance of male farmers (73.1%) observed in this study is consistent with previous findings reported by Adbaru (2024), who noted that men constitute most poultry farm owners and managers in African agricultural systems due to greater access to productive resources, land ownership, and decision-making roles. This similarity suggests that gender disparity in poultry production remains a common characteristic of commercial farming systems in the region. Notably, the considerable representation of youth aged 15–30 years reflects growing youth participation in commercial poultry production, supporting contemporary evidence that poultry farming has become an appealing economic avenue for younger generations (Añón et al., 2024). Additionally, the high proportion of married respondents (75%) may be attributed to the sector’s capacity to support household income and provide long-term livelihood stability. This trend resonates with the findings of Talema & Nigusie (2023), who also reported similar family-oriented engagement patterns. The relatively small household size (50%) recorded in this study may be linked to the participation of newly established young families and increasing urbanization pressures, aligning with the observations of Sapkota et al. (2020). Similarly, the predominance of farming as the principal occupation (61.5%) corroborates Ethiopia’s agrarian-driven economy as noted by Derbib, T. (2025) while the notable share of respondents engaged in secondary income activities (32.7%) indicates a deliberate pursuit of livelihood diversification.

In relation to experience and education, most poultry farmers (75%) possessed prior farming experience, affirming reports by McAreavey et al. (2025) that experienced farmers tend to achieve higher productivity outcomes. Furthermore, the substantial proportion of diploma- and degree-holders (38.5%) underscores the growing role of education in advancing modern agricultural practices, consistent with Giredaguo (2023). The significant influence of education ($p < 0.05$) reinforces the importance of skill-building and training initiatives. Similarly, significant relationships involving gender and marital status ($p < 0.05$) reflect the gender-structured nature of agricultural participation in Ethiopia (Li et al., 2025). Collectively, these trends highlight the need for policies aimed at enhancing youth participation and supporting women farmers to bolster the poultry subsector's performance.

Overall, the socio-demographic characteristics documented in this study align with national agricultural dynamics and demonstrate the pivotal role of gender, age, education, and farming experience in shaping participation and productivity in commercial poultry systems. Thus, targeted training programs and empowerment strategies—particularly for young and female farmers—could yield significant gains in sectoral growth and efficiency.

With respect to flock structure, the predominance of female chicks (68–72%) is consistent with global commercial poultry systems focused on maximizing egg production (Harrison et al., 2025). The preference for Bovans Brown chickens (55.8%) further reflects farmers' inclination toward high-performing layer breeds (Fushai et al., 2025). Despite breed preferences, the similarity in flock size across production units ($P > 0.05$) suggests that scale differences may be more strongly influenced by management capacity, feed availability, and resource allocation than by breed alone.

Regarding the management, these findings agree with the trends for modern poultry production systems. The dominance of intensive management systems attests to prevailing industry trends toward high-efficiency production models, which is in line with global intensification trends documented by Alvarado-Ramírez et al. (2022); furthermore, this strong preference is most likely due to established strengths in productivity indicators and degree of control (Stafford, 2011).

Similarly, the widespread superiority of deep litter housing over cage systems confirms previous research by Ahmed (2024) on its economic and well-being benefits. Consequently, these results affirm that deep litter systems remain the preferred choice, possibly due to reduced capital investment, greater freedom for bird behavior, simpler management procedures, and better conformity to animal welfare principles (Collins et al., 2021a).

Additionally, the significant preference for wood shavings over straw confirms the work of Singh et al. (2024) on improved moisture absorbency, while also suggesting that producers prioritize bedding types that optimize flock health and air quality. The quasi-universal adoption of the all-in-all-out stocking method is aligned with

Subedi et al. (2023)'s work on its biosecurity advantages, demonstrating a significant investment in disease control.

This pattern continues with disinfectant use, as the preference for formalin-Berekina combinations indicates an industry shift towards enhanced, multi-chemical sanitation regimens. Meanwhile, the ventilation quality scores, where 53.8% reported "excellent" ventilation, confirm the results of Olanrewaju et al. (2025) and indicate a growing awareness of environmental management's role in disease prevention. Collectively, these results affirm current best practices while also highlighting specific areas where management can be refined to optimize both animal welfare and production efficiency.

Concerning poultry feed, these findings provide strong empirical evidence that supports current knowledge of poultry feeding practices, while also revealing important subtleties. The strong majority in favor of commercial feed aligns with the results of Doyin et al. (2023). The results indicate that producers prefer nutritionally formulated, well-balanced feeds for optimum flock performance.

Similarly, the prevalence of mixed feeding systems confirms the data from Rufai et al. (2024) on cost-cutting strategies, while the virtual absence of farm-made-only feed supports concerns raised by Doyin et al. (2023) regarding nutritional variability in home-made rations. Consequently, these overall trends highlight producers' nuanced balance between cost efficiency and nutritional value.

Furthermore, feed sourcing information suggests access significantly influences purchasing behavior, with retailers being preferred over direct factory purchases. This preference is supplemented by encouraging indicators of nutritional knowledge. This is in line with Kappes et al. (2023) who reported. Additionally, feeding frequency patterns are consistent with established best practices, as twice-daily feeding emerged as the prevalent norm. Meanwhile, storage outcomes revealed that 25% of farms had poor storage facilities, which confirms warnings from Bari et al. (2023) regarding feed quality preservation and suggests an area for extension-based improvement. Nevertheless, the overall high feed restocking rate (80.8% within 1-4 months) reflects proactive management despite these storage limitations.

The findings on water management from this study provide comprehensive information that both verifies current poultry husbandry practices and contributes meaningful insights to the field. The nearly universal accessibility of water supports Elkhaiat et al. (2023)'s assertion that water availability is a basic welfare requirement; however, the 1.9% of farms lacking access represents a conspicuous gap that requires urgent intervention. Similarly, farmers who were significantly aware of water quantity requirements align with Amananti (2024)'s analysis of producer knowledge levels. Nevertheless, the minority lacking this awareness indicates an important area for targeted extension education. Consequently, while most practices meet essential water requirements, significant scope remains for improving water management knowledge (Hamel & Tan, 2022).

Furthermore, the distribution of water sources reveals significant variation, with piped water infrastructure being significantly more common, followed by well water and boreholes. This finding supports Irede et al. (2024)'s.

Additionally, data on watering methods support Ablamowicz (2007)'s recommendations, as *ad-libitum* systems were overwhelmingly predominant. Meanwhile, the persistence of timed watering systems (34.6% in total) resonates with Lunstad (2024)'s cautions about potential water withholding during peak demand periods. Collectively, these significant results ($p < 0.05$ throughout) depict an industry that largely meets basic water demands but nevertheless could improve in several key areas: implementing universal access, increasing knowledge transfer, enhancing water quality monitoring, and promoting best watering practices (Samaraweera et al., 2024). Concerning the marketing significance of this study provides overwhelming evidence that both supports and expands our understanding of poultry value chain dynamics. The strong preference for retailer sales aligns with El-Fakhrany et al. (2025)'s findings on business-to-business channel excellence, while the high institutional demand from hotels and restaurants (61.5%; $\chi^2 = 38.615$, $p = 0.001$) further emphasizes the importance of commercial buyers in the value chain.

Similarly, price determinants firmly favor established market traditions, with live weight (48.1%) and age (36.5%) being major factors as noted by Thangjam et al. (2024). However, the negligible impact of breed (15.4%) identifies a potential opportunity for product differentiation approaches. Consequently, these pricing frameworks demonstrate how marketplace dynamics fundamentally guide transactional factors in poultry trade.

Furthermore, logistics data significantly broadens our understanding of distribution channels. The predominant use of vehicle transport over manual methods confirms Chen et al. (2022)'s results on modernization patterns, while the geographical clustering around markets underscores the critical importance of location efficiency to poultry marketing economics (Tahmasbi, 2024).

Nevertheless, several priority challenges emerged from the findings. Infrastructure limitations (57.7%) and price uncertainty objectively validate concerns raised by Olanrewaju et al. (2022). About systemic limitations. These significant findings collectively indicate that while market channels function reasonably well, strategic interventions could focus on increasing cold chain infrastructure, developing price risk management instruments, improving rural market access, and enhancing producer-processor linkages (Omananyi, 2021).

In addition to agreeing with existing knowledge on poultry marketing systems, these results provide fresh insights with important policy implications for value chain upgrading initiatives. The methodological rigor of this research, evidenced by uniform statistical significance across key variables, lends considerable weight to these remarkable findings on contemporary poultry marketing dynamics (Saheed, 2023). Concerning the financing patterns in poultry farm economics, the findings provide empirical support for existing theories while highlighting important structural challenges. The heavy dependence on private savings observed in this study is

consistent with the findings of Khan et al. (2023), who reported that small- and medium-scale poultry farmers primarily relied on personal savings as their major source of startup and operational capital due to limited access to formal credit services. This similarity indicates that financial constraints remain a major barrier to the expansion and sustainability of poultry enterprises. Findings on limited access to formal financing, while the substantial reliance on cooperative credit (36.5%) enhances our understanding of alternative funding sources in the sector Webster and Alemayehu Tadesse (2025). Furthermore, the credit availability figures reveal serious constraints, as 57.7% of farmers reported being credit deprived. Although this result was, it strongly confirms Olanrewaju et al.'s (2022) concerns about financial constraints and suggests this may represent a widespread, systemic issue rather than a random pattern. Consequently, these funding trends collectively demonstrate how capital constraints likely hinder sector development and modernization Olanrewaju et al. (2025). Additionally, interest rate levels largely concur with Mottet et al.'s (2023) warnings, as 51.9% of borrowers faced rates exceeding 15%, creating significant barriers to farm improvement and expansion Olanrewaju et al. (2025). Meanwhile, expenditure priorities flock replacement (41.2%) over feed (31.4%) and health inputs confirm Aderibigbe's (2025) findings on .These notable statistical results (both significant and non-significant patterns) collectively indicate that: inclusive finance efforts could transform sector opportunities, alternative lending models warrant examination, interest rate subsidies would boost growth, and financial literacy programs could optimize resource utilization (Olanrewaju et al., 2025)). Regarding farm record the results of this research on record-keeping practices provide strong evidence that both support documented standards and contribute new knowledge regarding poultry farm management. The significant prevalence of record-keeping utilization reaffirms. According to Omowole et al. (2024) position on documentation as a criterion of professional farm management. Furthermore, the virtually universal maintenance of medical records further confirms the findings of Studies & State (2023). Consequently, these results collectively demonstrate an industry consensus on the critical importance of documentation for both operational and regulatory purposes Khan et al., 2025). Additionally, production and financial data enhance our understanding of management practices. Weight gain monitoring and feed cost tracking rates significantly exceed previous estimates by Singh et al. (2024) while systematic mortality record-keeping both duplicates and expands upon their study of health monitoring practices. These significant results ($p < 0.001$ throughout) collectively indicate that modern poultry farmers recognize record-keeping as essential for success, prioritize health and financial documentation, capture comprehensive production information, and have widely adopted professional management systems (Mariki, 2022).

Nevertheless, the relatively small proportion of farmers who do not keep records (3.8–15.4%) represents a crucial target for extension services, as noted by Collins et al. (2021b).The implication is that exceptional outreach efforts are needed to generalize best practices, particularly since most operations have already achieved exemplary documentation levels. Concerning pest and predator, the findings of this research on pest and predator prevalence provide compelling evidence that both support and validate existing concerns in

poultry farm management. The rampant rodent infestation validates the biosecurity weaknesses identified by Kamal et al. (2024), while the equally widespread predator infestation critically confirms the economic and welfare problems highlighted by Shahani et al. (2023). Furthermore, predator composition statistics significantly enhance our understanding of farm vulnerabilities. Cats emerged as the primary culprit, as forecast by Shahani et al. (2023), while combined cat-weasel pressures affected 23.1% of farms and weasels alone impacted 9.6%. Consequently, these significant results ($p < 0.001$ throughout) collectively reveal that current housing defenses are inadequate, free-range systems require re-engineering, predator-proof standards must be enhanced, and pest control schemes deserve top priority. Additionally, the pan-pest presence (96.2%) strongly supports Jiang et al. (2017) estimates, which identified rodents as responsible for disease transmission risks, feed contamination, and substantial production losses. Nevertheless, despite these formidable challenges from predators and pests, production outcomes could be significantly optimized through improved housing infrastructure, integrated pest management systems, predator deterrent technology, and comprehensive farmer education programs (Yarahmadi & Rajabpour, 2024). The near-universal prevalence of these biosecurity threats furthermore underscores the urgent need for systematic interventions that address both immediate control measures and long-term preventive strategies across the poultry farming sector.

Regarding the farmers' training and extension services, the empirical results on capacity development provide solid confirmation of existing conceptualizations of training among poultry farmers while identifying key areas for improvement. The high rate of training uptake overwhelmingly supports Wang et al. (2024) work on state-led extension services, particularly since government agencies emerged as the dominant training providers. Similarly, the findings on training frequency substantially extend Wang et al.'s (2024) work by demonstrating that while one-off trainings remain common, the lack of significant patterning suggests room for strengthening continuing education systems. Consequently, these findings indicate that while training reach is adequate, the depth and frequency of capacity building require enhancement (Musoke et al., 2024). Furthermore, methodology findings significantly validate the prescriptions of Musoke et al. (2024), as theoretical approaches substantially outweighed practical ones (7.4%), thereby revealing a clear need for more hands-on learning opportunities. Additionally, extension service findings mirror those of Musoke et al. (2024), showing satisfactory reach but heterogeneous service depth—with technical advice being far more common than integrated packages (28.8%). Concerning poultry farm hygiene and waste management, the hygiene results of this study provide valuable information that both supports and expands existing knowledge concerning poultry farm sanitation practices. The stringent waterier cleaning protocol validates Errico et al.'s (2023) emphasis on water quality management, demonstrating producers' recognition of this critical health factor. However, the less frequent cleaning of feeders confirms S. R. Rufai's (2022) concerns about potential feed contamination threats, indicating significant room for improvement in best practices. These contrasting frequencies demonstrate how producers prioritize different aspects of farm cleanliness (Endale et al., 2023). Furthermore, housing cleanliness data provides substantial additional evidence, including variable room cleaning patterns, predominant use of

teff straw litter, and monthly litter replacement standards (Kim et al., 2022). These findings generally support P. Singh & Singh's (2024) conclusions regarding material preferences, but nevertheless raise concerns about optimal replacement frequency, aligning with Gondek et al.'s (2025) recommendations for more intensive litter management. Consequently, these statistically significant results ($p < 0.05$ throughout) establish that while minimum hygiene practices are generally maintained, substantial potential exists to standardize sanitation protocols, increase feeder cleaning frequency, optimize litter management, and enhance overall biosecurity measures across poultry farming operations. Regarding the poultry culling, these findings of this study on culling practices provide strong empirical support for existing knowledge of poultry flock management strategies. The high proportion of planned culling supports Saleh et al.'s (2023) findings regarding active flock quality control by professional producers. Furthermore, the data on culling reasons strongly confirms Ejiofor (2022) study, as small size emerged as the primary justification, followed by deformities (19.2%) and multifactorial reasons (23.1%). These significant patterns ($p < 0.001$) indicate that producers deliberately remove unhealthy birds to maintain flock quality standards. Additionally, utilization data complements Ezeamii et al. (2024) economic rationale, as most culled birds enter the value chain through commercial sales or home consumption (30.8%). Consequently, these results collectively substantiate (Subedi et al. 2023) theoretical framework that views culling as both a quality control activity and an economic strategy. The findings demonstrate that modern poultry producers actively manage flock composition, incorporate specific culling criteria, optimize economic returns from all birds, and balance commercial with household needs through systematic culling practices

Conclusion

The study showed that commercial chicken rearing in Dambi Dollo and its surroundings is characterized by strict intensive management and deep litter housing systems, with exemplary practices like all-in-all-out stocking and record-keeping. However, there were serious challenges, particularly in biosecurity, and levels of rodent and predator problems were high. Use of commercial feed was common, but water management and market access require improvement. Insufficient production and marketing infrastructure and credit access also impede development. As a counter to enhance productivity and longevity, interventions in targeted pest management, infrastructure development, access to credit, and constant education of farmers are imperative.

Data Availability: The datasets generated and analyzed during this study are available from the corresponding authors upon reasonable request.

Conflict of Interest Statement: The authors affirm that there are no conflicts of interest associated with this research.

Ethics Statement: Ethical approval for this study involving human participants (poultry farmers) was granted by the Ethics Committee of the University of South Africa, College of Agriculture and Environmental Sciences (Approval No. 2024/CAES_AREC/5937).

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CHAPTER 6

Assessment on Constraints of Commercial Poultry Farms by Garrett's Ranking Technique in Dambi Dollo and its Surroundings, Western Ethiopia

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Abstract

The findings of the study showed that scale and commercial poultry farming engagement are closest to being linked with the socio-demographic traits of a farmer. Gender, age, education level, and years of experience all were shown to be statistically significant relationships ($p < 0.05$). Surprisingly, female farmers tended to work on considerably larger flock sizes (mean ~735 chicks) than did male farmers. Statistical tests (χ^2 , ANOVA) and Garrett's ranking were employed in the study to examine these correlations and identify the primary constraints. Regarding operational constraints, the most critical challenges ranked from 1 to 10 included: (1) cost of feed, (2) availability of improved birds, (3) high cost of birds, (4) lack of financing, (5) land/space availability, (6) electric disturbances, (7) high bird morbidity rates, (8) unavailability of feed ingredients, (9) disease outbreaks, and (10) high mortality rates. To address these challenges and enhance poultry production, targeted interventions are demanding. These include facilitating accesses to an affordable feed, promoting improved poultry breeds, granting land access, and "providing credit facilities" to farmers. Furthermore, addressing these constraints do not only boost productivity but also ensure sustainable growth in the commercial poultry sector.

Keywords Commercial Poultry, Flock size, Poultry Farms, Ranking Technique

INTRODUCTION

Poverty reduction and food security are major concerns in Ethiopia's development strategy, as around 29% of the populace exists under the countrywide insufficiency line (Kassegn and Endris, 2021). Furthermore, improper nutrition due to small energy and protein intake remains a persistent problem (Zahid *et al.*, 2024), since protein deficits in particular are well-documented across Africa (Bayala-Yaï *et al.*, 2024). To address this, animal protein sources play a crucial role, with poultry meat and eggs being particularly important (Abera Geleta, 2022). Consequently, focusing on poultry production is essential for achieving nutrition self-support and reducing hunger in Ethiopia (Agazhi and Meda, 2022).

Moreover, poultry production contributes significantly to poverty reduction, "Contributing to" rapid economic development, especially for vulnerable populations. Additionally, poultry farming requires minimal capital investment while providing quick returns (Viswanath, 2020). Currently, Ethiopia's poultry population exceeds 60 million (Mohammed, 2021), with production systems ranging from backyard to large-scale commercial operations. However, the commercial sector primarily consists of commercial chicken farms, with few intermediate to big operations (Barre *et al.*, 2023).

Despite the growing number of marketable chicken homesteads in Dambi Dollo and its contributions to livelihoods and food security (Tembo *et al.*, 2023), the sector's economic contribution remains modest at 2-3% (Yuyya, 2023). This limitation stems from various challenges, yet there is limited information about constraints facing commercial farms in Dambi Dollo. Therefore, this study was aimed to identify key challenges affecting the sustainability of commercial poultry farms in the region.

MATERIALS AND METHODS

DESCRIPTION OF THE STUDY AREA

Dambi Dollo, the capital town of the Kellem Wollega Zone in the Oromia Region, is 642 km to the west of Addis Ababa. The zone measures 987,457 hectares in width and is surrounded by the West Wollega and Buno Bedele Zones, Ilu A/Bora Zone, and Gambella region. Its topography is extremely diverse with altitudes ranging from 200 to 3,450 meters above sea level, which constitutes three agro-ecological zones: Highland (26.1%), midland (41.4%), and lowland (32.5%). The region possesses a wide range of temperatures (10°C to 34°C) and high annual rainfall levels, between 1,400 mm and 3,200 mm (Kumsa *et al.*, 2024).

SAMPLE SIZE

Cross-sectional study design was employed to identify the major challenges faced by commercial poultry farms in Dambi Dollo and surrounding areas. Due to the limited number of such farms in the region, purposive sampling was used to ensure the inclusion of active producers with relevant experience. This approach, while non-random, was necessary to obtain meaningful data and allowed for the inclusion of farms varying in size, experience, and management style, thereby enhancing regional representativeness.

According to local agricultural and microenterprise office records, approximately 52 commercial poultry farms were registered at the time of the study. Although a full census was considered, resource and time limitations prevented reaching all farms. Nonetheless, by including all accessible farms, the study closely approximates a census and offers highly representative insights.

SAMPLING DESIGN

To systematically gather information on production constraints, a checklist was developed, and farm leaders or heads of households were purposively selected as key informants due to their direct involvement and decision-making roles in farm management. These participants were then asked to rank the identified issues in order of perceived priority using Garrett's Ranking Technique, enabling clear identification of the most critical challenges faced by the sector.

DATA COLLECTION AND ANALYSIS

Data was collected through personal interviews using a pretested, semi-structured

questionnaire administered to farm heads or owners organized under the commercial poultry and microenterprise offices. The aim was to identify the key constraints perceived by commercial poultry producers. The 28 constraint items were developed through a combination of literature review and a scoping study conducted during the pilot phase. Open-ended interviews with a purposive sample of extension officers and poultry farmers helped generate an initial list, which was then refined into a structured format for the main survey. This process ensured both contextual relevance and practical applicability. The finalized questionnaire is now included as supplementary material. To analyze the data, Chi-square tests were used to examine associations between socio-demographic variables and engagement in commercial poultry farming, rather than comparing observed to theoretical distributions. The high p-values reported reflect targeted statistical analyses (Chi-square and ANOVA), conducted using SPSS, to assess relationships between socio-demographic characteristics and key constraints or performance indicators. Cross-tabulations were also performed to explore group differences (e.g., by education level or experience), and the findings have been integrated into the discussion section accordingly. The heads or leaders of farms were compelled to rank the reasons for which poultry production was being hindered. The reasons were put to Garrett's ranking technique on six steps for explaining results. These were:

Step 1: Rankings provided by the respondents for each factor were considered.

Step 2: Rankings given by each respondent on their own were converted into percentage position based on the following formula: Where; R_{ij} = Ranking given for the i th factor by the j th person, N_j = Number of factors ranked by the j th person.

Step 3: Percentage position scores were obtained with the assistance of Garrett's Ranking Conversion Table, and every percentage position was converted into a score using Garrett's Table (Shanjeevika *et al.*, 2022).

Step 4: The complete mark of every factor was obtained by summing up the scores of all respondents who had ranked that factor.

Step 5: Mean scores were obtained by dividing the total score with the number of respondents.

Step 6: Mean scores of all the factors were ranked in descending order to find the most influential factors according to their ranks assigned.

RESULT

SOCIO-DEMOGRAPHIC CHARACTERISTICS

The socio-demographic characteristics of commercial poultry farmers in and around Dambi Dollo are presented in Table 1. The survey revealed distinct socio-demographic patterns, showing that the majority of respondents were male (73.1%) and fell within the 15–30 age group (53.8%). Additionally, 75% of the respondents were married. In terms of occupation, 61.5% were primarily farmers, while 50% were household members. Furthermore, experience levels varied, with 75% of farmers having prior poultry experience; of these, 59.6% had 1–3 years of experience.

Table 1: Socio demographic characteristics of commercial poultry farms in and around Dambi Dollo.

Variable	Category	N	%	X ²	P-value
Sex of respondents	M	38	73.1	11.077 ^a	.001
	F	14	26.9		
Age of respondents	<15	3	5.8	29.077 ^b	.001
	15-30	28	53.8		
	31-45	15	28.8		
	46-60	6	11.5		
Marital status of producers	Married	39	75.0	70.154 ^b	.001
	Single	7	13.5		
	Divorced	3	5.8		
	Widowed	3	5.8		
Occupation of producers	Farmers	32	61.5	24.269 ^c	.001
	Private job	17	32.7		
	Govt.	3	5.8		
	Employers				
Family size	1-3	26	50.0	23.692 ^b	.001
	4-6	16	30.8		
	More than 6	10	19.2		
Experience in year	<3	31	59.6	21.038 ^c	.001
	3-6	17	32.7		
	More than 6	4	7.7		
Educational level	Illiterate	4	7.7	27.692 ^d	.001
	Read and write	5	9.6		
	Grade 1-4	3	5.8		
	Grade 5-8	9	17.3		
	High school	5	21.1		
	College and university	20	38.5		

Regarding education levels, 38.5% held college or university degrees. Meanwhile, family sizes were relatively small, with 50% of the respondents were household heads, consisting of 1–3

members. Additionally, 61.5% of respondents were solely engaged in agriculture, while 32.7% combined farming with trade, and a small proportion (5.8%) had other secondary occupations. Hence, statistical testing through chi-square tests showed considerable differences (*p* < 0.001) for all the socio-demographic variables. These were gender (*p* < 0.05), marriage status (*p* < 0.05), and educational level (*p* < 0.05), which showed considerable effects on poultry farm operations.

FLOCK SIZE OF CHICKS IN COMMERCIAL POULTRY FARMS IN AND AROUND DAMBI DOLLO

As shown in Table 2, the study examined flock size and birds breeds across 52 commercial poultry farms in and around Dambi Dollo town. The results revealed a mean flock size of 734.6 ± 20.9 birds, with female chicks (654.8 ± 24.5) significantly outnumbering males ($569. \pm 32.7$). In terms of breed composition, Bovans Brown dominated (55.8%, mean: 905.8), followed by Saso T44 (23.1%, mean: 554.6) and mixed breeds (21.2%, mean: 589.6). However, statistical analysis showed no significant influence of breed on mean flock size ($P > 0.05$).

Table 2: Flock size and breeds of chicks in small scale poultry farms in and around Dambi Dollo, Oromia Region, Ethiopia in June 2025.

Variables		N(%)	Mean (SEM)
Flock Size		52(100)	734.6154 (20.89343)
Sex	Female chicks	52(100%)	654.83 (24.499)
	Male chicks	18(34.6%)	569.23 (32.700)
Breed	Bovans brown (egg type)	29(55.8%)	905.7692 (17.24053)
	Saso T44	12(23.1)	554.6154 (15.07513)
	Mixed	11(21.2)	589.6154(12.89814)

Note: N (%) describes number or percent of producers; SEM-standard error of mean, means with the different letter of superscript in the same column did differ significantly ($P < 0.05$).

CHALLENGE OF COMMERCIAL POULTRY FARM RANKING

As presented in Table 3, the ranked limitations faced by commercial chicken farms in Dambi Dollo reveal critical operational challenges. The data shows that feed cost is the foremost constraint (Mean Score: 65.36), followed closely by inaccessibility of improved birds (64.28) and high bird prices (64.01), highlighting significant procurement difficulties. Additionally, financial constraints (63.01) and land scarcity (59.90) further hinder operations,

underscoring the dual challenges of capital and space availability. These top five constraints collectively suggest that affordable inputs and better resource access would enhance sustainability and productivity.

Table 3: Rank of constraints faced in Commercial poultry farms in and around Dambi Dollo, Oromia Region, Ethiopia.

Constraints	Total Score	Mean Score	Garrett's rank
Cost of feed	3399	65.36	1
Non-Availability of improved birds in a time	3343	64.28	2
High cost of birds	3329	64.01	3
Lack of finance	3277	63.01	4
unavailability of land/space	3115	59.90	5
Electric disturbance	3098	59.57	6
High rate of morbidity birds	3025	58.17	7
Un availability of feed and feed ingredients	3002	57.73	8
Disease outbreak	2938	56.5	9
mortality of adult birds, mortality of day-old chicken	2929	56.32	10
Lack of training	2873	55.25	11
Cannibalism	2864	55.07	12
High cost of medicine vaccine	2800	53.84	13
Inability to pay constant attention	2758	53.03	14
Lack of veterinary care	2752	52.92	15

Market linkage and promotion problems	2730	52.5	16
lack of technical know-how handling	2712	52.15	17
In ability to diagnose sick birds	2624	50.46	18
High initial investment	2596	49.92	19
Poor credit facility	2569	49.40	20
Labor problem	2251	43.28	21
High rate of interest for loans	2172	41.76	22
Losses due to changes in environmental conditions	2166	41.65	23
Un availability of waste disposal	2046	39.34	24
Lack of equipment etc.	2000	38.46	25
difficulty for water	1949	37.48	26
lack of extension service	1681	32.32	27
Loss of birds and eggs due to predators	1365	26.25	28

Beyond these primary concerns, electric disturbances (59.57) and high morbidity rates (58.17) pose operational risks, while feed shortages (57.73) and disease outbreaks (56.50) directly threaten flock health. Furthermore, mortality issues (56.32) and inadequate training (55.25) exacerbate these challenges, revealing gaps in knowledge and infrastructure. Other significant hurdles include cannibalism (55.07) and costly medicines (53.84), which point to the need for improved health management practices. Addressing these mid-tier constraints could substantially boost farm efficiency and animal welfare. At the lower-priority end, weak market linkages (52.50) and technical knowledge gaps (52.15) reflect systemic support deficiencies. Moreover, difficulties in disease recognition (50.46) and high startup costs (49.92) discourage new entrants, whereas limited credit access (49.40) restricts expansion. Labor shortages (43.28) and high loan interest rates (41.76) further strain operations, emphasizing the need for financial

and workforce interventions to sustain poultry farming livelihoods.

Among the least urgent but still impactful constraints are environmental losses (41.65), waste disposal issues (39.34), and equipment shortages (38.46). Infrastructure-related challenges like water access (37.48) and poor extension services (32.32), along with minor predator threats (26.25), complete the list. Although these rank lower, their resolution could improve overall farm conditions. A comprehensive approach addressing both high- and low-priority constraints would enhance the resilience and productivity of poultry farming in the region.

DISCUSSION

The predominance of male farmers (73.1%) is consistent with broader patterns in African agriculture, where men often control productive resources and farm ownership (Adbaru,2024). However, the notable involvement of youth (15–30 years) reflects a shift, with poultry increasingly seen as a viable livelihood option for younger generations (Anon, 2024). This demographic trend could be leveraged to modernize the sector, especially since educated youth (38.5% with diplomas/degrees) bring higher adoption potential for technology and improved practices (Giredaguo, 2023). Importantly, education showed a significant influence ($p < 0.05$) on farm performance, reinforcing the need for targeted training programs that build technical and managerial capacity.

Experience also played a crucial role, as 75% of farmers had prior exposure to poultry, supporting McAreavey *et al.* (2023), who emphasized experience as a key productivity driver. However, despite this, farmers still face a complex network of interrelated constraints that hinder optimal output. For instance, financial constraints (Rank 4) directly affect the ability to purchase quality feed (Rank 1), which accounts for up to 75% of production costs (Al-Shuwaysh *et al.*, 2023). Inadequate feeding leads to poor bird health, increasing vulnerability to disease outbreaks especially where biosecurity and vaccination are weak. This cycle explains why health-related challenges remain prevalent despite farmer experience.

Bird availability and cost (Ranks 2 and 3) are also closely tied to financial capacity. Without sufficient funds or access to certain issue faced by over 70% of commercial farms in similar contexts (Akpabio *et al.*, 2023) farmers cannot source high-quality chicks, further affecting productivity and survival rates (Assefa *et al.*, 2023). Moreover, the significant proportion of farmers engaged in secondary businesses (32.7%) suggests that income from poultry alone may

be insufficient, prompting diversification as a coping strategy rather than as an economic opportunity. The interplay between land scarcity (Rank 5), urban expansion, and energy insecurity (Rank 6) further exacerbates productivity challenges. Limited space restricts biosecure housing, while power cuts (Mugabe, 2025) disrupt brooding and feeding systems, increasing mortality. These infrastructural issues are particularly damaging for urban and peri-urban farmers, where population density limits expansion and investment.

Despite 75% of farmers having prior experience, the low rank of training access (Rank 11) signals a critical gap. This aligns with Lyanga (2023), who found that only a quarter of Tanzanian poultry farmers accessed extension services. Training directly influences farmers' ability to manage feed quality, disease outbreaks, and record-keeping factors that collectively determine economic viability (Mateos-González *et al.*, 2024). Our findings suggest that experience alone is insufficient without continuous learning and support, particularly in the face of evolving challenges like climate variability. Market constraints, while ranked lower (Rank 16), still impact profitability. Middlemen dominate value chains, capturing a significant share of revenue (Amarender and Naresh, 2023), while rising drug prices (Lysholm *et al.*, 2025) reduce the feasibility of effective disease control. These structural inefficiencies reflect a broader lack of farmer bargaining power, highlighting the need for cooperative models or government intervention. Environmental challenges, though currently ranked low (Rank 23), are projected to worsen. Thornton *et al.* (2022) predict increased heat stress mortality by 2030, and youth outmigration from agriculture (Kropff *et al.*, 2023) could erode the labor base needed to adapt. These trends emphasize the need for climate-smart infrastructure and automation to future-proof the sector. Overall, our findings confirm several known constraints (e.g., feed cost, chick quality), while adding nuance to others, such as the growing role of educated youth and the underappreciated importance of training. Unlike some studies that treat constraints in isolation, we demonstrate how financial, technical, and infrastructural challenges are deeply interconnected. Addressing these through integrated strategies combining credit access, training, input supply chains, and infrastructure will be key to transforming small-scale commercial poultry into a resilient and profitable enterprise in Ethiopia.

CONCLUSION

The study revealed that the most significant constraints to commercial poultry farms in Dambi Dollo include high feed costs, low access to improved breeds, financial gaps, land scarcity, and high rates of disease outbreaks. To alleviate these constraints, context. Accordingly, we have rephrased the sentence for clarity and conciseness to: Essential interventions include feed subsidies, improved breeding programs, and accessible credit facilities. Additionally, land allocation schemes and better veterinary services are required to address space and health challenges. Furthermore, increasing farmers' training and improving market linkages will enhance productivity. In addition, investment in infrastructure such as solar power for uninterrupted electricity will support sustainable operations.

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NOVELTY STATEMENT

This study particularly highlights Assessment on Constraints of Commercial Poultry Farms by Garrett's Rank-ing Technique. Through the integration of statistical analysis with Garrett's ranking, it provides a ranked picture of constraints to operation and gives evidence-based information for priority-intervention based improvements in poultry productivity and sustainability.

AUTHOR'S CONTRIBUTION

All authors contributed equally to data interpretation, manuscript writing, and reviewing the manuscript.

DATA AVAILABILITY

Data available on request from authors.

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ETHICS STATEMENT

For human subjects research (the farmers) Ethics Committee of South Africa University, College of Environmental sciences_ (Approval No.2024/CAES_ AREC/5937).

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CHAPTER 7

Graded Levels of Dried Blood–Rumen Content Mixture as a Substitute for Soybean Meal in SASSO-C44 Broiler Chickens: Effects on Feed Utilization, Body Weight Gain, Feed Conversion Ratio, and Survival Rate

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Abstract

The study was employed to evaluate graded level dried blood–rumen content mixture (DBRCM) as a partial substitute for soybean meal in SASSO -C44 broiler chicks' diets. Two-hundred-day-old chicks were allocated at random to five diets arranged into a completely randomized design, each treatment having four replicates of ten birds. The dried blood-rumen content mixture (DBRCM) was incorporated into the experimental diets at graded inclusion levels of 0%, 20%, 40%, 60% as a replacement for soybean meal, with the 0% inclusion level serving as the control treatment. Starter and finisher rations were formulated to be iso-caloric and iso-nitrogenous, and birds were fed for 56 days. Daily dry matter intake (DMI) was significantly affected by dietary treatment ($P < 0.05$), ranging from 66.38 to 71.60 g/bird/day. Birds fed the diet containing 45% DBRCM had the lowest DMI (66.38 g/bird/day), which was significantly lower than those fed 0%, 15%, and 60% DBRCM diets. Daily body weight gain ranged from 29.8 to 31.5 g/bird/day, with no significant treatment effects ($P > 0.05$). Similarly, feed conversion ratio ranged from 2.22 to 2.29, and no significant differences were observed among treatments ($P > 0.05$). Mortality rate was not significantly affected by dietary treatment ($P > 0.05$). Overall, the results suggest DBRCM may replace up to 60% of soybean meals in both starter and finisher diets for SASSO C44 broilers without detrimental effects on growth, feed efficiency, or survival.

Keywords: Body weight gain, Broiler chick, Chick Mortality rate, Ethiopia.

Introduction

Bovine blood–rumen content mixture (BBRCM) is an abattoir by-product with substantial potential as an affordable and locally accessible protein source for poultry feed. Previous studies have shown that incorporating BBRCM in poultry diets can improve growth performance, reduce feed costs, and partially replace conventional protein sources such as soybean meal without adverse effects on productivity (Yitbarek, Mersso, et al., 2016). However, despite these promising findings, limited information exists regarding the optimal inclusion level of BBRCM in layer diets and its effects on egg production and quality traits under local production conditions, which justifies the need for the present study. When properly processed, BBRCM can be safely incorporated into poultry diets, providing economic advantages while simultaneously offering a practical strategy to mitigate environmental pollution.

Abattoirs produce significant volumes of solid waste and effluents, including blood, rumen contents, and wash water. In Ethiopia, with a cattle population estimated at 53.99 million (Yousuf & Yusuf, 2022) and an annual slaughter rate of roughly 7% (Kanchora et al., 2020), approximately 3.8 million animals were slaughtered each year. This generates nearly 133,000 quintals of dried rumen content and 38 million liters of blood that could be recovered and processed into feed ingredients (Bezabih et al., 2017; Soldado et al., 2021).

Typically, abattoir blood is separated into plasma and blood corpuscles, with plasma accounting for 60% (8% solids) and blood corpuscles 40% (38% solids) of the total (Koutsoumanis et al., 2021). From every 100 kg of whole blood, approximately 4.8 kg of plasma powder and 15.2 kg of blood corpuscle powder could be obtained. Yitbarek et al. (2018) reported that Ethiopia was producing 76,000 quintals of blood meal. At market prices of 300 Birr per quintal for dried rumen content and 800 Birr per quintal for blood meal, these by-products could generate roughly 39.9 million and 60.8 million Birr, respectively. Nevertheless, due to underutilization, the country currently experiences estimated annual losses of about 100.6 million Birr (Yitbarek, Tamir, et al., 2016). In Dambi Dollo, municipal abattoirs process approximately 55,000 cattle each year, producing an estimated 16,500 kg of dried rumen matter and 55,000 liters of blood (yielding roughly 11,000 kg of blood meal), assuming an average animal weight of 250 kg (Bezabih et al., 2017). However, due to the significant availability of these by-products, they are frequently discarded, leading to environmental pollution such as foul odors, fly infestations, and

contamination of surface and groundwater with pathogens and toxic compounds (Siddiqua et al., 2022; Riaz et al., 2023). A greater necessity was reported to reduce the environmental cost and increase the economic benefit from rumen content and blood has generated interest in utilizing these by-products as a protein source for poultry (Shuma, Hundie Senbeta, and Dikeledi Petunia 2025). However, no effort had yet been attempted in Ethiopia, including Dambi Dollo, to utilize these by-products as broiler ration ingredients. This study was therefore aimed at assessing the growth performance, carcass characteristics, and selected blood parameters of broiler chickens fed diets containing dried bovine blood–rumen content mixtures as partial replacements for soybean meal, an expensive protein supplement widely used in Ethiopia. It was hypothesized that graded inclusion levels of dried blood–rumen content mixture would significantly influence feed intake, growth performance, and nutrient utilization of SASSO C44 broiler chickens.

Materials and Methods

Description of the Study Area

The research was carried out in Dambi Dollo town, situated within the Kellem Wollega Zone of western Oromia, in Ethiopia. The study area is approximately 642 km west of the capital, Addis Ababa. The town lies at an altitude ranging from 1,500 to 1,740 meters above sea level. It receives an average annual rainfall of 850–1,308 mm, with temperatures ranging from 15°C to 28°C, covering an area of roughly 6,160 hectares. Dambi Dollo had reached a maximum elevation of 2,420 meters above sea level.

Collection and Processing of Blood

Blood was collected immediately after cattle slaughter at the Dambi Dollo municipal abattoir. The blood was heated to 100 °C for 45 minutes to evaporate excess moisture and destroy possible disease-causing organisms. The coagulated material was spread uniformly on clean plastic sheets and sun-dried for 3–5 days, stirring frequently to facilitate even drying and minimize contamination risks. In this study, 144 kg of fresh blood was collected from cattle in the Dambi Dollo University abattoir.

Collection and Processing of Rumen Content

Fresh rumen contents were obtained from recently eviscerated cattle at the municipal slaughterhouse. The rumen was carefully opened, and its contents were transferred into a large metal container. The material was then boiled for two hours, with periodic stirring to prevent scorching and reduce microbial contamination. Following boiling, the rumen contents were spread on clean plastic sheets and sun-dried, being turned and mixed at least four times per day to ensure uniform drying.

Preparation of Dried Blood–Rumen Content Mixture (DBRCM)

The dried rumen content and sun-dried blood were combined in equal proportions (1:1) (Yitbarek, Tamir, and Mengistu 2016) to produce the dried blood–rumen content mixture (DBRCM), which was subsequently incorporated as a partial substitute for soybean meal in both starter and finisher diets for broiler chickens.

Housing Preparation: Prior to chick placement, the experimental pens were thoroughly cleaned, disinfected, and left vacant for an appropriate period to reduce disease risk. Feeders, waterers, and other equipment were cleaned and disinfected before installation. Fresh litter was then spread uniformly on the floor, and the brooding facilities were prepared and tested to ensure suitable environmental conditions for the chicks.

Experimental Birds and Management

A total of 200 one-day-old SASSO C44 broiler chicks were sourced from Alema poultry farms, one of Ethiopia's nationally recognized and reputable poultry enterprises. The chicks were randomly allocated to 10 pens (each measuring 1.8 m²) according to a Completely Randomized Design (CRD), with 10 chicks per pen and four replicates per treatment. The pens were constructed using timber and mesh wire and fitted with 200 W heat bulbs. Upon arrival, the chicks were placed in the brooding unit with temperatures set at 32-33°C is commonly recommended as the target brooding temperature for day-old broiler chicks and monitored three times daily, morning, midday, and evening, following the procedure described by Okonkwo (2022). Upon arrival, the chicks were placed in the prepared brooding units and provided with clean drinking water and starter feed ad libitum. Feed and water were continuously available throughout the experimental period. Routine vaccination and health management practices were implemented according to standard broiler management procedures.

Experimental Diets

A dried blood-rumen content mixture was prepared to replace soybean meals at different graded amounts. All diets were designed to be iso-caloric and iso-nitrogenous. Starter diets (days 1–28) were formulated to provide 3,000 kcal ME/kg DM and 23% CP, while finisher diets (days 29–56) contained 3,200 kcal ME/kg DM and 20% CP (Hanumantarao, 2017). The ingredients used were maize (*Zea mays*), wheat middling, noug (*Guizotia abyssinica*) seed cake, roasted soybean (*Glycine max*), fish meal, vitamin premix, lysine, methionine, salt, and limestone. These treatments comprised the following combinations

Justification of Different Dietary Treatments and Controls

The dietary treatments were selected to evaluate the effect of progressively replacing roasted soybean meal (RSBM) with dried blood–rumen content mixture (DBRCM) as a protein source in SASSO-C44 broiler diets. The treatment levels were designed to provide a clear dose-response pattern while identifying a practical level of DBRCM replacement that could be used without adversely affecting poultry performance.

T1 (0% DBRCM replacement) was included as the **negative/baseline control**, in which roasted soybean meal was used as the sole alternative protein source. This treatment provided the reference against which the effects of DBRCM replacement at different inclusion levels could be evaluated.

T2 (20% DBRCM replacement) represented a **low level of replacement**. It was included to determine whether a modest substitution of RSBM with DBRCM could maintain broiler growth and feed utilization while reducing dependence on soybean-based protein.

T3 (40% DBRCM replacement) represented an **intermediate replacement level**. This treatment was included to assess whether a substantial proportion of RSBM protein could be replaced by DBRCM without compromising growth performance, feed efficiency, and carcass characteristics.

T4 (60% DBRCM replacement) represented a **high replacement level**. It was included to determine the upper practical level of RSBM replacement and to evaluate whether increasing

DBRCM use would result in any adverse effects on feed intake, growth performance, feed conversion, or carcass characteristics.

T5 (commercial starter and finisher diets) was included as a **positive/external control** to provide a benchmark against a commercially formulated diet. This enabled the performance of birds receiving experimental diets containing RSBM and DBRCM to be compared with birds receiving a readily available commercial feed under the same experimental conditions.

Overall, the use of **0%, 20%, 40%, and 60% replacement levels** provided a progressive gradient for evaluating the biological and economic response to DBRCM, while the **commercial diet served as an external benchmark** for evaluating the practical performance of the experimental diets. The treatment structure therefore allowed the study to determine not only whether DBRCM could replace RSBM, but also the extent to which it could be used without compromising broiler production performance.

Performance Evaluation

The following: The performance of broiler chickens was evaluated based on average dry matter intake (ADMI), body weight gain (BWG), feed conversion ratio (FCR), and chick survival rate throughout the experimental period rate were attributes measured over the experimental period. Feeds were weighed using feed offered and feed refusals were weighed using a digital weighing balance (± 0.01 g accuracy). Daily feed intake was determined as the difference between the amount of feed offered and the feed refused on the following day. and offered to the pen, the following day in the morning, the leftover was re-weighed to obtain feed refusal. Thereafter, Dry Matter Intake (g/day) calculated daily feed intake = Dry Matter Offered (g/day) – Dry Matter Refused (g/day)

$$\text{Nutrient Intake (g/day)} = \text{DMI (g/day)} \times \text{Nutrient Concentration (\%)} / 100$$

The term "nutrient intake" was intended rather than "nutrient digestibility." The statement has revised to clearly describe the procedure used to calculate dry matter and nutrient intakes from feed offered and feed refusals on a dry matter basis. Individuals' birds were weighed at the beginning of the experiment and then on a weekly basis, Thereafter, body weight Improvement was employed by calculating differences of the two successive weighing, and average daily

weight gain was estimated by body weight change divided by experimental days. Feed conversion ratio was estimated by total feed intake divided by total weight gain. Nutrient conversion ratios (CP, ME, CF, and Ca) were expressed as a ratio of nutrient consumption to body weight gain.

Chemical Analysis

Representative samples of feed ingredients, the refusals, the were taken to the nutrition laboratory of the National Veterinary Institute, Bishoftu, Ethiopia for chemical analysis. Dry matter (DM), extract (EE), crude fiber (CF), ash content, and crude protein (CP) were determined for the study Indah, A. S., Permana, I. G., & Despal. (2020). Protein content determination was undertaken by multiplying nitrogen content which was determined from the feed and refusal samples using the Kjeldahl method. Crude protein content was then calculated by multiplying the measured nitrogen content by the conversion factor of 6.25nitrogen by 6.25. Calcium content was measured by atomic absorption spectrometry after dry ashing according to Yusuf et al. (2022).

The metabolizable energy (ME) of feed materials was calculated from the following equation:

Metabolizable energy (ME, kcal/kg DM) of the experimental diets was estimated from their chemical composition using the equation:

$$\text{ME (kcal/kg DM)} = 3951 + (54.4 \times \text{EE}) - (88.7 \times \text{CF}) - (40.8 \times \text{Ash})$$

where EE = ether extract (% DM), CF = crude fiber (% DM), and Ash = ash content (% DM). The values of EE, CF, and ash were obtained from laboratory analyses of the experimental diets.

Statistical Analysis

All measured response variables, including feed intake, body weight gain, feed conversion ratio, and survival rate, were analyzed using analysis of variance (ANOVA) under the General Linear Model (GLM) procedure of SAS software (version 9.4; SAS Institute Inc., Cary, NC, USA). The experiment was arranged in a Completely Randomized Design (CRD), with pen considered as the experimental unit. The statistical model used was: $Y_{ij} = \mu + T_i + e_{ij}$, where Y_{ij} represents the observed response variable, μ is the overall mean, T_i is the fixed effect of treatment, and e_{ij} is the random error term. Treatment means were compared using Tukey's Honest Significant Difference (HSD) test, and differences were considered significant at $P < 0.05$.

Results

The proximate nutrient profiles for blood meal, dried rumen content, and the combined dried blood-rumen content mixture (DBRCM) are summarized in Table 1.

Table 1. Chemical composition of blood meal, dried rumen content, and dried blood- rumen content mixtures (DBRCM) collected and processed in Dambi Dollo as DM basis.

No	Feed type	DM	MM	CF	CP	EE	Ca	NFE	Kcal ME/Kg DM
1	Blood Meal	85.33	10.63	1.41	74.78	1.39	1.88	11.80	3299.40
2	DRC	87.03	14.09	40.10	15.75	1.08	2.02	28.98	1699.73
3	DBRCM	88.00	11.29	18.18	44.17	1.43	2.09	24.93	2636.17

DRC- Dried Rumen Content; DBRCM- Dried Blood Rumen Content Mixture; DM -Dry Matter; CP-Crude Protein; ME-Metabolizable Energy; CF-Crude Fiber; EE-Ether Extract; MM-Mineral Matter; NFE-Nitrogen Free Extract; Ca-Calcium

Table 2 gives a summary of the proximate and metabolizable energy composition of feed ingredients incorporated into experimental diets on a dry-matter basis. The result depicts that the DBMCM had higher CP when compared with the soybean which was owed to replace each other.

Table 2. Proximate and energy composition (% , unless otherwise stated) of the feed ingredients used in the preparation of experimental diets, expressed on a dry matter (DM) basis.

Feed type	DM	Ash (MM)	CF	CP	%	Ca	NFE	ME (Kcal/kg DM)
DBRCM	88.00	11.29	18.18	44.17	1.43	2.09	24.93	2636.17
NSC	96.00	4.97	29.06	33.68	9.52	1.85	22.78	2833.31
Maize	90.23	5.25	4.99	8.40	1.93	1.85	79.44	3288.66
Soybean	96.07	5.55	17.80	40.41	5.98	1.88	30.26	3058.30
Wheat	91.37	1.86	2.52	11.55	2.18	1.11	81.89	3512.77
Fish meal	94.97	22.32	4.42	51.20	3.60	8.66	18.45	2844.12

Abbreviations: DBRCM – Dried Blood–Rumen Content Mixture; NSC – Noug Seed Cake; DM – Dry Matter; CP – Crude Protein; ME – Metabolizable Energy; CF – Crude Fiber; EE – Ether Extract; MM – Mineral Matter; NFE – Nitrogen-Free Extract; Ca – Calcium.

Table 3 presents the ingredient composition and corresponding nutrient profiles of both starter and finisher broiler diets for experimental treatments. The formulation points to some strategic changes in ingredient inclusion in a way that maintains balanced levels of nutrients and thus assures optimal supply of protein, energy, and fiber for growth performance evaluation under the varying dietary treatments.

Table 3. Composition of ingredients and nutrients in starters and finisher diets formulated for different experimental treatment groups.

Ingredients %	Starter diets					Finisher diets				
	T1	T2	T3	T4	T5 (control)	T1	T2	T3	T4	T5 (control)
Feed ingredients										
Soybean	30	24	18	12		30	24	18	12	
DBRMC	0	6	12	18		0	6	12	18	
NCS	15.7	15.1	14.5	12.4		2.5	2	1.6	1.2	
Fishmeal	2.4	2.2	2.1	2.5		2	1.9	1.2	0.8	
Maize	39.5	40.4	40.8	39.9		47.9	49.1	49.4	50.1	
Wheat	9.3	9.2	9.5	12.1		14.5	13.9	14.7	14.8	
Limestone	1.2	1.2	1.2	1.2		1.2	1.2	1.2	1.2	
Vitamin premix	1	1	1	1		1	1	1	1	
Salt	0.5	0.5	0.5	0.5		0.5	0.5	0.5	0.5	
Lysine	0.2	0.2	0.2	0.2		0.2	0.2	0.2	0.2	
Methionine	0.2	0.2	0.2	0.2		0.2	0.2	0.2	0.2	
Total	100	100	100	100		100	100	100	100	
DM (%)	89.43	88.95	87.68	87.45	89.3	90.06	90.2	89.3	89.5	89.87
CP (% DM)	23.01	23.05	23.08	23.1	23	20	20.05	20	20.1	20.03
ME (kcal/Kg DM)	3073	3049	3021	3012	3084	3285	3264	3236	3210	3286
CF (% DM)	4.7	4.8	4.7	4.4	3.8	2.8	2.2	3	2.9	3
MM (% DM)	11.57	11.28	10.67	10.42	11.4	12.98	12.76	12.33	11.1	12.638
EE (% DM)	7.3	6.6	4.2	3.8	3.6	8.6	7	5.8	4.1	5.5
NFE (% DM)	34.8	34.1	34.8	35.5	41.3	43.6	44.2	44.3	44.9	47.9

Ca (% DM)	1.27	1.6	1.5	1.4	1.8	0.96	0.98	0.99	1.1	1.3
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Notes: RSBM refers to Roasted Soybean Meal; DBRCM, Dried Blood–Rumen Content Mixture; and NSC, Noug Seed Cake. Nutrient abbreviations used include DM (Dry Matter), CP (Crude Protein), ME (Metabolizable Energy), CF (Crude Fiber), EE (Ether Extract), NFE (Nitrogen-Free Extract), and Ca (Calcium).

T1: Starter and finisher diets containing roasted soybean meal as the sole protein source (0% DBRCM replacement).

T2: Starter and finisher diets in which roasted soybean meal was replaced by dried bovine blood–rumen content mixture (DBRCM) at 20% of the protein source.

T3: Starter and finisher diets in which roasted soybean meal was replaced by DBRCM at 40% of the protein source.

T4: Starter and finisher diets in which roasted soybean meal was replaced by DBRCM at 60% of the protein source.

T5: Commercial starter and finisher diets used as the positive control.

Dry matter and Nutrient intake during the entire Study Period

The mean daily nutrient intake of SASSO_C44 broiler chicks (1-28 days) fed on various levels of dried blood rumen content mixture as a replacement for soybean meal is presented in Table 4. Daily dry matter intake (DMI) differed significantly among treatment groups ($P < 0.05$). Mean separation using Tukey's HSD test showed that birds fed T1 (0% DBRCM) and T5 (commercial feed) had significantly higher DMI than those fed higher levels of DBRCM inclusion, particularly T4 (60% DBRCM), while intermediate treatments showed intermediate responses, as indicated by superscript comparisons. There was significant difference in daily DMI among treatment groups. However, birds fed on T1 (0% DBRCM) and T5 (Commercial feed) had higher ($P < 0.05$) total DMI than those on T4 (60%DBRCM).

During the starter phase, broiler chicks expressed huge variation in dry matter intake between diets. Dry matter daily mean intake was between 32.54 g/bird in T4 and 36.36 g/bird in T5, with T1 and T5 exhibiting the greatest intake significantly ($P < 0.05$). Total dry matter intake was significantly higher ($P < 0.05$) in broilers fed T5 (1017.98 g/bird) and T1 (1012.38 g/bird) compared to those fed T4 (911.06 g/bird). While crude protein (CP) intake did not vary ($p > 0.05$) among treatments, crude fiber (CF) intake was significantly ($P < 0.05$) higher in T1 and T2 (1.91 g/bird) and significantly ($P < 0.05$) lower in T4 (1.65 g) and T5 (1.55 g) ($P < 0.05$). About metabolizable energy (ME), birds fed T5 (125.98 kcal/bird/day) and T1 (124.84 kcal/bird/day) took up

significantly more energy than T4 (112.65 kcal/bird/day) ($P<0.05$). Calcium-dependent intake also varied extensively ($P<0.05$), and T2 (0.64 g/bird/day) showed the highest value, followed by T1 and T4 (0.52 g/bird/day) with the lowest values.

The mean dry matter and nutrient intake of birds during the finisher phase is presented in Table 4. The mean daily DMI during the finisher phase was 105.84, 104.86, 100.88, 101.45 and 106.58 gram/bird/day for T1, T2, T3, T4 and T5, respectively. The study revealed that dry matter and nutrient intake patterns shifted to reflect dietary intake patterns of developing birds. The highest mean daily DM intake was T5 (106.58 g/bird) and T1 (105.84 g/bird), which was significantly ($P<0.05$) higher than T3 (100.88 g/bird), T2(104.86^{ab} g/bird), T4(101.45g/bird). Interestingly, total DM intake showed distinctive differences ($p<0.05$) with T5 (2984.31 g) and T1 (2963.52 g) significantly higher than T3 (2824.68 g) T2(2935.99), and T4 (2840.67 g).

Despite these variations in DM, the CP intake was statistically unchanged across the treatments ($p>0.05$) Crude fiber intake varied significantly ($p<0.05$) where T5 (3.55 g/bird) and T1 (3.53 g) took the highest amount, followed by T2 (2.56 g). ME intake rose similarly ($p<0.05$) where T5 (389.14 kcal/bird) and T1 (386.32 kcal/bird) were significantly greater than T3 (366.80 kcal) and T4 (361.85 kcal). Additionally, calcium consumption increased rapidly in T5 (1.54 g/bird/day) and exceeded that of all other treatments ($p<0.05$) which implied a supplementation effect.

The mean dry matter and nutrient intake during the entire experiment is presented in Table 4. The daily DMI of birds fed on the dietary treatments were 71.60, 69.81, 67.26, 66.38 and 71.60 grams for T1, T2, T3, T4 and T5, respectively. Birds fed on T4 had the lowest DMI ($p<0.05$) compared with T1, T2, T3 and T5. Birds fed on T4 (60%DBRCM) had shown the lowest ($P<0.05$) total dry matter intake (TDMI) compared with T1, T2, T3 and T5.

Average daily crude fiber (CF) intake by SASSO birds ranged from 2.72 to 3.00 g/bird, and there was no variation ($p>0.05$) Intake of metabolizable energy (ME) varied significantly ($P<0.05$) from 233.33 to 254.80 kcal/bird. Calcium (Ca) intake also varied significantly ($P<0.05$), ranging from 0.89 to 1.07 g/bird.

Throughout the 56 days, cumulative intake values of broiler chicks also had consistent patterns with phase-wise trends. Numerically, mean daily DM intake was not different among all treatments ($P<0.05$) but with T1 and T5 (71.60 g/bird) being maximum and T4 (66.38 g/bird)

being minimum. However, total DM intake expressed significant differences ($P<0.05$) with T1 and T5 (4009.60 g/bird) being significantly higher compared to T4 (3717.00 g).

CP consumption was not statistically different by treatments ($p>0.05$), though T5 numerically had the highest (17.21 g/bird/day). Furthermore, birds fed on T4 had the lowest ($P<0.05$) CP intake compared with other treatment groups. Similarly, CF consumption was not statistically different ($p>0.05$) though there were minimal numerical differences. Nevertheless, ME consumption was different by diet ($P<0.05$) as T5 (254.80 kcal/bird) and T1 (254.32 kcal/bird) still had the highest consumption rates, while T4 (233.33 kcal/bird) had the least. Calcium intake also displayed clear statistical differences ($P<0.05$) with T5 (1.07 g/bird/day) being the highest and T1 (0.89 g/bird/day) being the lowest, possibly reflecting differences in mineral content of the diets.

Table 4 shows the patterns of dry matter and nutrient intake by SASSO C44 broiler chicks during the starter and finisher, as well as overall feeding phases. Data captures differential feed consumption and nutrient uptake across treatments to provide important insights on dietary influences related to growth efficiency, nutrient utilization, and performance across the whole production cycle.

Table 4. Dry matter and nutrient intake of SASSO C44 broiler chicks during starter (1–28 days), finisher (29–56 days), and the entire experimental period (1–56 days).

Parameters				Experimental Diets					SEM	P-value
				T1	T2	T3	T4	T5		
Starter Phase										
Mean	daily	DM	intake						0.727	0.001
	(g/bird)			36.16 ^a	35.40 ^{ab}	33.77 ^{bc}	32.54 ^c	36.36 ^a		
Mean	total	DM	intake						26.96	0.001
	(g/bird)			1012.38 ^a	991.19 ^b	945.56 ^c	911.06 ^d	1017.98 ^a		
Mean	daily	CP	intake(g/bird)	9.35 ^a	9.17 ^a	8.86 ^a	8.64 ^a	8.36 ^a	2.09	0.775
Mean	daily	CF	intake(g/bird)	1.91 ^a	1.91 ^a	1.80 ^a	1.65 ^b	1.55 ^b	0.003	0.001
Mean	daily		ME						10.05	0.001
	intake(kcal/bird)			124.84 ^a	121.27 ^{ab}	115.93 ^{cb}	112.65 ^c	125.98 ^a		

Mean daily Ca intake(g/bird)	0.52 ^c	0.64 ^a	0.58 ^{ab}	0.52 ^{cb}	0.56 ^{ab}	0.01	0.003
Finisher phase							
Mean daily DM intake (g/bird)	105.84 ^{ab}	104.86 ^{ab}	100.88 ^b	101.45 ^{ab}	106.58 ^a	6.56	0.021
Mean total DM intake (g/bird)	2963.52 ^a	2935.99 ^b	2824.68 ^a	2840.67 ^d	2984.31 ^c	15.19	0.001
Mean daily CP intake(g/bird)	23.14 ^a	23.36 ^a	22.39 ^a	22.64 ^a	23.72 ^a	1.64	0.72
Mean daily CF intake(g/bird)	3.53 ^{ab}	2.56 ^c	3.40 ^b	3.38 ^b	3.55 ^a	0.04	0.001
Mean daily ME intake(kcal/bird)	386.32 ^a	380.28 ^a	366.80 ^b	361.85 ^b	389.14 ^a	20.64	0.001
Mean daily Ca intake(g/bird)	1.13 ^c	1.14 ^c	1.12 ^c	1.24 ^b	1.54 ^a	0.001	0.001
Entire Experimental Period							
Mean daily DM intake (g/bird)	71.60 ^a	69.81 ^a	67.26 ^a	66.38 ^a	71.60 ^a	6.71	0.028
Mean total DM intake (g/bird)	4009.60 ^a	3909.36 ^b	3766.56 ^c	3717.00 ^d	4009.60 ^a	20.19	0.001
Mean daily CP intake(g/bird)	17.08 ^a	16.81 ^a	16.28 ^a	16.20 ^a	17.21 ^a	1.87	0.770
Mean daily CF intake(g/bird)	3.00 ^a	2.73 ^a	2.93 ^c	2.74 ^a	2.72 ^a	0.13	0.730
Mean daily ME intake(kcal/bird)	254.32 ^a	246.21 ^b	237.77 ^c	233.33 ^c	254.80 ^a	13.14	0.001
Mean daily Ca intake(g/bird)	0.89 ^c	1.01 ^b	0.93 ^{bc}	0.93 ^{cb}	1.07 ^a	0.001	0.001

Within each row, means followed by different superscripts indicate statistically significant differences at $P < 0.05$. The abbreviations used are DM – Dry Matter; CP – Crude Protein; CF – Crude Fiber; ME – Metabolizable Energy; Ca – Calcium; g – gram; SEM – Standard Error of the Mean. Dietary treatments are defined as follows:

Body Weight Changes of SASSO C44 Broiler Chicks during the entire Study Period

The body weight development of broiler chicks during the starter phase is presented in Table 5. Initial weight was significantly comparable across all dietary groups. Mean daily weight gain did not differ significantly ($P > 0.05$) among treatments, as indicated by Tukey's HSD test, although birds fed T5 (26.1 g/bird/day) and T1 (26.0 g/bird/day) showed numerically higher values compared to the other treatments. Birds fed 40% DBRCM (T3) showed significantly lower daily

gains compared with those fed T1 (0% DBRCM) diet, while those fed a T4 (60% DBRCM) diet recorded significantly lower final body weight and total gain compared with those on T5.

Final body weight was significantly higher ($P < 0.05$) in birds fed diets T1, T2, and T5 (771.5, 769.4, and 772.7 g, respectively) compared to those fed T3 (732.3 g) and T4 (746.4 g). These findings suggest that no or moderate replacement of soybean meals with DBRCM supports optimal growth during the starter phase, whereas higher inclusion levels may negatively affect early weight gain. During the finisher phase, mean daily weight gains ranged from 34.5 g per bird in T4 to 36.9 g per bird in T5, with no significant differences observed among treatments ($P > 0.05$). Likewise, final body weights at the end of the finisher period, ranging from 1713 g (T4) to 1807 g (T5), and total weight gains were statistically similar across all groups ($P > 0.05$). Importantly, birds that had experienced reduced growth due to higher DBRCM inclusion during the starter phase (T3 and T4) exhibited compensatory growth during the finisher stage, suggesting that the early negative effects were offset over time. Across the entire 56-day experimental period, mean daily weight gains for T1 through T5 were 30.9, 30.9, 29.9, 29.8, and 31.5 g per bird, respectively, with no statistically significant differences among treatments ($P > 0.05$). Final body weights ranged from 1713 g in T4 to 1807 g in T5, and total weight gain trends paralleled daily gains, with T5 achieving the highest overall growth (1765.6 g total gain; 31.5 g/day) and T4 the lowest (1671 g total gain; 29.8 g/day). Mortality rates remained consistently low and did not differ significantly across treatments ($P > 0.05$).

Table 5. Changes in body weight of SASSO C44 broiler chicks during the starter, finisher, and entire experimental period fed-on graded levels DBRCM as a partial replacement for soybean meal.

Parameters	Experimental Diets						
	T1	T2	T3	T4	T5	SEM	P-value
Starter Phase							
Initial body weight(g)	41.5	41.6	41.4	41.3	41.3	0.037	0.24
Mean final body weight(g)	771.5 ^a	769.4 ^a	732.3 ^c	746.4 ^b	772.7 ^a	22	0.001
Mean daily weight gain(g/bird)	26.0 ^a	25.9 ^a	24.6 ^c	25.1 ^b	26.1 ^a	0.028	0.001
Mean total gain(g)	730 ^a	727.7 ^a	690.8 ^c	705 ^b	731.3 ^a	22	0.001
Finisher phase							
Initial body weight(g)	771.5 ^a	769.4 ^a	732.3 ^c	746.4 ^b	772.7 ^a	21.5	0.001
Mean final body weight(g)	1774	1772	1720.6	1713	1807	15	0.12
Mean daily weight gain(g/bird)	35.8	35.8	35.2	34.5	36.9	3.9	0.54
Mean total gain(g)	1003	1002.6	988.3	966.6	1034.3	29.32	0.55
Entire Experimental Period							
Initial body weight(g)	41.5	41.6	41.4	41.3	41.3	0.037	0.24
Mean final body weight(g)	1774	1772.3	1720.6	1713	1807	15	0.12
Mean daily weight gain(g/bird)	30.9	30.9	29.9	29.8	31.5	0.94	0.12
Mean total gain(g)	1732.5	1730.6	1679	1671	1765.6	15.03	0.12
Mortality rate (%)	0	0.5	0.25	0.25	0	0.3	0.67

Values within a row marked by different superscripts denote statistically significant differences ($P < 0.05$). Units: g = grams. Dietary treatments are defined as: T1 = 0% DBRCM + 100% roasted SBM; T2 = 20% DBRCM + 80% roasted SBM; T3 = 40% DBRCM + 60% roasted SBM; T4 = 60% DBRCM + 40% roasted SBM; T5 = commercial feed (roasted). SEM = standard error of the mean.

Feed and Nutrient Conversion Efficiency during the entire Study Period

The feed and nutrient conversion efficiency of SASSO C44 broilers fed diets containing graded levels of dried blood–rumen content mixture (DBRCM) as a partial substitute for soybean meal (SBM) during the starter (1–28 days), finisher (29–56 days), and the overall experimental period (1–56 days) is summarized in Table 6.

During the starter phase, no significant differences ($P > 0.05$) were observed among treatments for any of the measured conversion parameters. Feed conversion ratio (FCR) ranged from 1.49 to

1.56 g dry matter intake (DMI)/g weight gain, while protein conversion ratio (PCR) varied slightly from 0.34 to 0.36 g crude protein intake (CPI)/g gain, indicating consistent efficiency across all dietary treatments.

In the finisher phase, diets significantly affected feed conversion ratio (FCR), with birds fed T3 and T5 diets showing better efficiency (2.87 and 2.88 g DMI/g gain, respectively) compared with the other treatment groups. Meanwhile, PCR (0.63–0.66 g CPI/g gain), energy conversion ratio (ECR; 10.39–10.78 kcal MEI/g gain), and fiber and calcium conversion ratios did not differ significantly ($P > 0.05$).

Over the full 56-day period, Statistical analysis showed that feed conversion ratio (FCR) was not significantly affected by the dietary treatments over the full 56-day experimental period ($P > 0.05$). Across treatments, FCR values ranged from 2.22 to 2.29 g DMI/g gain, indicating comparable efficiency of feed utilization among all treatment groups.”. Notably, feed conversion ratio energy conversion ratio energy conversion ratio showed a significant improvement ($P < 0.05$), with T4 exhibiting the most efficient energy utilization (7.82 kcal MEI/g gain), followed by T3 and T5. Conversion ratios for protein, fiber, and calcium were unaffected by dietary treatments ($P > 0.05$).

Table 6. Feed and nutrient conversion ratios of SASSO C44 broilers fed diets with graded levels of DBRCM replacing soybean meal.

Parameters	Experimental Diets					SEM	P-value
	T1	T2	T3	T4	T5		
Starter Phase							
Feed conversion ratio (g DMI I/g gain)	1.56 ^a	1.53 ^a	1.56 ^a	1.49 ^a	1.56 ^a	0.011	0.083
Protein conversion ratio (g CPI/g gain)	0.36 ^a	0.35 ^a	0.36 ^a	0.34 ^a	0.36 ^a	0.001	0.965
Energy conversion ratio (kcal MEI/g gain)	4.21 ^a	4.19 ^a	4.37 ^a	4.27 ^a	4.22 ^a	0.278	0.988
Fiber conversion ratio (g CFI/g gain)	0.07 ^a	0.07 ^a	0.07 ^a	0.07 ^a	0.06 ^a	0.062	0.526
Calcium conversion ratio (g CaI/g gain)	0.02 ^a	0.02 ^a	0.02 ^a	0.02 ^a	0.02 ^a	0.002	0.999
Finisher phase							
Feed conversion ratio (g DM I/g gain)	2.96 ^a	2.93 ^{ab}	2.87 ^b	2.92 ^{ab}	2.88 ^b	0.001	0.009

Protein conversion ratio (g CPI/g gain)	0.65 ^a	0.65 ^a	0.63 ^a	0.66 ^a	0.64 ^a	0.042	0.999
Energy conversion ratio (kcal MEI/g gain)	10.78 ^a	10.62 ^a	10.39 ^a	10.48 ^a	10.53 ^a	3.823	0.530
Fiber conversion ratio (g CFI/g gain)	0.09 ^a	0.07 ^a	0.10 ^a	0.09 ^a	0.10 ^a	0.03	0.964
Calcium conversion ratio (g CaI/g gain)	0.03 ^a	0.03 ^a	0.03 ^a	0.04 ^a	0.04 ^a	0.01	0.970
Entire Experimental Period							
Feed conversion ratio (g DMI I/g gain)	2.29 ^a	2.27 ^a	2.24 ^a	2.22 ^a	2.26 ^a	0.029	0.984
Protein conversion ratio (g CPI/g gain)	0.55 ^a	0.54 ^a	0.54 ^a	0.54 ^a	0.54 ^a	0.038	0.999
Energy conversion ratio (kcal MEI/g gain)	8.13 ^a	7.98 ^{cb}	7.91 ^c	7.82 ^d	8.04 ^b	0.001	0.001
Fiber conversion ratio (g CFI/g gain)	0.10 ^a	0.09 ^a	0.10 ^a	0.09 ^a	0.09 ^a	0.05	0.982
Calcium conversion ratio (g CaI/g gain)	0.03 ^a	0.03 ^a	0.03 ^a	0.03 ^a	0.03 ^a	0.005	0.997

Notes: Within each row, means followed by different superscripts denote statistically significant differences ($P < 0.05$). Abbreviations used are: DMI – Dry Matter Intake; CPI – Crude Protein Intake; CFI – Crude Fiber Intake; MEI – Metabolizable Energy Intake; CaI – Calcium Intake; g – gram. Dietary treatment codes are as follows: T1 – 100% Roasted SBM (0% DBRCM); T2 – 80% Roasted SBM + 20% DBRCM; T3 – 60% Roasted SBM + 40% DBRCM; T4 – 40% Roasted SBM + 60% DBRCM; T5 – Commercial Roasted Feed. SEM – Standard Error of the Mean.

Discussion

Chemical Composition of Dried Blood–Rumen Content Mixture (DBRCM)

The DM content of dried blood–rumen contents mixture (DBRCM) determined in the present study confirms the effectiveness of drying and is in accord with the research results of Oloruntola et al. (2018) who reported DM contents of more than 90% in similar blends. The high crude protein (CP) content (44.17%) is in line with the previous studies by Zelalem et al. (2022) who reported 46.9% CP in DBRC and hence suggested its application as a protein-rich substitute feed component. The 18.18% crude fibre (CF) value is a bit higher than the 17.4% CF content reported Awad & Ali, (2024), that might be because of the rumen content, which is rich in fiber. The Mineral matter (MM) (11.29%) determined in the present study agrees with the results documented by Odukoya et al. (2020), whose reported the ash contents in the range of 10% and 14%. Ether extract (EE) value of 1.43% confirms its low-fat profile, which is consistent with the result reported by Odukoya et al. (2020), which recorded EE less than 2% for DBRC. Nitrogen-free extract (NFE) of 24.93% fits general expectations for this type of mixture, with minimal direct comparisons; it suggests moderate non-structural carbohydrate content. The metabolizable

energy (ME) value of 2,636.17 kcal/kg DM compares favorably with the range of 2,300 to 2,600 kcal/kg reported by Grace, (2021) in blood–rumen mixtures, supporting the DBRCM as a source of energy. Lastly, the 2.09% content of calcium (Ca) is higher than that for dried rumen digesta by itself at 0.21%(Pradesh & Vishvavidyalaya, 2018), but consistent with measurements in blood-included mixtures(Olayemi et al., 2025), i.e., it is also considerably capable of supporting diet mineral requirements.

Dry Matter and Nutrient Intake During the Entire Study Period

Daily dry matter (DM) intake varied significantly among treatments, with higher intake observed in birds fed T1 and T5 diets, while T4 showed comparatively lower intake. Overall, inclusion of DBRCM appeared to influence feed consumption during the early growth stage. This trend is consistent with findings by Yitbarek et al. (2016) and Saleh et al. (2025), who reported that moderate inclusion of alternative protein sources can improve feed intake in broilers, likely due to improved diet palatability and nutrient balance.

Crude protein (CP) intake remained statistically similar across all treatments ($P > 0.05$), suggesting that birds maintained adequate protein consumption regardless of DBRCM levels, a pattern also noted by Chisoro et al. (2025). In contrast, crude fiber (CF) intake was significantly higher in birds fed T1 and T2 compared with those fed T4 and T5 ($P < 0.05$), reflecting the influence of DBRCM inclusion on fiber intake. This finding is consistent with Aljenaïd et al. (2012).), reflecting the influence of DBRCM inclusion on fiber intake, consistent with findings by Crude fiber (CF) intake was significantly higher in birds fed T1 and T2 compared with those fed T4 and T5 ($P < 0.05$), reflecting the influence of DBRCM inclusion on fiber intake. This agrees with Aljenaïd et al. (2012), who reported increased fiber intake in broilers fed diets with higher levels of fibrous feed ingredients, attributed to the higher crude fiber content of the diets.

Metabolizable energy (ME) intake differed significantly among treatments, with birds fed T5 and T1 showing higher intake, while T4 recorded the lowest values. The higher ME intake in T5 and T1 reflects improved energy consumption associated with diet composition, whereas the reduced intake in T4 may indicate lower dietary energy availability or intake. This pattern suggests that DBRCM inclusion influenced energy utilization and feeding behaviour. These findings agree with Bezabih et al. (2017), who reported that variations in diet composition can significantly affect energy intake, metabolic efficiency, and feeding responses in broilers. Calcium (Ca) intake also differed significantly ($P < 0.05$), peaking

in T2 (0.64 g/bird/day) and lowest in T1 and T4 (0.52 g/bird/day), in agreement with Mohandas et al. (2023), highlighting the sensitivity of mineral intake to varying DBRCM levels.

During the finisher phase (29–56 days), dry matter (DM) intake patterns were consistent with those observed in the starter phase, reflecting feeding behavior in later growth stages. Daily DM consumption was significantly higher in T5 (106.58 g/bird) and T1 (105.84 g/bird) compared to T3 (100.88 g/bird), T2 (104.86 g/bird), and T4 (101.45 g/bird) ($P < 0.05$). Similarly, total DM intake differed significantly ($P < 0.05$), with T5 (2984.31 g/bird) and T1 (2963.52 g/bird) exceeding the other treatments, followed by T2, T4, and T3. This pattern likely reflects differences in diet palatability, nutrient density, and metabolic efficiency, in line with findings by (Benefits 2024) and (Shah et al. 2022).

Crude protein (CP) intake did not differ significantly among treatments ($P > 0.05$), indicating stable protein consumption across all diets, consistent with observations by (Baiyeri et al. 2024). In contrast, crude fiber (CF) intake varied significantly ($P < 0.05$), with the highest values recorded in T5 (3.55 g/bird) and T1 (3.53 g/bird), followed by T2 (2.56 g/bird), supporting prior reports that fiber intake is influenced by DBRCM inclusion (Wang et al., 2020).

Metabolizable energy (ME) intake mirrored DM consumption, showing significant differences among treatments ($P < 0.05$). T5 (389.14 kcal/bird) and T1 (386.32 kcal/bird) exhibited superior energy intake compared with T3 (366.80 kcal/bird) and T4 (361.85 kcal/bird), confirming the link between diet quality, palatability, and energy utilization as reported by (Bezabih et al. 2017).

Calcium (Ca) intake also differed significantly ($P < 0.05$), with T5 achieving the highest daily intake (1.54 g/bird/day) relative to the other treatments. This observation aligns with Nys et al. (2018), highlighting that DBRCM-based diets can effectively enhance mineral absorption and utilization in growing broilers.

Overall, these results indicate that moderate inclusion of DBRCM maintains protein intake while influencing DM, energy, fiber, and mineral consumption, emphasizing the importance of balanced diet formulation to optimize nutrient utilization and growth performance during the finisher stage.

Throughout the full 56-day rearing period, cumulative nutrient intake of SASSO C44 broilers followed patterns observed during the starter and finisher phases. Average daily dry matter (DM)

intake showed significant variation among treatments ($P < 0.05$), with birds in T1 and T5 consuming the highest amounts (71.60 g/bird), while T4 recorded the lowest intake (66.38 g/bird). This trend aligns with findings by Production & State (2024), which reported improved DM intake in broilers fed blood–rumen content mixtures compared with conventional diets. Similarly, total DM consumption differed significantly ($P < 0.05$), with T1 and T5 achieving 4009.60 g/bird, surpassing T4 (3717.00 g/bird), corroborating Eldeeb et al. (2025), who observed increased total feed intake with inclusion of 10% dried rumen content.

Crude protein (CP) intake was not significantly affected by dietary treatments ($P > 0.05$), although T5 showed a slightly higher daily intake (17.21 g/bird). This finding agrees with Bezabih et al. (2017), who reported uniform protein utilization across broilers fed graded levels of DBRCM. Likewise, crude fiber (CF) consumption did not differ significantly ($P > 0.05$), yet similar numerical patterns were observed, supporting Bezabih et al. (2017), who highlighted that moderate DBRCM inclusion can enhance fiber digestibility without altering overall intake.

Metabolizable energy (ME) intake varied significantly among treatments ($P < 0.05$), with T5 (254.80 kcal/bird) and T1 (254.32 kcal/bird) showing the highest energy consumption, whereas T4 (233.33 kcal/bird) had the lowest. These results are consistent with Mustapha et al. (2019), who demonstrated higher ME intake and improved feed efficiency in broilers receiving up to 10% rumen content in their diets. Calcium (Ca) intake also differed significantly ($P < 0.05$), with T5 achieving the highest daily intake (1.07 g/bird) and T1 the lowest (0.89 g/bird), aligning with a study by Wondater & Ayanie (2023), who attributed variation in mineral absorption to the compositional differences of rumen ash in DBRCM-containing diets.

Overall, these findings suggest that moderate inclusion of DBRCM maintains protein and fiber intake while slightly influencing energy and mineral consumption, indicating its suitability as a partial replacement for soybean meal in broiler diets without compromising nutrient intake.

Body Weight Changes and Feed Efficiency of Broilers Fed Diets with DBRCM During the entire Study Period

During the starter phase, chicks across all dietary treatments displayed comparable initial body weights, confirming an even starting point among groups. This observation aligns with Yitbarek,

Tamir, et al. (2016), who noted no significant weight differences prior to the introduction of DBRC in diets. However, distinctions became apparent in final body weights and weight gains.

Birds fed diets with low or no replacement of soybean meal by dried blood–rumen content (T1, T2, and T5) attained significantly higher final weights than those fed higher levels of DBRC inclusion. Mean daily weight gain showed a similar pattern, with the highest value recorded in T5 and the lowest in T3 ($P < 0.05$).

This response is likely attributed to better nutrient availability and digestibility in diets with low or no DBRC inclusion, whereas higher inclusion levels may have reduced growth performance due to the relatively higher fiber content and possible anti-nutritional effects, which can impair nutrient utilization and feed efficiency. These findings agree with Chisoro et al. (2025), El Sherif et al. (2023), and Attia et al. (2020), who reported that moderate inclusion of DBRC supports optimal growth, while excessive inclusion can negatively affect early growth performance due to reduced nutrient digestibility and utilization.

During the finisher phase, final body weight did not differ significantly among treatment groups ($P > 0.05$), indicating that varying levels of DBRCM inclusion had no significant effect on body weight at the end of the finishing period. Similarly, mean daily weight gains showed no significant variation across diets suggesting that birds initially affected by higher levels of DBRC were able to compensate for earlier growth deficits. These findings are consistent with reports by Bezabih et al. (2017) and Iwedan (2023), emphasizing the broilers' ability to exhibit compensatory growth when provided with nutritionally balanced finisher diets. Over the entire 56-day experimental period, final body weight did not differ significantly among treatment groups ($P > 0.05$), indicating that partial replacement of soybean meal with DBRCM had no adverse effect on overall growth performance. This finding agrees with Yitbarek et al. (2016), who reported that inclusion of alternative protein sources in broiler diets did not significantly affect final body weight when the diets were formulated to meet the birds' nutrient requirements. Trends in average daily gain and total weight gain mirrored this pattern, with T5 achieving the highest cumulative gain (1765.6 g; 31.5 g/bird/day) and T4 the lowest (1671 g; 29.8 g/bird/day). Although these differences were not statistically significant, the results suggest that moderate or optimal inclusion of DBRC effectively supports growth performance, consistent with observations by (Shittu et al. 2022). Mortality rates remained low and were unaffected by dietary treatments ($P > 0.05$), indicating that DBRC inclusion is safe for maintaining broiler health (V et al., 2025).

Feed and Nutrient Conversion Ratios During the entire Study Period

During the starter phase, feed efficiency parameters showed no significant differences among treatments, with feed conversion ratio (FCR) ranging from 1.49 to 1.56 g DMI/g gain and protein conversion ratio (PCR) from 0.34 to 0.36 g CPI/g gain ($P > 0.05$), in line with the findings of (Yitbarek, Tamir, et al. 2016). In the finisher phase, FCR exhibited slight variation, with birds receiving T3 and T5 diets displaying marginally better feed efficiency (2.87 and 2.88 g DMI/g gain), whereas PCR (0.63–0.66 g CPI/g gain), energy conversion ratio (ECR; 10.39–10.78 kcal MEI/g gain), and fiber and calcium utilization remained statistically unchanged ($P > 0.05$), reflecting trends reported by (El Sherif et al. 2023). Across the full 56-day experimental period, FCR remained consistent among treatments (2.22–2.29 g DMI/g gain; $P > 0.05$). However, energy utilization showed significant improvement ($P < 0.05$), with T4 achieving the highest energy efficiency (7.82 kcal MEI/g gain), followed by T3 and T5, supporting the observations of (Shuma et al. 2025). Protein, fiber, and calcium conversion ratios did not differ significantly across treatments ($P > 0.05$), consistent with the results of (AlZunaidy et al. 2023)

Conclusion

The findings of this study indicate that inclusion of dried blood–rumen content mixture (DBRCM) in broiler diets had positively influenced feed consumption, nutrient utilization, and growth performance of SASSO C44 chickens. Across both the starter and finisher phases, dry matter and nutrient intake remained comparable to the control diet up to about 40% DBRCM incorporation, however, minor numerical reduction was observed at the 60% DBRCM inclusion level. Body weight gain was maintained even at the highest inclusion during the starter phase, and both daily and cumulative gains remained steady throughout the finisher period. Similarly, feed and nutrient conversion efficiencies, as well as survival rates, were not significantly affected, reflecting effective nutrient utilization and overall bird health. These results demonstrated that DBRCM can safely replace soybean meal in broiler rations up to 60% without compromising feed intake, digestibility, growth performance, and feed efficiency. Consequently, DBRCM offers a sustainable, cost-effective poultry feed protein source alternative, capable of reducing feed costs while supporting optimal growth and productivity in broiler production. Further studies are recommended to evaluate the long-term effects of dried blood–rumen content mixture (DBRCM) on carcass characteristics, meat quality, and physiological health parameters of broiler chickens. In addition, economic analysis under different production systems and environmental conditions should be conducted to determine its practical feasibility for smallholder and commercial poultry producers. Investigating higher inclusion levels, different processing methods, and its application in other poultry species such as layers would also provide broader evidence on its potential as an alternative protein source.

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CHAPTER 8

Growth Performance and economic efficiency of SASSO-C44 Broilers Fed on Diets containing varying levels of Dried Blood-Rumen Mixture as a substitute for Roasted Soybean Meal

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ABSTRACT

This study evaluated the effects of partially replacing roasted soybean meal (RSBM) with a locally processed dried blood–rumen content mixture (DBRCM) in broiler diets on growth performance and economic efficiency. A total of 200 SASSO-C44 broiler chicks were randomly allocated to five dietary treatments in a completely randomized design. The treatments consisted of graded inclusion levels of DBRCM (0%, 20%, 40%, and 60%) and a commercial feed used as a control. During the starter phase, dry matter intake (DMI) and body weight gain (BWG) declined significantly as the level of DBRCM in the diet increased ($p < 0.05$). Birds fed higher DBRCM inclusion levels (T3 and T4) recorded significantly lower mean daily DMI (33.92 and 33.17 g/bird, respectively) compared with those receiving the control and lower inclusion diets (T1: 37.05 g/bird; T5: 37.45 g/bird). A similar trend was observed for final body weight, which decreased from 771.5 g in T1 to 732.3 g in T3, with a slight improvement in T5. However, over the entire 56-day experimental period, final body weight, feed conversion ratio (FCR), and overall performance index did not differ significantly among treatments ($p \geq 0.05$). Economic analysis showed that diets containing 40% and 60% DBRCM significantly reduced feed cost per kilogram of weight gain, net revenue, and overall economic efficiency ($p < 0.05$). Overall, the findings indicate that DBRCM can serve as a viable and low-cost

alternative protein source in broiler production, contributing to improved sustainability without compromising overall productivity.

Keywords: DBRCM economic efficiency performance index roasted soybean meal

Introduction

In developing countries, poultry production benefits from low labor and housing costs and favorable climatic conditions for simple housing systems; nevertheless, feed remains the dominant cost component, accounting for about 70%–85% of total production costs (Shuma et al. 2025), largely driven by the high prices of protein-rich ingredients such as soybean meal, ground-nut cake, and fish meal (Beaumont et al. 2022). This economic reality underscores the urgent need to identify locally available, low-cost alternative protein sources that do not directly compete with human food. Dried blood–rumen content mixture (DBRCM), obtainable from backyard slaughtering sites, slaughter slabs, slaughterhouses, and abattoirs, represents a promising option, particularly in Ethiopia where a large livestock population generates substantial quantities of rumen content and blood annually (Roccabruna et al. 2026). Estimates indicate that slaughtered cattle produce considerable amounts of rumen content dry matter and blood, translating into large volumes of potential feed resources and significant economic value if properly processed and commercialized, with additional benefits in reducing environmental pollution caused by improper disposal of these by-products (Wang et al. 2025). Recent studies have strengthened the scientific basis for replacing conventional soybean meal with alternative protein sources, showing that partial substitution with agro-industrial or slaughterhouse by-products can sustain or improve protein efficiency, growth performance, and metabolic status when diets are nutritionally balanced and appropriately processed, as demonstrated in broiler chickens (Tibebu et al. 2024) and using blood meal as a soybean meal replacer (Gupta et al. 2023). Despite this growing body of evidence, limited recent research has been conducted in Ethiopia, including in Dambi Dollo, on the systematic evaluation of rumen content and blood-based mixtures such as DBRCM for poultry feeding, thereby leaving a clear and persisting knowledge gap in terms of nutritional value, biological utilization, and economic feasibility under local production conditions (Osei-Adjei et al. 2025). Therefore, in response to persistent feed cost challenges, environmental concerns, and recent advances

in alternative protein utilization, this study was conducted to assess the growth performance and economic efficiency of SASSO-C44 broiler chickens fed diets containing graded levels of DBRCM as a partial replacement for roasted soybean meal.

Materials and Methods

Study Area

The study was conducted in Dambi Dollo town, located in the Kellem Wollega Zone of western Oromia, Ethiopia, approximately 642 km west of Addis Ababa. The area lies at an altitude ranging from 1500 to 1740 m above sea level and receives annual rainfall between 850 and 1308 mm, with temperatures ranging from 15°C to 28°C. Dambi Dollo town covers approximately 6160 ha and is situated at an elevation of about 2420 m above sea level.

Strengths and Limitations of the Study

Strengths of the Study

A major strength of this study lies in its strong practical relevance to poultry production under developing-country conditions. The experimental diets were formulated using locally available feed resources and processed with simple, low-cost techniques (boiling, sun-drying, and roasting), enhancing the applicability and scalability of the findings for small- and medium-scale poultry producers. The use of a commercially important dual-purpose strain (SASSO-C44) further strengthens the relevance of the results to current production systems in Ethiopia and similar agro-ecological zones.

Methodologically, the study employed a completely randomized design with adequate replication, isocaloric and isonitrogenous diets, and standardized bird management and health programs, which together minimized confounding effects and improved the reliability of dietary comparisons. In addition, the inclusion of a commercial feed treatment provided a realistic benchmark against industry standards, strengthening the validity of performance and economic interpretations.

Another key strength is the integrated evaluation approach, which combined growth performance, health management, chemical composition analysis, and economic efficiency. This holistic assessment allows conclusions to be drawn not only on nutritional adequacy but also on economic feasibility and sustainability, which are critical factors for

feed innovation. Furthermore, laboratory-based proximate analyses conducted at a national reference institute ensured the credibility and accuracy of nutrient characterization.

Limitations of the Study

Despite these strengths, the study has certain limitations that should be acknowledged. First, the experiment was conducted under controlled on-station conditions, which may not fully capture the variability in management, hygiene, and environmental stressors commonly encountered in smallholder or semi-intensive production systems. Therefore, caution is warranted when extrapolating the findings directly to all production settings. Second, while growth performance and economic indicators were comprehensively evaluated, the study did not assess nutrient digestibility, amino acid availability, or gut health responses, which could provide deeper physiological explanations for the observed outcomes. In particular, the variable composition of rumen content and blood—depending on animal diet and slaughter conditions—may influence nutrient consistency, and this variability was not chemically standardized beyond proximate analysis.

Third, the processing methods relied on sun-drying, which, although practical and cost-effective, may be influenced by weather conditions and could lead to variation in drying efficiency and microbial safety if not carefully managed. Additionally, the study focused on a single mixing ratio (1:1) of dried blood to rumen content, limiting conclusions about the optimal proportion of these two components. Finally, the duration of the study was limited to the starter and finisher phases, and no post-slaughter carcass traits or meat quality parameters were evaluated, which are important considerations for market acceptance and consumer preference.

Implications for Future Research

Future studies should validate these findings under on-farm conditions, include digestibility and amino acid profiling, and explore alternative processing and mixing ratios to optimize nutritional consistency. Investigations into gut microbiota response, carcass characteristics, and long-term health implications would further strengthen the scientific and practical foundation for widespread adoption of DBRCM in poultry feed-ing systems.

Blood Collection and Processing

Fresh cattle blood was collected immediately after slaughter. To reduce microbial contamination and moisture content, the blood was boiled at 100°C for 45 min. The boiled blood was poured onto clean plastic sheets to prevent contamination and sun-dried for 3–5 days, depending on weather conditions and material thickness. The dried blood was ground using a hand mortar and sieved through a 3-mm mesh to achieve uniform particle size comparable to commercial broiler feed.

Rumen Content Collection and Processing

Fresh rumen contents were collected from cattle slaughtered at the Dambi Dollo University municipal abattoir. The rumen material was boiled for 2 h in a metallic vat placed over an open fire, with occasional stirring to reduce microbial load. The boiled material was spread on sanitized plastic sheets and sun-dried for 3–4 days. Oversized particles were crushed using a hand mortar and passed through a 3-mm sieve to obtain uniform particle size.

Preparation of Dried Blood–Rumen Content Mixture

Dried blood and dried rumen content were thoroughly mixed in a 1:1 ratio to produce DBRCM, which was incorporated into broiler diets at different inclusion levels as a replacement for roasted soybean meal.

Roasted Soybean Meal Preparation

Full-fat soybeans were purchased from the Dambi Dollo local market. The seeds were cleaned by winnowing and hand-picking, washed with water, and roasted on a metal tray for 15 min with frequent stirring until a golden-brown color was achieved. Roasting was performed to deactivate antinutritional factors such as trypsin inhibitors. The roasted soybeans were then ground and sieved through a 3-mm mesh to produce roasted soybean meal for diet formulation.

Experimental Birds and Management

Two-hundred-day-old SASSO-C44 broiler chicks were obtained from Ethio Chicken PLC and randomly allocated to experimental pens using a completely randomized design

(CRD). Twenty pens (1.8 m² each; 0.12 m² per bird) constructed of wood and wire mesh were used. The pens were cleaned, disinfected with 37% formalin 2 weeks prior to chick placement, and allowed to dry.

Each pen was bedded with dried straw to a depth of 8 cm. Brooding temperature was maintained at 35°C–32°C during the first week and reduced by 2°C weekly thereafter using 200-W bulbs. Adequate ventilation was ensured through window openings. Birds were provided feed and fresh water ad libitum. Vaccinations against Newcastle disease (HB1 and Lasota) were administered on days 7, 21, and 45; Gumboro disease on days 14, 28, and 42; and fowl typhoid on day 49. Amprolium was administered prophylactically against coccidiosis.

Experimental Design and Diets

Experimental diets were formulated using maize, wheat mid-dling's, noug seed cake, roasted soybean meal, DBRCM, fish meal, vitamin premix, lysine, methionine, salt, and limestone. All ingredients were ground to pass through a 3-mm sieve. Diets were formulated to be isocaloric and isonitrogenous. Starter diets (1–28 days) contained 3000 kcal ME/kg DM and 23% crude protein, while finisher diets (29–56 days) contained 3200 kcal ME/kg DM and 20% crude protein. Treatments were as follows:

Justification of Different Dietary Treatments and Controls

The dietary treatments were selected to evaluate the effect of progressively replacing roasted soybean meal (RSBM) with dried blood–rumen content mixture (DBRCM) as a protein source in SASSO-C44 broiler diets. The treatment levels were designed to provide a clear dose-response pattern while identifying a practical level of DBRCM replacement that could be used without adversely affecting poultry performance.

T1 (0% DBRCM replacement) was included as the **negative/baseline control**, in which roasted soybean meal was used as the sole alternative protein source. This treatment provided the reference against which the effects of DBRCM replacement at different inclusion levels could be evaluated.

T2 (20% DBRCM replacement) represented a **low level of replacement**. It was included to determine whether a modest substitution of RSBM with DBRCM could maintain broiler growth and feed utilization while reducing dependence on soybean-based protein.

T3 (40% DBRCM replacement) represented an **intermediate replacement level**. This treatment was included to assess whether a substantial proportion of RSBM protein could be replaced by DBRCM without compromising growth performance, feed efficiency, and carcass characteristics.

T4 (60% DBRCM replacement) represented a **high replacement level**. It was included to determine the upper practical level of RSBM replacement and to evaluate whether increasing DBRCM use would result in any adverse effects on feed intake, growth performance, feed conversion, or carcass characteristics.

T5 (commercial starter and finisher diets) was included as a **positive/external control** to provide a benchmark against a commercially formulated diet. This enabled the performance of birds receiving experimental diets containing RSBM and DBRCM to be compared with birds receiving a readily available commercial feed under the same experimental conditions.

Overall, the use of **0%, 20%, 40%, and 60% replacement levels** provided a progressive gradient for evaluating the biological and economic response to DBRCM, while the **commercial diet served as an external benchmark** for evaluating the practical performance of the experimental diets. The treatment structure therefore allowed the study to determine not only whether DBRCM could replace RSBM, but also the extent to which it could be used without compromising broiler production performance.

Data Collection

Feed intake was recorded daily, and dry matter intake was calculated. Birds were weighed weekly to determine body weight gain, average daily gain, feed conversion ratio, and performance index. Mortality was recorded throughout the experiment.

Chemical Analysis

Representative samples of feed ingredients, diets, and refusals were analyzed for dry matter, crude protein, ether extract, crude fiber, and ash content at the National Veterinary Institute, Bishoftu, Ethiopia. Metabolizable energy was estimated using standard equations.

Economic Analysis

Economic efficiency was evaluated based on feed cost per kilo-gram of weight gain, total revenue, net revenue, economic efficiency, and relative economic efficiency.

Statistical Analysis

Data was analyzed using ANOVA with the General Linear Model procedure of SAS version 9.4. Treatment means were separated using Tukey's test, and significance was declared at $p < 0.05$.

Novelty and Knowledge Gap

Though some research work has been conducted on the nutritional value of rumen contents or blood meal as an alternative poultry feed, most of these studies were carried out on a small scale, at a single inclusion level, or using nonlocal broiler strains. Furthermore, most of these studies did not consider the biological and economic efficiency of the feed supplementations simultaneously. In Ethiopia, most of the studies conducted on rumen contents or blood meal as poultry feed supplements have been limited to the use of these two products separately, with little emphasis on the joint use of the two products as a dried blood–rumen content mixture (DBRCM), which has a balanced protein profile and better amino acid availability. Additionally, there is a lack of empirical information on the graded replacement levels of roasted soybean meal with DBRCM in actual production settings, especially for SASSO-C44 broiler chickens, which are widely recommended for semi-intensive production in Ethiopia.

Moreover, it is also important to note that in most of the previous studies, there was a lack of consideration of environmental sustainability factors, such as waste reduction and abattoir by-product valorization, in addition to economic performance indicators for small- and medium-scale poultry farmers. Therefore, this study fills these important research gaps by examining the effects of various levels of DBRCM implementation on the growth performance, feed efficiency, and economic returns of SASSO-C44 broilers. By making

connections between animal performance, feed cost savings, and environmental waste management in the local Ethiopian setting, this study presents new and location-specific evidence to support the sustainable use of slaughterhouse by-products as alternative protein sources in poultry production systems.

Results

The chemical composition of the ingredients, including blood meal, dried rumen content, and DBRCM, is presented in Table 1. Blood and rumen contents were collected immediately after slaughter, processed separately, and combined in a 1:1 ratio before chemical analysis at the National Veterinary Institute, Bishoftu, Ethiopia.

Chick Starter and Finisher Ration Feed Ingredients

The feed ingredients and chemical composition of the five dietary treatment groups of starter and finisher ration are presented in Table 2.

Dry Matter Intake, Body Weight Change, and Feed Conversion Ratio of SASSO-C44 Broiler Chicks

Dry matter intake (DMI), body weight change, and feed conversion ratio (FCR) of SASSO-C44 broiler chicks fed diets containing graded levels of dried blood–rumen content mixture (DBRCM) as a replacement for roasted soybean meal are presented in Table 3. During the starter phase, birds fed DBRCM-containing diets exhibited significant differences in daily DMI compared with the control group ($p < 0.05$). The lowest DMI ($p < 0.05$) was recorded in birds receiving the 60% DBRCM diet (T4) during both the finisher phase and the overall experimental period. Body weight gain was also significantly affected by dietary treatment. During the starter phase, birds fed the 60% DBRCM diet (T4) recorded the lowest body weight gain. Significant differences in body weight gain among treatments were observed during the finisher phase and across the entire experimental period ($p < 0.05$). Feed conversion ratio was significantly influenced by dietary treatment during both the starter and finisher phases ($p < 0.05$). However, when evaluated over the full 56-day production cycle, overall FCR did not differ significantly among the treatment groups ($p \geq 0.05$).

Performance Index and Mortality of Broilers Fed DBRCM-Based Diets

The performance index of broiler chickens fed diets containing graded levels of dried

blood–rumen content mixture (DBRCM) as a substitute for roasted soybean meal is pre-sented in Table 4. No significant differences ($p \geq 0.05$) were observed in the performance index among the dietary treat-ments during the starter phase, finisher phase, or over the en-tire experimental period.

TABLE 1 | Chemical composition of feed ingredients used for preparing experimental diets as DM basis.

No	Feed type	DM%	Ash (MM)%	CF%	CP%	EE%	Ca%	NFE%	ME (kcal/kg DM)
1	DBRCM	88.00	11.29	18.18	44.17	1.43	2.09	24.93	2636.17
2	NSC	96.00	4.97	29.06	33.68	9.52	1.85	22.78	2833.31
3	Maize	90.23	5.25	4.99	8.40	1.93	1.85	79.44	3288.66
4	S. Bean	96.07	5.55	17.80	40.41	5.98	1.88	30.26	3058.30
5	Wheat	91.37	1.86	2.52	11.55	2.18	1.11	81.89	3512.77
6	Fish meal	94.97	22.32	4.42	51.20	3.60	8.66	18.45	2844.12

Abbreviations: Ca, calcium; CF, crude fiber; CP, crude protein; DBRCM, dried blood–rumen content mixture; DM, dry matter; EE, ether extract; kg, kilogram; ME, metabolizable energy; MM, mineral matter; NFE, nitrogen free extract; NSC, noug seed cake.

TABLE 2 | Proportion of ingredients used in formulating broiler starter and finisher rations, and chemical composition of the treatment groups.

Ingredients %	For broilers starters					For broilers finisher				
	T1	T2	T3	T4	T5	T1	T2	T3	T4	T5 (control)
	(control)									
Feed ingredients										
Soyabean	30	24	18	12		30	24	18	12	
DBRMC	0	6	12	18		0	6	12	18	
NCS	15.	15.1	14.5	12.4		2.5	2	1.6	1.2	

	7									
Fishmeal	2.4	2.2	2.1	2.5		2	1.9	1.2	0.8	
Maize	39.	40.4	40.8	39.9		47.9	49.1	49.4	50.1	
	5									
Wheat	9.3	9.2	9.5	12.1		14.5	13.9	14.7	14.8	
Limestone	1.2	1.2	1.2	1.2		1.2	1.2	1.2	1.2	
Vitamin premix	1	1	1	1		1	1	1	1	
Salt	0.5	0.5	0.5	0.5		0.5	0.5	0.5	0.5	
Lysine	0.2	0.2	0.2	0.2		0.2	0.2	0.2	0.2	
Methionine	0.2	0.2	0.2	0.2		0.2	0.2	0.2	0.2	
Total	100	100	100	100		100	100	100	100	
DM (%)	89.4	88.95	87.68	87.45	89.3	90.0	90.2	89.3	89.5	89.87
	3					6				
CP (% DM)	23.0	23.05	23.08	23.1	23	19.6	20.05	19.75	20.1	20.03
	1					8				
ME (kcal/Kg DM)	307	3049	3021	3012	3084	3285	3264	3236	3210	32,086
	3									
CF (% DM)	4.7	4.8	4.7	4.4	3.8	2.8	2.2	3	2.9	3
MM (% DM)	11.5	11.28	10.67	10.42	11.4	12.9	12.76	12.33	11.1	12.638
	7					8				
EE (% DM)	7.3	6.6	4.2	3.8	3.6	8.6	7	5.8	4.1	5.5
NFE (% DM)	277	2704	2560	2499	2744	43.6	44.2	44.3	44.9	47.9
	5									
Ca (% DM)	1.2	1.6	1.5	1.4	1.37	0.96	0.98	0.99	1.1	1.3
	7									

Note: Roasted soybean meal; DBRCM = Dried Blood Rumen Content Mixture; NSC = Noug Seed Cake; T1 = 0% DBRCM + 100% RSBM, T2 = 20% DBRCM + 80% RSBM; T3 = 40%

DBRCM + 60% RSBM; T4 = 60% DBRCM + 40% RSBM; T5 = commercial feed.

Abbreviations: Ca, calcium; CF, crude fiber; CP, crude protein; DM, dry matter; EE, ether extract; ME, metabolizable energy; NFE, nitrogen free extract.

Similarly, mean mortality rate was not significantly affected by dietary treatment ($p \geq 0.05$), indicating that inclusion of DBRCM had no adverse effect on bird survival.

Economic Efficiency of Experimental Diets

The economic efficiency of experimental diets is presented in Table 5. The cost per kilogram of feed differed significantly among dietary treatments ($p < 0.05$). Diets T1 and T5 were the most expensive on a per-kilogram basis, whereas T4 was the least expensive ($p < 0.05$). Similarly, the cost per kilogram of body weight gain varied significantly among treatments ($p < 0.05$). The highest cost per kilogram of gain was observed in birds fed diets T1 and T5, while the lowest cost was recorded in birds fed diet T4. Significant differences ($p < 0.05$) were also observed in total feed cost across treatments, with birds in T5 incurring the highest total feed cost and those in T4 incurring the lowest. Economic efficiency differed significantly among dietary treatments ($p < 0.05$). Birds fed diets T3 and T4 exhibited the highest economic efficiency, whereas those fed diets T1 and T5 showed the lowest economic efficiency.

Growth Performance and Feed Conversion Rate

Final body weights of broiler chickens did not differ significantly among dietary treatments ($p \geq 0.05$), with a mean final weight of 1.75 kg. This finding indicates that substituting roasted soybean meal with dried blood-rumen content mixture (DBRCM) at any of the inclusion levels tested did not adversely affect final growth performance. In contrast, total feed consumption per bird differed significantly among treatments ($p = 0.001$). Birds fed the T4 diet consumed the least amount of feed (4.44 kg per bird), which was significantly lower ($p < 0.05$) than feed intake recorded for birds.

TABLE 3 Dry matter intake, body weight change, feed conversion ratio and mortality rate of SASSO-C44 broiler chicks during starter phase (1–28 days), finisher phase (29–56 days), and enter experiment (1–56 days).

Parameters	Experimental diets						<i>p</i>
	T1	T2	T3	T4	T5	SEM	
<i>Starter phase</i>							
Mean daily DM intake (g/bird)	37.05 ^b c	35.13 ^{bc}	33.92 ^c	33.17 ^c	37.45 ^a	0.67	0.003
Mean total DM intake (g/bird)	10.13 ^a	9.91 ^b	9.44 ^c	9.18 ^d	10.19 ^a	11.49	0.001
Initial body weight (g)	41.5 ^a	41.6 ^a	41.4 ^a	41.3 ^a	41.3 ^a	0.037	0.24
Mean final body weight (g)	771.5 ^a	769.4 ^a	732.3 ^c	746.4 ^b	772.7 ^a	22	0.001
Mean daily weight gain (g/bird)	26.0 ^a	25.9 ^a	24.6 ^c	25.1 ^b	26.1 ^a	0.028	0.001
Mean total gain (g)	730 ^a	727.7 ^a	690.8 ^c	705 ^b	731.3 ^a	22	0.001
FCR (gDMI I/g gain)	1.56 ^a	1.53 ^a	1.56 ^a	1.49 ^a	1.56 ^a	0.011	0.083
<i>Finisher phase</i>							
Mean daily DM intake (g/bird)	107.6 ^a	104.6 ^{ab}	101.2 ^b	100.8 ^b	108.5 ^a	2.98	0.001
Mean total DM intake (g/bird)	2964 ^b	2937 ^c	2826 ^e	2838 ^d	2989 ^a	9.6	0.007
Initial body weight (g)	771.5 ^a	769.4 ^a	732.3 ^c	746.4 ^b	772.7 ^a	21.5	0.001
Mean final body weight (g)	1774 ^a	1772 ^a	1720.6 ^a	1713 ^a	1807 ^a	2963	0.12
Mean daily weight gain (g/bird)	35.8 ^a	35.8 ^a	35.2 ^a	34.5 ^a	36.9 ^a	3.9	0.54
Mean total gain (g)	1003 ^a	1002.6 ^a	988.3 ^a	966.6 ^a	1034.3 ^a	3059	0.55

FCR (gDMI I/g gain)	2.96 ^a	2.93 ^{ab}	2.87 ^b	2.92 ^{ab}	2.88 ^b	0.001	0.009
<i>Entire experimental period</i>							
Mean daily DM intake (g/bird)	71.6 ^a	69.81 ^b	67.25 ^c	66.37 ^c	71.6 ^a	0.4	0.001
Mean total DM intake (g/bird)	4010 ^a	3908 ^b	3764 ^c	3717 ^d	4009 ^a	2.29	0.001
Initial body weight (g)	41.5 ^a	41.6 ^a	41.4 ^a	41.3 ^a	41.3 ^a	0.037	0.24
Mean final body weight (g)	1774 ^a	1772.3 ^a	1720.6 ^a	1713 ^a	1807 ^a	2963 ^a	0.12
Mean daily weight gain (g/bird)	30.9 ^a	30.9 ^a	29.9 ^a	29.8 ^a	31.5 ^a	0.94	0.12
Mean total gain (g)	1732.5 ^a	1730.6 ^a	1679 ^a	1671 ^a	1765.6 ^a	2966	0.12
FCR (gDMI I/g gain)	2.29 ^a	2.27 ^a	2.24 ^a	2.22 ^a	2.26 ^a	0.029	0.984

Note: Means with a different superscript in a row are significantly different ($p < 0.05$);

T1—0% DBRCM + 100% RSBM; T2—20% DBRCM + 80% RSBM; T3—40% DBRCM + 60% RSBM; T4—60% DBRCM + 40% RSBM; T5—commercial feed.

Abbreviations: DMI, dry matter intake; FCR, feed conversion ratio; g, gram; SEM, standard error of the mean. In n T5 (4.66 kg) and T1 (4.82 kg). However, feed intake of birds fed the T4 diet did not differ significantly ($p \geq 0.05$) from those fed T2 (4.73 kg) and T3 (4.65 kg). The highly significant treatment effect indicates that differences in feed intake were not due to random variation but were associated with dietary formulation, particularly the level of DBRCM inclusion, which had a measurable influence on total feed consumption.

Feed Cost Analysis

The cost per kilogram of feed was directly influenced by dietary formulation, particularly the inclusion level of dried blood–rumen content mixture (DBRCM). The control diet (T5), which contained no DBRCM, had the highest feed cost at 75.5 Birr/ kg (approximately

USD 1.34/kg) and was significantly more ex-pensive than all other diets ($p < 0.05$). Feed cost per kilogram decreased progressively with increasing levels of DBRCM inclu-sion, with diet T4 recording the lowest cost at 52.38 Birr/kg (ap-proximately USD 0.93/kg). This inverse relationship between DBRCM inclusion and feed cost was also reflected in the cost per kilogram of body weight gain. Birds fed diets T3 and T4 recorded the lowest and most economical costs per kilogram of gain, at 137.76 Birr/kg (approx-imately USD 2.44/kg) and 129.01 Birr/kg (approximately USD 2.28/kg), respectively. These values were significantly lower ($p < 0.05$) than those observed for birds fed T1 (168.9 Birr/kg; approximately USD 2.99/kg) and T5 (185.47 Birr/kg; approxi-mately USD 3.28/kg).

Table 4. Performance index of broilers fed diets containing graded levels of DBRCM during starter phase (1–28 days), finisher phase (29–56 days), and the entire

Performance index	Experimental diets					Mean	SEM	<i>p</i>
	T1	T2	T3	T4	T5			
Starter phase	55.31	55.68	53.0	58.21	54.45	55.34	34	0.78
Finisher phase	33.47	34.19	34.28	33.19	36.12	34.22	11.69	0.75
Entire experiment	72.5	74.75	72.0	72	76.25	73.5	4.96	0.055
Number of mortalities	0	2	1	1	0	0.8	0.13	0.001
Mean mortality	0	0.5	0.25	0.25	0	02	0.02	0.02
Mortality %	0	5	2.5	2.5	0	2	2.5	0.02
Survival %	100	95	97.5	97.5	100	98	2.5	0.02

Note: T1 = 0% DBRCM + 100% RSBM; T2 = 20% DBRCM + 80% RSBM; T3 = 40% DBRCM + 60% RSBM; T4 = 60% DBRCM + 40% RSBM; T5 = commercial feed. SEM:

standard error of the mean performance index (PI) = (body weight in kg/FCR) $\times$ 100.

TABLE 5 Economic efficiency of trial rations.

Parameters	Experimental diet					Mean	SEM	<i>p</i>
	T1	T2	T3	T4	T5			
Mean final body weight (kg)	1.774	1.772 ^a	1.720 ^a	1.7013 ^a	1.806 ^a	1.75	0.2	0.12

a

Feed cost/kg feed (Birr)	66.45 b	61.18 ^c	55.35 ^d	52.38 ^e	75.5 ^a	62.17	4.87	0.00 1
Total feed consumed/bird (kg)	4.82 ^a	4.73 ^b	4.65 ^b	4.44 ^c	4.66 ^b	4.66	0.01	0.00 1
Feed cost/kg gain (Birr)	168.9 b	151.03 ^c	137.76 ^d	129.01 ^d	185.47 ^a	154	21.026	0.00 1
Total feed cost (Birr/bird)	299 ^b	268 ^c	236 ^d	221 ^e	337 ^a	272	25.59	0.00 1
Total revenue (Birr/bird)	949 ^{ab}	942 ^{ab}	945 ^{ab}	930 ^b	955 ^a	942	113	0.02
Net revenue (Birr/bird)	650 ^b	675 ^b	697 ^a	706 ^a	619 ^c	668	98	0.00 1
Economic efficiency (EE)	2.17 ^c	2.50 ^b	2.94 ^a	3.19 ^a	1.84 ^d	2.53	0.01	0.00 1
Relative economic efficiency (REE)	1.18 ^c	1.35 ^b	1.6 ^a	1.73 ^a	1 ^d	1.37	0.04	0.00 1

Note: Means with a different superscript in a row are significantly different ($p < 0.05$); T1 = 0% DBRCM + 100% RSBM; T2 = 20% DBRCM + 80% RSBM; T3 = 40% DBRCM + 60% RSBM; T4 = 60% DBRCM + 40% RSBM; T5 = commercial feed; SEM = standard error of the mean; kg = kilogram; total revenue (Birr) = total gain (kg) $\times$ price of 1 kg body weight on sale; net revenue = total revenue from the gain – total feed cost (Birr); economic efficiency = net revenue/total feed cost; relative economic efficiency = economic efficiency/control economic efficiency, (Birr = Ethiopian Cash). Similarly, total feed cost per bird followed the same trend. Diet T4 resulted in the lowest total feed cost per bird (221 Birr; ap-proximately USD 3.91), whereas birds fed the control diet (T5) incurred the highest cost (337 Birr per bird; approximately USD 5.96). Overall, these results clearly demonstrate the substan-tial cost-saving potential of incorporating DBRCM into broiler diets, particularly in resource-limited production systems.

Economic Returns and Efficiency

Although total revenue per bird did not differ significantly among dietary treatments ($p \geq$

0.05), ranging narrowly from 930 to 955 Birr (approximately USD 16.91–17.36), both net revenue and overall economic efficiency differed significantly ($p < 0.05$). The highest net revenue was obtained from birds fed diet T4 (706 Birr; approximately USD 12.84), followed closely by those fed diet T3 (697 Birr; approximately USD 12.67). These two diets generated substantially higher net returns than the remaining treatments. In contrast, birds fed the control diet (T5) generated the highest gross revenue but recorded the lowest net revenue (619 Birr; approximately USD 11.25), largely due to the high cost of feed. Economic efficiency (EE) and relative economic efficiency (REE) followed a similar pattern. Diet T4 exhibited the highest efficiency (EE= 3.19; REE= 1.73), which was statistically comparable to T3 but significantly superior to T1, T2, and T5. The control diet (T5) recorded the lowest efficiency values (EE= 1.84; REE= 1.00), indicating comparatively poor economic viability.

Discussion

This study advances existing knowledge on the use of dried blood–rumen content mixture (DBRCM) in broiler nutrition by moving beyond descriptive performance outcomes to interpret the biological significance of the results. Specifically, it elucidates the physiological and biochemical mechanisms through which DBRCM influences feed intake, growth dynamics, nutrient utilization, and economic efficiency, thereby demonstrating clear progress over earlier studies that primarily reported agreements or discrepancies in performance responses without mechanistic explanation. The observed reduction in dry matter intake (DMI) with increasing DBRCM inclusion—most pronounced in the 60% replacement group (T4) reflects more than simple diet rejection; it aligns with established physiological responses to changes in sensory cues and gastrointestinal signaling. In broilers, feed palatability is strongly influenced by visual and olfactory characteristics, which interact with central appetite regulation pathways (e.g., hypothalamic neuropeptides) to modulate voluntary intake (San-Miguel et al. 2023). The darker color and stronger odor of high-DBRCM diets likely triggered early satiety responses through conditioned aversion and altered chemosensory feedback, consistent with findings in poultry nutrition where changes in diet appearance and odor influence intake behavior (Vasluianu et al. 2024).

Moreover, the elevated crude fiber content in DBRCM alters digesta physical properties,

increasing bulk and retention time in the gut. This mechanical effect activates mechanoreceptors in the upper gastrointestinal tract that signal satiety via vagal afferents, reducing subsequent feeding bouts (Beaumont et al. 2022). From a biochemical perspective, high fiber also binds bile acids and digestive enzymes, which can reduce nutrient solubilization and slow the rate of carbohydrate and protein digestion (Rasool et al. 2023). Such changes can shift the balance of nutrient signals reaching the small intestine and ceca, with downstream effects on hormones like cholecystokinin and peptide YY that suppress appetite (van der Eijk et al. 2025).

These mechanistic interpretations extend beyond earlier descriptive reports (Sherif et al. 2025) by connecting macronutrient composition with gut physiology and neuroendocrine regulation. They support the emerging consensus in recent high-impact studies that fiber-mediated modulation of intake is not solely a function of physical bulk but also involves integrated neural and hormonal pathways influencing feed behavior in broilers (Rasool et al. 2023).

The observed reduction in feed intake with increasing DBRCM inclusion, particularly at the 60% level, must be interpreted through the lens of digestive physiology and nutrient signaling, not just palatability. Although sensory factors such as odor and appearance likely contributed to initial aversion, the nutrient composition and physical properties of DBRCM diets interact with gut sensory and metabolic pathways that regulate appetite. High crude fiber increases digesta viscosity and bulk, which in turn stimulates mechanoreceptors and gut hormone release (e.g., cholecystokinin and peptide YY) that signal satiety to the central nervous system (Rasool et al. 2023). Additionally, high fiber can sequester bile salts and digestive enzymes, slowing carbohydrate and protein hydrolysis in the small intestine and reducing the post-ingestive nutrient signals that typically stimulate feeding (Kumar and Srivastava 2025). These integrated sensory and metabolic feedback mechanisms help explain why intake declines with higher DBRCM even when energy and amino acid levels are balanced. Importantly, despite lower DMI, final body weight did not differ significantly among treatments, indicating that DBRC diets sustained growth potential. This outcome reflects a biologically relevant compensation in nutrient utilization efficiency rather than a simple equivalence of end weights. The high biological value of blood-derived proteins, especially rich in lysine and leucine, supports efficient muscle protein syn-

thesis even when overall intake is lower (Potu et al. 2025). In addition, older broilers adapt digestive enzyme secretion and absorptive capacity, allowing more complete extraction of available nutrients from diets with complex protein and fiber structures. Recent studies have reported similar compensatory growth effects where diets with high-value amino acid profiles or enzyme supplementation enable broilers to maintain growth despite reduced intake (San-Miguel et al. 2023). This demonstrates progress beyond earlier reports that merely noted intake suppression without probing how birds biologically adjust to alternative feed substrates.

The significant depression in body weight gain (BWG) during the starter phase at high DBRCM levels underscores a well-recognized developmental constraint in young broilers. Newly hatched chicks exhibit low digestive enzyme activity, immature mucosal surfaces, and limited hindgut fermentation capacity (Potu et al. 2025). Under such conditions, high-fiber diets can reduce the availability of digestible amino acids and energy, particularly when protease and carbohydrase activities are insufficient to break down complex protein–fiber matrices. Reduced digestible amino acid flux from the gut lumen to the blood-stream directly limits protein deposition and growth during early life (Obafemi et al. 2024). By explicitly linking starter phase growth suppression to biochemical limitations in digestion and absorption, this work deepens understanding beyond earlier descriptive accounts and underscores the need for phase-specific formulation strategies when integrating unconventional protein sources.

In contrast, as birds mature into the finisher phase, the convergence of BWG across treatments reflects a genuine physiological adaptation. With age, broilers exhibit increased gut surface area, enhanced secretion of digestive enzymes (including proteases and carbohydrases), and a more complex hindgut microbial community capable of fermenting fiber fractions (Wang et al. 2025). The presence of partially digested plant substrates and rumen microflora residues in DBRCM likely provided fermentable substrates for the hindgut microbiota, generating short-chain fatty acids that serve as additional energy sources and positively influence gut health and nutrient absorption (Yitbarek and Dagnaw 2022). This adaptive response illustrates a dynamic shift in nutrient utilization efficiency over time, rather than a static outcome, and represents a significant advance relative to earlier studies that did not consider temporal changes in digestive capacity.

These findings carry several important implications for future research. First, evaluating the developmental trajectory of digestive enzymes and gut hormone profiles in broilers fed DBRCM could clarify the biochemical mechanisms of adaptation and identify optimal inclusion thresholds for each growth phase. Second, research into exogenous enzyme supplementation (e.g., cellulases or proteases) may help mitigate early-phase digestibility constraints, reducing intake suppression without compromising economic benefits. Third, characterizing changes in hindgut microbial communities in response to DBRCM offers the potential to harness microbial fermentation pathways for improved nutrient extraction.

In sum, the present results not only confirm that moderate DBRCM inclusion supports acceptable growth performance but also illuminate the interconnected physiological, biochemical, and microbial processes that underline these outcomes. By moving beyond simple performance comparisons to mechanistic interpretation, this study aligns with recent high-impact literature calling for a deeper understanding of how alternative feed ingredients interact with animal biology, thereby strengthening the scientific basis for sustainable poultry nutrition innovations.

The observed pattern in feed conversion ratio (FCR) further underscores the dynamic nature of how broilers physiologically adapt to DBRCM-based diets over time. At the starter and finisher phases, higher DBRCM inclusion impaired FCR, suggesting initial inefficiencies in nutrient digestion and utilization. This may be rooted in age-dependent differences in digestive enzyme activity: younger birds have lower endogenous protease and carbohydrase expression, which limits their ability to efficiently hydrolyze complex proteins and fiber components present in DBRCM (Beaumont et al. 2022). Likewise, the physical interactions between soluble fiber and digestive enzymes can create a viscous digesta environment that reduces enzyme–substrate contact, impairing nutrient absorption and transiently increasing maintenance energy costs relative to growth (Kumar and Srivastava 2025). However, the absence of significant differences in overall FCR across the 56-day cycle suggests that broilers compensate metabolically and physiologically as they mature. This compensation likely involves (i) enhanced amino acid absorption efficiency, (ii) improved nitrogen retention, and (iii) shifts in energy partitioning favoring anabolic processes over maintenance metabolism. As birds age, both brush border enzyme capacity and intestinal surface area increase, which enhances the digestion and absorption of both

peptides and amino acids from complex protein matrices like DBRCM (Cohen et al. 2025). Furthermore, older birds demonstrate a more robust hindgut microbiota, increasing fermentation of fibrous components into short-chain fatty acids that contribute additional metabolizable energy (Sherif et al. 2025). Collectively, these physiological adaptations explain how early inefficiencies associated with DBRCM can be offset over time—a process also observed in other studies on unconventional feedstuffs when diets are nutritionally balanced and age-appropriate (Sedghi et al. 2022). From an economic standpoint, the reduction in feed cost with increasing DBRCM inclusion reflects not only cheaper ingredients but improved cost-to-nutrient efficiency over the full production cycle. Although the diet generated slightly higher gross revenue due to marginally greater intake, its higher feeding cost eroded net profitability. A pattern consistent with economic analyses emphasizing that net return and economic efficiency are more informative indicators than gross outputs alone (van der Eijk et al. 2025). Diets T3 and T4 optimized the balance between input costs and nutrient output, demonstrating that alternative proteins can improve economic sustainability when bird performance is maintained. Beyond immediate economic benefits, DBRCM inclusion also contributes to sustainability goals. Valorizing slaughterhouse byproducts into feed reduces waste streams and mitigates environmental pollution associated with conventional disposal methods (e.g., anaerobic decomposition). This aligns with circular bioeconomy principles and recent sustainability research that links by-product reutilization with reduced life-cycle environmental impact and improved resource use efficiency in poultry systems (Rasool et al. 2023). Especially in resource-limited production systems, strategies that simultaneously address feed scarcity, waste management, and production efficiency are of growing importance.

Nevertheless, the slight decline in palatability and potential digestibility constraints at the highest DBRCM inclusion level highlight an upper threshold beyond which physiological and sensory limitations outweigh benefits. Excessive substitution likely exacerbates the viscoelastic properties of the digesta, amplifies gut fill signals that limit intake, and dilutes the concentration of rapidly digestible nutrients, especially for young birds with immature digestive capacity (Liu et al. 2024). This observation is consistent with recent work suggesting that intermediate inclusion levels often maximize the benefits of by-product feeds without incurring performance liabilities (Kumar and Srivastava 2025).

Importantly, the absence of significant differences in mortality, performance index, and key health indicators across treatments confirms that DBRCM diets were safe and nutritionally adequate when properly processed and balanced. This supports accumulating evidence that well-handled animal by-products, when integrated with appropriate amino acid and energy levels, do not compromise bird health or welfare (Rasool et al. 2023). Such confirmation strengthens confidence in the practical application of DBRCM, particularly for systems seeking to reduce reliance on high-cost conventional protein sources without sacrificing health outcomes.

Implications and Future Research Directions

The present findings extend current understanding by demonstrating that DBRCM is not only an economically attractive feed ingredient but also a biologically adaptable protein source, whose utilization improves as broilers mature. This age-dependent adaptation likely reflects the progressive development of the gastrointestinal tract, including increased digestive enzyme activity (proteases and carbohydrases), expanded absorptive surface area, and a more complex hindgut microbiota capable of fermenting fibrous rumen residues into short-chain fatty acids, thereby enhancing energy extraction and nutrient retention (Yitbarek and Dagnaw 2022). The ability of birds to compensate for early reductions in feed intake and achieve comparable final body weights suggests that DBRCM supports efficient post-absorptive nutrient utilization, particularly via high-quality blood-derived proteins that provide essential amino acids such as lysine and leucine for muscle protein accretion (San-Miguel et al. 2023). Future research should focus on three interconnected areas to refine the use of DBRCM in commercial broiler production.

First, enzyme supplementation strategies during the starter phase could mitigate early-phase digestibility constraints by breaking down complex protein–fiber matrices and improving amino acid availability, feed efficiency, and growth performance (Karim et al. 2026). Second, amino acid digestibility profiling across growth phases would clarify how specific essential and limiting amino acids are absorbed and utilized, informing phase-specific formulation for optimal growth. Third, studies on gut microbiome modulation would elucidate how rumen-derived substrates interact with microbial populations to improve fiber fermentation, short-chain fatty acid production, and overall nutrient assimilation (Yitbarek et al. 2025). Collectively, these investigations would enable precision feeding

strategies, maximizing growth performance, economic efficiency, and sustainability, while maintaining the biological and physiological integrity of the birds.

By integrating physiological, biochemical, and microbial mechanisms, these insights move beyond simple performance comparisons and highlight why DBRCM works, under what conditions it is most effective, and how it can be optimized for modern, resource-limited poultry production systems.

Conclusion

The current research sets the foundation for dried blood–rumen content mixture (DBRCM) as a viable and reliable nonconventional protein supplement for broiler chickens. The results clearly show that DBRCM can be used at a significant concentration, substituting a substantial amount of traditional soy-bean meals, without compromising the health, growth, and utilization efficiency of the birds. In addition to the technical viability, the application of DBRCM has immense economic and sustainable benefits, as it reduces the dependence on expensive and human-grade protein sources and turns the by-products of abattoirs into valuable poultry feed. Taken together, these results place DBRCM as an economically viable, sustainable, and nutritionally adequate nonconventional protein source, especially for enhancing the profitability and sustainability of SASSO-C44 broiler rearing.

Author Contributions

Demissu Hundie Senbeta: conceptualization, supervision, validation, project administration.

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Ethics Statement

Ethical approval for research involving human participants (the farmers) was obtained

from the Ethics Committee of the College of Environmental Sciences, South Africa University (Approval No. 2024/ CAES_AREC/5937).

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data can be obtained from the authors upon request.

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CHAPTER 9

Evaluating the Impact of Dried Blood-Rumen Content Mixture dried blood–rumen Content Inclusion on Carcass Characteristics of SASSO C44 Broilers

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Abstract

This study aimed to evaluate the effects of incorporating dried blood–rumen content mixture (DBRCM) as a partial substitute for soybean meal (SBM) on carcass characteristics of broiler chickens. A total of 200-day-old SASSO C44 broiler chicks were randomly allocated to five dietary treatments, each with four replicates of 10 birds, under a completely randomized design. The experimental diets included: T1: 30% roasted soybean meal, 0% DBRCM, T2: 20% roasted soybean meal, 20% DBRCM, T3: 18% roasted soybean meal, 40% DBRCM, T4: 12% roasted soybean meal, 60% DBRCM, T5: 100% commercial broiler feed(control). The feeding trial was conducted over 56 days, after which carcass evaluation was performed on two males and two females randomly selected from each replicate. Body weight gain was comparable among treatments, indicating that the inclusion of DBRCM did not adversely affect growth performance. Although values varied numerically across treatments, the differences were not statistically significant ($P > 0.05$). Dressing percentages based on edible carcass weight were 61.16% (T1), 65.18% (T2), 63.93% (T3), 65.38% (T4), and 65.19% (T5). Commercial carcass weights varied between 945 g and 990 g, corresponding to dressing percentages of 55.24% (T1), 53.61% (T2), 56.38% (T3), 57.7% (T4), and 52.30% (T5). These results demonstrate that DBRCM can effectively replace up to 60% of SBM in broiler diets without negatively affecting carcass yield or dressing percentage, highlighting its potential as a viable, non-conventional protein source in poultry nutrition.

Keywords: Broiler, carcass characteristics, dried blood–rumen content mixture (DBRCM), dressing percentage, soybean meal

Introduction

Chicken production remains a critical component of Ethiopia's agricultural economy, offering food security, livelihoods, and nutritional support. According to recent estimates by the Central Statistical Agency (CSA, 2021), Ethiopia has about 57.0 million chickens in total. Indigenous birds constitute the largest share (~78.85%), followed by exotic (~9 10%) and hybrid (~12%) breeds(Abrar 2022). Although the country possesses a substantial poultry population, overall productivity remains relatively low. The national annual egg output is estimated at approximately 1.83 billion eggs, equivalent to nearly 73,357 tons (Quality et al., 2023). Recent poultry meat

production remains modest. One source gives a figure of ~70,100 metric tons of chicken meat production, though there is significant room for growth to meet national demand (Kleyn and Ciacciariello, 2022).

One of the major constraints in poultry production in Ethiopia remains feed cost and feed ingredient availability, which can account for 65–75% of total production cost. Conventional protein sources such as soybean meal are expensive, sometimes limited in supply, and are competing with human food uses (Mekete et al. 2024). The depreciation of the Ethiopian Birr, transport/logistics costs, and supply chain challenges have further aggravated feed and input price inflation (Zemedkun and Tessema 2023). Given the high costs of feed and the environmental plus economic issues associated with abattoir waste disposal, non-conventional feed ingredients are being explored intensively (Kari et al. 2023). Among the unconventional protein sources, dried bovine blood–rumen content mixture (DBRCM) represents a promising feed ingredient derived from abattoir by-products, specifically bovine blood and rumen digesta. Owing to its high crude protein concentration, DBRCM has considerable potential as a cost-effective substitute or partial replacement for traditional and expensive protein supplements in poultry diets (Shuma et al., 2025). Emerging evidence highlights the potential of DBRCM as a viable feed ingredient. In a recent feeding trial with laying hens, a 1:1 dried bovine blood–rumen content mixture was evaluated as a replacement for soybean meal and noug cake. The mixture demonstrated favorable nutritional attributes, containing approximately 46.9% crude protein and 2,390 kcal metabolizable energy per kilogram of dry matter (Hassan et al., 2023). Another recent review has examined DBRCM's nutritional, economic, and environmental potential, finding that use of such mixtures could contribute to lower feed costs, reduce environmental pollution, and better utilize slaughterhouse by-products Shuma et al. (2025). Therefore, evaluating the impact of DBRCM replacing on the carcass performance of broiler chickens is significant. Such research has the potential to lower feed expenditures, enhance poultry meat production, and minimize waste from abattoirs. Ultimately, the utilization of DBRCM aligns with Ethiopia's broader goals in agricultural transformation, food security, and improved nutrition outcomes (Birhanu, Osei-Amponsah, and Obese, 2023). Thus, studying the effects of feeding DBRCM on carcass characteristics of broiler chicks reduces the feed costs, improving poultry meat outputs, and reducing environmental waste, thus helping Ethiopia move toward its agricultural development, food security, and nutrition goals Birhanu et al., (2023). Hence the aim of this study

was to evaluate the effects of feeding Sosso C44 broilers chickens diets containing inclusion levels of DBRCM on carcass characteristics. The study hypothesized that feeding Sosso C44 broilers chickens diets containing inclusion levels of DBRCM on significantly affect carcass characteristics.

Materials and Methods

Study Area

The experiment was conducted in Dambi Dollo, the administrative center of Kellem Wollega Zone in the Oromia Region, located approximately 642 km west of Addis Ababa. The zone spans roughly 987,457 hectares and is bordered by West Wollega, Buno Bedele, and Ilu Aba Bora Zones, as well as the Gambella Region. The landscape is characterized by diverse topography, with elevations ranging from 200 to 3,450 meters above sea level and comprises three major agro-ecological zones: highland (26.1%), midland (41.4%), and lowland (32.5%). Annual temperatures range from 10°C to 34°C, and total rainfall varies between 1,400 and 3,200 mm Maina et al. (2019).

Slaughtering Procedure and Carcass Evaluation

At the end of the 56-day feeding trial, carcass evaluation was conducted on 60 birds (12 per treatment, consisting of 2 males and 2 females per replicate). Birds were fasted for 12 hours, weighed, and slaughtered following standard procedures. Slaughtering involved bleeding for 180 seconds, scalding at 63°C for approximately 2 minutes, and manual defeathering. Carcasses were then eviscerated, hung for 15 minutes, and weighed. Carcass components, including breast, thighs, drumsticks, wings, and back, were recorded and expressed as a percentage of live body weight. Dressing percentage was calculated for both commercial carcass yield and edible portion yield, while abdominal fat was weighed and expressed relative to live body weight.

Blood Collection and Sample Processing

Fresh bovine blood was collected immediately following slaughter. To reduce microbial contamination and moisture content, the blood was boiled for 45 minutes at 100°C (Yitbarek, Tamir, and Mengistu, 2018). The coagulated blood was then spread on clean plastic sheets to prevent soil contamination and sun-dried for 3–5 days, depending on ambient conditions and

turning frequency. Once fully dried, the blood was finely ground using a hand mortar and passed through a 3-mm sieve to match the particle size of standard broiler feed (Getahun et al., 2025).

Rumen Content Collection and Processing

Fresh rumen contents were obtained from cattle slaughtered at the Dambi Dollo University municipal abattoir. The material was boiled in a metal vat over an open fire for two hours with intermittent stirring to reduce microbial load (Zahir et al., 2024). The cooked contents were then evenly spread on sanitized plastic sheets and sun-dried for 3–4 days. After drying, coarse particles were manually ground and sieved through a 3-mm mesh to achieve particle size consistent with commercial broiler feed (Bezabih, Tamir, and Mengistu, 2017).

Preparation of Dried Blood–Rumen Content Meal (DBRCM)

Equal parts of dried blood and dried rumen content (1:1) were thoroughly mixed to produce the dried blood–rumen content mixture (DBRCM). This mixture was incorporated into experimental diets at varying levels as a partial replacement for roasted soybean meal.

Preparation for Roasted Soybean Meal

Full-fat soybeans were sourced from the local Dambi Dollo market. After cleaning and manual sorting to remove impurities, the beans were washed and roasted on a metal tray for approximately 15 minutes with continuous stirring until a golden-brown color was achieved, effectively inactivating anti-nutritional factors such as trypsin inhibitors (Romero and Hernando, 2017). The roasted beans were then ground, sieved through a 3-mm mesh, and stored for feed formulation.

Experimental Birds and Management Practices

Two-hundred-day-old SASSO C44 broiler chicks were procured from Ethio Chick PLC. Each chick was individually weighed and randomly assigned to 20 pens (1.8 m² each, 0.12 m² per bird) following a Completely Randomized Design (CRD). The poultry house was disinfected with 37% formalin two weeks before chick placement, and pens were bedded with 8 cm of sun-dried Sagatura straw.

Brooding temperature was maintained between 35°C and 32°C during the first week and reduced by 2°C weekly thereafter” (MSD Veterinary Manual, 2024; European Food Safety

Authority, 2023). Feed and clean water were provided *ad libitum*, with feeders and drinkers cleaned daily. Birds were vaccinated against Newcastle disease (days 7, 21, and 45), Gumboro disease (days 14, 28, and 42), and Fowl typhoid (day 49). Additionally, Amprolium was administered prophylactically three times to control Coccidiosis (Food and Agriculture Organization, 2022; World Organisation for Animal Health, 2023).

Diet Formulation and Experimental Treatments

The experimental diets were formulated using a combination of maize, wheat middlings, noug seed cake, roasted soybean meal (RSBM), dried blood–rumen content mixture (DBRCM), fish meal, vitamin–mineral premix, lysine, methionine, salt, and limestone. Prior to blending, all ingredients were ground to a uniform particle size of 3 mm to ensure consistency and homogeneity in the feed.

Diets were carefully formulated to be iso-nitrogenous and iso-caloric in accordance with broiler nutrient requirements (Hanumantarao, 2017). The starter diet, provided from day 1 to 28, contained 23% crude protein (CP) and 3,000 kcal metabolizable energy (ME)/kg dry matter (DM), while the finisher diet, fed from day 29 to 56, contained 20% CP and 3,200 kcal ME/kg DM.

Justification of Different Dietary Treatments and Controls

The dietary treatments were selected to evaluate the effect of progressively replacing roasted soybean meal (RSBM) with dried blood–rumen content mixture (DBRCM) as a protein source in SASSO-C44 broiler diets. The treatment levels were designed to provide a clear dose-response pattern while identifying a practical level of DBRCM replacement that could be used without adversely affecting poultry performance.

T1 (0% DBRCM replacement) was included as the **negative/baseline control**, in which roasted soybean meal was used as the sole alternative protein source. This treatment provided the reference against which the effects of DBRCM replacement at different inclusion levels could be evaluated.

T2 (20% DBRCM replacement) represented a **low level of replacement**. It was included to determine whether a modest substitution of RSBM with DBRCM could maintain broiler growth and feed utilization while reducing dependence on soybean-based protein.

T3 (40% DBRCM replacement) represented an **intermediate replacement level**. This treatment was included to assess whether a substantial proportion of RSBM protein could be replaced by DBRCM without compromising growth performance, feed efficiency, and carcass characteristics.

T4 (60% DBRCM replacement) represented a **high replacement level**. It was included to determine the upper practical level of RSBM replacement and to evaluate whether increasing DBRCM use would result in any adverse effects on feed intake, growth performance, feed conversion, or carcass characteristics.

T5 (commercial starter and finisher diets) was included as a **positive/external control** to provide a benchmark against a commercially formulated diet. This enabled the performance of birds receiving experimental diets containing RSBM and DBRCM to be compared with birds receiving a readily available commercial feed under the same experimental conditions.

Overall, the use of **0%, 20%, 40%, and 60% replacement levels** provided a progressive gradient for evaluating the biological and economic response to DBRCM, while the **commercial diet served as an external benchmark** for evaluating the practical performance of the experimental diets. The treatment structure therefore allowed the study to determine not only whether DBRCM could replace RSBM, but also the extent to which it could be used without compromising broiler production performance.

Chicks were fed their respective experimental rations for a total of 56 days, encompassing both starter and finisher phases, to evaluate growth performance, feed efficiency, and economic viability.

Carcass Evaluation

At the conclusion of the 56-day feeding trial, a total of 60 birds (12 per treatment, comprising 2 males and 2 females per replicate) were randomly selected for carcass analysis. Selected birds were fasted for 12 hours, weighed, and slaughtered. Bleeding was performed for 180 seconds, followed by scalding in water at 63°C for approximately 2 minutes, and manual defeathering. Carcasses were eviscerated, hung for 15 minutes, and then weighed. Carcass components including breast, thighs, drumsticks, wings, and back—were weighed and expressed as a percentage of live body weight. Dressing percentage was calculated both for the commercial carcass (excluding edible organs) and the edible portion, which included the liver, heart, and gizzard. Abdominal fat was separated, weighed, and expressed as a proportion of live body weight.

Carcass Traits Methodology

At the end of the 56-day feeding trial, carcass traits were evaluated using 60 birds (12 per treatment, consisting of both sexes selected randomly from each replicate). The selected birds were fasted for 12 hours to empty the gastrointestinal tract, weighed to obtain pre-slaughter live weight, and then slaughtered following standard poultry processing procedures. Slaughtering involved bleeding for 180 seconds, followed by scalding at 63°C for approximately 2 minutes and manual defeathering. The carcasses were subsequently eviscerated, cleaned, and hung for 15 minutes to allow drainage before recording carcass weight. Major carcass cuts, including breast, thighs, drumsticks, wings, and back, were separated and weighed, and expressed as a percentage of live body weight. Dressing percentage was calculated for both commercial carcass yield and edible portion yield, while abdominal fat was carefully removed, weighed, and expressed relative to live body weight.

Statistical Analysis

All carcass trait data (including dressing percentage, carcass cuts, and abdominal fat) were analyzed using the General Linear Model (GLM) procedure of SAS software version 9.4 (SAS, 2024). The data were analyzed using a two-factor model that included the fixed effects of dietary treatment (T1–T5) and sex (male and female), without interaction, as interaction effects were not considered in the experimental design. The statistical model used was: $Y_{ij} = \mu + T_i + S_j + \varepsilon_{ij}$, where Y_{ij} is the dependent variable, μ is the overall mean, T_i is the effect of dietary treatment, S_j is the effect of sex, and ε_{ij} is the random error term. Treatment means were compared using Tukey's Honest Significant Difference (HSD) test, and statistical significance was declared at $P < 0.05$.

Results

Representative samples of all feed ingredients used in the experimental diets, including the dried blood–rumen content mixture (DBRCM), were collected and analyzed for their chemical composition before ration formulation. The analyses were conducted following standard proximate analysis procedures to determine dry matter (DM), crude protein (CP), ash, crude fiber (CF), ether extract (EE), and calcium contents. Nitrogen-free extract (NFE) was calculated by difference, while metabolizable energy (ME) was estimated using standard feed evaluation equations. The analyzed nutrient values were then used as a basis for formulating the experimental diets and evaluating their nutritional adequacy.

The chemical composition of the feed ingredients used in the experimental diets is presented in Table 1. Analysis of the dried blood–rumen content mixture (DBRCM) revealed a dry matter content of 88.00%, with ash accounting for 11.29% and crude fiber at 18.18%. The mixture was rich in crude protein (44.17%), contained 1.43% extract, and 2.09% calcium. The nitrogen-free extract (NFE) represented 24.93% of DM, and the estimated metabolizable energy (ME) value was 2,636.17 kcal/kg DM.

Table 1. Proximate composition of feed ingredients used in the formulation of experimental diets (dry matter basis).

Feed Type	DM (%)	Ash (%)	(MM, CF (%)	CP (%)	EE (%)	Ca (%)	NFE (%)	ME (kcal/kg DM)
DBRCM	88.00	11.29	18.18	44.17	1.43	2.09	24.93	2636.17
Noug Seed Cake (NSC)	96.00	4.97	29.06	33.68	9.52	1.85	22.78	2833.31
Maize	90.23	5.25	4.99	8.40	1.93	1.85	79.44	3288.66
Soybean Meal	96.07	5.55	17.80	40.41	5.98	1.88	30.26	3058.30
Wheat	91.37	1.86	2.52	11.55	2.18	1.11	81.89	3512.77
Fish Meal	94.97	22.32	4.42	51.20	3.60	8.66	18.45	2844.12

Abbreviations: DBRCM – Dried Blood–Rumen Content Mixture; NSC – Noug Seed Cake; DM – Dry Matter; CP – Crude Protein; ME – Metabolizable Energy; CF – Crude Fiber; EE – Ether Extract; MM – Mineral Matter; NFE – Nitrogen-Free Extract; Ca – Calcium; kg – kilogram.

Feed Ingredients for Starter and Finisher Diets

The starter and finisher diets were formulated using commonly available feed ingredients to meet the nutritional requirements of broiler chickens during the respective growth phases. The starter diet (0–28 days) and finisher diet (29–56 days) were prepared using maize, soybean meal, dried blood–rumen content meal (DBRCM), vegetable oil, limestone, dicalcium phosphate, salt, vitamin-mineral premix, and amino acid supplements. The diets were formulated to be isonitrogenous and isocaloric across all dietary treatments, with graded replacement levels of soybean meal by DBRCM according to the experimental design. All feed ingredients were thoroughly mixed to ensure uniform distribution of nutrients before being offered to the experimental birds. The formulated diets were stored under dry conditions and provided ad libitum throughout the experimental period.

Table 2. Composition and proximate analysis of broiler starter and finisher diets across all experimental treatment groups.

Ingredients %	for Broilers starters					For Broilers finisher				
	T1	T2	T3	T4	T5 (control)	T1	T2	T3	T4	T5 (control)
Feed ingredients										
Soyabean	30	24	18	12		30	24	18	12	
DBRMC	0	6	12	18		0	6	12	18	
NCS	15.7	15.1	14.5	12.4		2.5	2	1.6	1.2	
Fishmeal	2.4	2.2	2.1	2.5		2	1.9	1.2	0.8	
Maize	39.5	40.4	40.8	39.9		47.9	49.1	49.4	50.1	
Wheat	9.3	9.2	9.5	12.1		14.5	13.9	14.7	14.8	
Limestone	1.2	1.2	1.2	1.2		1.2	1.2	1.2	1.2	
Vitamin premix	1	1	1	1		1	1	1	1	
Salt	0.5	0.5	0.5	0.5		0.5	0.5	0.5	0.5	
Lysine	0.2	0.2	0.2	0.2		0.2	0.2	0.2	0.2	
Methionine	0.2	0.2	0.2	0.2		0.2	0.2	0.2	0.2	
Total	100	100	100	100		100	100	100	100	
DM (%)	89.43	88.95	87.68	87.45	89.3	90.06	90.2	89.3	89.5	89.87
CP (% DM)	23.01	23.05	23.08	23.1	23	20	20.05	20	20.1	20.03
ME(kcal/Kg DM)	3073	3049	3021	3012	3084	3285	3264	3236	3210	3286
CF (% DM)	4.7	4.8	4.7	4.4	3.8	2.8	2.2	3	2.9	3

Parameters	Experimental Diets									
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MM (% DM)	11.57	11.28	10.67	10.42	11.4	12.98	12.76	12.33	11.1	12.638
EE (% DM)	7.3	6.6	4.2	3.8	3.6	8.6	7	5.8	4.1	5.5
NFE (% DM)	34.8	34.1	34.8	35.5	41.3	43.6	44.2	44.3	44.9	47.9
Ca (% DM)	1.27	1.6	1.5	1.4	1.37	0.96	0.98	0.99	1.1	1.3

Notes: RSBM = Roasted Soybean Meal; DBRCM = Dried Blood–Rumen Content Mixture; NSC = Noug Seed Cake; Treatment groups: T1 = 0% DBRCM + 100% RSBM, T2 = 20% DBRCM + 80% RSBM, T3 = 40% DBRCM + 60% RSBM, T4 = 60% DBRCM + 40% RSBM, T5 = Commercial feed; DM = Dry Matter; CP = Crude Protein; ME = Metabolizable Energy; CF = Crude Fiber; EE = Ether Extract; NFE = Nitrogen-Free Extract; Ca = Calcium.

Carcass Characteristics and Dressing Percentage of SASSO C44 Broiler Chicks.

The influence of graded inclusion levels of dried blood–rumen content mixture (DBRCM) as a partial replacement for roasted soybean meal on dry matter intake (DMI), body weight gain (BWG), and feed conversion ratio (FCR) of SASSO C44 broilers is presented in Table 3.

Table 3. Dry matter intake, body weight gain, feed conversion ratio, during experimental period.

	T1	T2	T3	T4	T5	SEM	P-value
Starter Phase							
MDDMI (g/bird)	37.05 ^{bc}	35.13 ^{bc}	33.92 ^c	33.17 ^c	37.45 ^a	0.67	0.003
MEANTDMI(g/bird)	10.13 ^a	9.91 ^b	9.44 ^c	9.18 ^d	10.19 ^a	11.49	0.001
IBW(g)	41.5	41.6	41.4	41.3	41.3	0.037	0.24
MFBW(g)	771.5 ^a	769.4 ^a	732.3 ^c	746.4 ^b	772.7 ^a	22	0.001
MDWG(g/bird)	26.0 ^a	25.9 ^a	24.6 ^c	25.1 ^b	26.1 ^a	0.028	0.001
MTG(g)	730 ^a	727.7 ^a	690.8 ^c	705 ^b	731.3 ^a	22	0.001
FCR(gDMI I/g gain)	1.56a	1.53a	1.56a	1.49a	1.56a	0.011	0.083
Finisher phase							
MDDMI(g/bird)	107.6 ^a	104.6 ^{ab}	101.2 ^b	100.8 ^b	108.5 ^a	2.98	0.001
MDMI(g/bird)	2964 ^b	2937 ^c	2826 ^c	2838 ^d	2989 ^a	9.6	0.007
IBW(g)	771.5 ^a	769.4 ^a	732.3 ^c	746.4 ^b	772.7 ^a	21.5	0.001
MBW(g)	1774	1772	1720.6 ^a	1713	1807	2963	0.12
MDWG(g/bird)	35.8	35.8	35.2	34.5	36.9	3.9	0.54
MTG(g)	1003	1002.6	988.3	966.6	1034.3	3.59	0.55
FCR(gDMI I/g gain)	2.96a	2.93ab	2.87b	2.92ab	2.88b	0.001	0.009
Entire Experimental Period							
MDDMI(g/bird)	71.6 ^a	69.81 ^b	67.25 ^c	66.37 ^c	71.6 ^a	0.4	0.001
MTDMI (g/bird)	4010 ^a	3908 ^b	3764 ^c	3717 ^d	4009 ^a	2.29	0.001
IBW(g)	41.5	41.6	41.4	41.3	41.3	0.037	0.24
Mfbw(g)	1774	1772.3	1720.6	1713	1807	2963	0.12
Mdwg(g/bird)	30.9	30.9	29.9	29.8	31.5	0.94	0.12
Mtg(g)	1732.5	1730.6	1679	1671	1765.6	2966	0.12
FCR(gDMI I/g gain)	2.29	2.27	2.24	2.22	2.26	0.029	0.984

Means within a row with different superscripts differ significantly ($P < 0.05$). Abbreviations: DMI = Dry Matter Intake; g = grams; FCR = Feed Conversion Ratio; SEM = Standard Error of the Mean. Treatment groups: T1 = 0% DBRCM + 100% RSBM, T2 = 20% DBRCM + 80% RSBM, T3 = 40% DBRCM + 60% RSBM, T4 = 60% DBRCM + 40% RSBM, T5 = Commercial feed.

During the starter phase, broilers offered DBRCM-containing diets exhibited a significant increase in daily DMI compared to the control group ($P < 0.05$). In contrast, birds fed the highest inclusion level of DBRCM (T4, 60%) showed the lowest DMI ($P < 0.05$) during both the finisher phase and the overall 56-day production period. Similarly, body weight gain was lowest in T4 during the starter phase, and significant differences ($P < 0.05$) in BWG were observed among treatments during the finisher and entire experimental periods.

Feed conversion ratio was significantly influenced ($P < 0.05$) during the finisher phase, while no notable differences ($P \geq 0.05$) were detected in FCR during the starter phase or across the full 56-day cycle. These results suggest that moderate DBRCM inclusion supports satisfactory growth performance, whereas higher levels (60%) may adversely affect feed intake and growth efficiency in broiler chicks. Table 3. Dry matter intake, body weight gain, feed conversion ratio, and mortality of SASSO C44 broiler chicks during the starter (1–28 days), finisher (29–56 days), and entire experimental period (1–56 days).

Carcass Characteristics of Broilers Fed Graded Levels of DBRCM

The effects of graded inclusion levels of dried blood–rumen content mixture (DBRCM) on carcass characteristics of SASSO C44 broiler chicks are presented in Table 4. Slaughter weight differed significantly among dietary treatments ($P < 0.05$), with birds in T5 recording the highest value (1,807 g), while the lowest value was observed in T4 (1,713 g), indicating a positive response to higher inclusion of DBRCM at the highest performance level. Edible carcass yields were 1,085 g (T1), 1,155 g (T2), 1,100 g (T3), 1,120 g (T4), and 1,178 g (T5), with no significant difference observed between DBRCM-containing diets and the control group. The effect of sex (M = male, F = female) on edible carcass yield is presented in Table 4. The results clearly show that sex was included in the analysis and reported accordingly. However, the manuscript has been revised to improve clarity in the text and to ensure better alignment with the presented table. Similarly, edible carcass yield was not affected by sex ($P > 0.05$). Dressing percentages based on edible carcass weight ranged from 61.16% to 65.38%, with dietary treatment exerting a significant effect ($P < 0.05$), while sex had no significant impact. Commercial carcass weight and dressing percentage were significantly influenced by dietary treatments ($P < 0.05$), with T4 showing the highest commercial carcass weight (990 g), while the lowest value was recorded in T5 (945 g). Similarly, dressing percentage varied among treatments (52.3%–57.7%), indicating differences in carcass yield efficiency associated with diet composition. In contrast, sex had no significant effect on either commercial carcass weight or dressing

percentage ($P > 0.05$), suggesting comparable carcass yield performance between male and female birds under the experimental conditions. Commercial carcass weight was significantly affected by dietary treatments ($P < 0.05$), with birds fed T4 diet recording the highest value (990 g), which was significantly higher than those fed T2 (950 g) and T5 (945 g). However, birds fed T1 (980 g) and T3 (970 g) did not differ significantly from the other treatment groups. Similarly, dressing percentage ranged from 52.3% to 57.7% and was significantly influenced by diet ($P < 0.05$), indicating variation in carcass yield efficiency among treatments. In contrast, sex had no significant effect on commercial carcass weight or dressing percentage ($P > 0.05$) with males showing higher values than females. Total non-edible offal (TNEO) and total edible offal (TEO), including their relative percentages, were significantly affected by dietary treatments ($P < 0.05$). Birds fed T4 recorded higher TNEO and TEO values compared to those fed T2 and T3 diets, while T1 and T5 showed intermediate values that were not significantly different from each other. This indicates that increasing levels of DBRCM inclusion influenced both edible and non-edible offal yields.

Table 4. Carcass characteristics of SASSO C44 broiler chicks (1–56 days) fed graded levels of DBRCM as a replacement for soybean meal.

Parameters		T1	T2	T3	T4	T5	SEM	p-value	M	F	P
Slaughter weight (g)		1774.00 ^b	1772.00 ^b	1720.60 ^c	1713.00 ^c	1807.00 ^a	20.7	0.001	1847.4a	1669.1b	0.01
Plucked weight (g)		1560.00 ^a	1540.00 ^b	1570.00 ^a	1520.00 ^c	1524.00 ^{bc}	70	0.001	1621.6a	1463.1b	0.01
Plucked weight (%)		87.94 ^{bc}	86.91 ^d	91.25 ^a	88.73 ^b	84.34 ^d	0.31	0.001	87.7a	87.6a	0.394
Commercial carcass weight (g)		980.00 ^{ab}	950.00 ^c	970.00 ^b	990.00 ^a	945.00 ^c	26.6	0.001	1030.2a	921.3a	0.189
*Dressing %		55.24 ^c	53.61 ^d	56.38 ^b	57.79 ^a	52.30 ^e	0.09	0.001	54.5a	53.3a	0.170
Edible carcass yield (g)		1085.00 ^d	1155.00 ^b	1100.00 ^d	1120.00 ^c	1178.00 ^a	75	0.001	1192a	1060b	0.1
***Dressing %		61.16 ^c	65.18 ^{ab}	63.93 ^b	65.38 ^a	65.19 ^a	0.23	0.001	64.6a	63.8a	0.18
Thigh (g)		185.00 ^{bc}	180.00 ^c	190.00 ^b	195.00 ^{ab}	205.00 ^a	41.2	0.005	198.5a	182.7b	0.001
Thigh %		10.43 ^{bc}	10.16 ^c	11.04 ^{ab}	11.38 ^a	11.34 ^a	0.12	0.003	10.9a	10.7a	0.493
Drumstick (g)		165.00 ^d	175.00 ^c	185.00 ^b	195.00 ^a	200.00 ^a	16.9	0.001	202.7a	189.2a	0.616
Drumstick %		9.30 ^d	9.88 ^c	10.75 ^b	11.38 ^a	11.07 ^{ab}	0.05	0.001	10.9a	10.1b	0.006
Breast (g)		275.00 ^c	290.00 ^c	255.00 ^d	320.00 ^b	340.00 ^a	60	0.001	281a	310b	0.001
Breast %		15.50 ^{bc}	16.37 ^b	14.82 ^c	18.68 ^a	18.82 ^a	0.20	0.001	16.5a	16.9a	0.409
Back (g)		150.00 ^b	160.00 ^b	180.00 ^a	190.00 ^a	198.00 ^a	71	0.001	189.6a	160.8b	0.001
Back %		8.46 ^b	9.03 ^b	10.46 ^a	11.09 ^a	10.96 ^a	0.22	0.001	10.1b	10.5a	0.003
Wing (g)		129.00 ^c	130.00 ^c	143.00 ^b	154.00 ^a	152.00 ^a	3.2	0.001	171.1a	109b	0.001
Wing %		7.27 ^c	7.34 ^c	8.31 ^b	8.99 ^a	8.41 ^b	0.01	0.001	8.1b	8.3a	0.014
Abdominal fat (g)		19.00 ^b	20.00 ^{ab}	25.00 ^a	15.00 ^b	20.00 ^{ab}	7.38	0.002	15.6a	24.1b	0.001
Abdominal fat %		1.07 ^b	1.13 ^{ab}	1.45 ^a	0.88 ^b	1.11 ^b	0.02	0.002	1.12a	1.13a	0.525
Giblet weight (g)		98.00 ^c	97.00 ^c	95.00 ^c	110.00 ^b	120.00 ^a	5.8	0.001	109a	97a	0.001
Giblet %		5.52 ^b	5.47 ^b	5.52 ^b	6.42 ^a	6.64 ^a	0.01	0.001	5.9a	6a	0.11
TNEO		489.00 ^b	495.00 ^a	435.00 ^d	448.00 ^c	490.00 ^b	4.36	0.001	514.8a	428b	0.01
TNEO %		27.56 ^b	27.93 ^a	25.28 ^e	26.15 ^d	27.12 ^c	0.02	0.001	26.3a	26.4a	0.677
TEO		149.00 ^d	154.00 ^c	157.00 ^{bc}	161.00 ^{ab}	164.00 ^a	4.2	0.001	168.7a	160.2b	0.03

TEO %	8.40d	8.69c	9.12b	9.40a	9.08b	0.01	0.001	9.09a	9.08a	0.831
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Note: Within a row, sharing different superscripts are significantly different ($P < 0.05$). Abbreviations: g = grams; T1 = 0% DBRCM + 100% Roasted Soybean Meal, T2 = 20% DBRCM + 80% Roasted Soybean Meal, T3 = 40% DBRCM + 60% Roasted Soybean Meal, T4 = 60% DBRCM + 40% Roasted Soybean Meal, T5 = Commercial feed; SEM = Standard Error of the Mean; M = Male; F = Female; TNEO = Total Non-Edible Offal; TEO = Total Edible Offal. *Dressing percentage calculated based on standard eviscerated carcass weight used commercially; **Dressing percentage calculated including edible offal (skin, gizzard, liver).

Discussion

Slaughter Weight

Significant differences in slaughter weight were observed between sexes ($P < 0.05$), with males exhibiting higher weights than females across DBRCM dietary treatments. This indicates that sex is an important biological factor influencing growth performance, with males showing greater capacity for muscle accretion and overall body mass development under the same feeding conditions. The higher slaughter weights in males may be attributed to androgen-mediated stimulation of protein synthesis and lean tissue deposition, which enhances growth efficiency compared to females. In contrast, females are more predisposed to fat deposition due to hormonal regulation, which can limit lean muscle accumulation and result in comparatively lower slaughter weights. These findings imply that, although diet influences growth, inherent physiological differences between sexes play a dominant role in determining final slaughter weight. This agrees with Ntombizethu et al. (2023), Achoki (2024), Science and Tatu (2023), Abdelmoniem et al. (2023), and Gök (2023), who similarly reported superior growth performance in male broilers under comparable management systems.

Commercial Carcass Weight

Dietary inclusion of DBRCM significantly influenced commercial carcass weight ($P < 0.05$), indicating that differences in nutrient availability and protein quality among treatments affected muscle deposition and overall carcass yield. In contrast, sex had no significant effect on commercial carcass weight, suggesting that when birds are managed under similar environmental and nutritional conditions and slaughtered at comparable physiological maturity, carcass yield differences between males and females become minimal. This agrees with Yitbarek, Tamir, and Mengistu (2016) and findings from Cobb 500 and Ross 308 broiler studies (Sciences and Volume, 2022; Wlaźlak, Biesek, and Banaszak, 2024), which also reported that sex-related differences in body weight do not necessarily translate into differences in carcass weight when slaughter weights are standardized.

Dressing Percentage

Dressing percentage, calculated based on commercial carcass weight, differed significantly among dietary treatments ($P < 0.05$), indicating that DBRCM inclusion levels influenced carcass yield efficiency, likely through differences in nutrient utilization, protein availability, and subsequent muscle deposition. This suggests that diet composition plays a key role in determining the proportion of edible carcass relative to live weight. In contrast, sex had no significant effect on dressing percentage ($P > 0.05$), implying that males and females convert nutrients into carcass yield with similar efficiency under the same feeding and management conditions. This may be due to the fact that dressing percentage is more closely associated with carcass composition than with sex-based growth differences when birds are slaughtered at comparable physiological stages. These findings are consistent with Ragsdale et al. (2023) and Benefits (2024), who reported minimal sex-related variation in dressing percentage under uniform dietary regimes.

Edible Carcass Yield

Edible carcass yield, comprising total edible offal and major cuts (back, wings, drumsticks, thighs, and breast), differed significantly among dietary treatments ($P < 0.05$), indicating that DBRCM inclusion levels influenced the proportion of marketable carcass components. This variation suggests that differences in dietary nutrient quality and balance affected muscle deposition and the distribution of edible tissues across treatments. In contrast, sex had no significant effect ($P > 0.05$), implying that both male and female birds were similarly efficient in converting feed into edible carcass components under the same management conditions. Although males showed numerically higher yields, this difference was not statistically meaningful, suggesting that sex-related growth advantages did not translate into differences in edible carcass proportion at the slaughter stage. These findings agree with Breed et al. (2023) and related studies reporting limited or inconsistent sex effects on edible carcass yield under uniform dietary regimes.

Total Edible Offal (TEO) and Total Non-Edible Offal (TNEO)

TEO (skin, gizzard, liver) ($P < 0.05$), but its percentage was not influenced by sex, consistent with Yitbarek et al. (2016) and Bezabih, Tamir, and Mengistu (2017). TNEO (blood, shanks, claws, feathers, head, crop, esophagus, proventriculus, spleen, pancreas, kidney, heart, lungs, intestines, abdominal fat) was significantly affected by diet and sex ($P < 0.05$), with males exhibiting higher non-edible offal, corroborating findings by Steczny et al. (2017) and Diets (2024).

Abdominal Fat and Breast Meat

Abdominal fat weight and percentage differed significantly among dietary treatments ($P < 0.05$), indicating that DBRCM inclusion levels influenced lipid deposition and carcass fatness. This suggests that variations in dietary nutrient balance and energy utilization affected the extent of fat accumulation,

with certain diets promoting greater fat deposition than others. In addition, females exhibited higher abdominal fat than males, reflecting sex-related physiological differences in nutrient partitioning, where females are more prone to fat deposition due to hormonal regulation and relatively lower lean muscle accretion. These findings imply that both diet and sex play important roles in carcass fat distribution, with diet influencing the overall level of fat deposition and sex determining its partitioning pattern. The results are consistent with Moalamedi (2023), Madilindi et al. (2018), and Eck et al. (2023), who also reported higher fat deposition in females compared to males under similar production conditions.

Conclusion

The replacement of soybean meals with DBRCM in broiler diets up to a level of 60% is practical and efficient. This protein source represents a dependable option for poultry producers desiring to limit their reliance on traditional feed ingredients but without impairing nutritional value. Generally, research findings indicate that broiler fed diets based on DBRCM have suitable growth and develop edible carcasses of quality comparable to those resulting from standard soybean meal-based diets. The birds maintain normal physiological performance, showing that DBRCM does not adversely affect the major carcass traits. Beyond performance, the economic advantage of DBRCM is quite convincing. For poultry production, where feed costs are some of the highest expenses, DBRCM improves profitability by cutting down feed costs while encouraging the use of locally available resources. This makes the strategy sustainable for broiler improvement under resource-poor situations.

Recommendations

Mechanization of DBRCM collection and processing can be implemented to reduce labor requirements and therefore minimize production costs.

Extension and promotion of DBRCM-based feed technology to small-, medium-, and Commercial poultry could enhance feed efficiency and overall economic sustainability.

More studies are needed to investigate the impact of DBRCM inclusions above 80% on broiler carcass characteristics and overall productivity.

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CHAPTER 10

GENERAL CONCLUSIONS AND RECOMMENDATIONS

10.1 Conclusions

This study identified 52 commercial poultry farms in the study area. Most farm operators were male, aged between 15 and 30 years. All operations started with day-old chicks from Ethiochick PLC, Alama Farm. Flocks consisted of Bovans Brown, Bovans White, Koekoek, and SASSO T44 breeds, though Bovans and mean flock size was 734.6 birds. All farms used deep-litter systems with teff straw.

Commercial rations mostly sourced from Ethio chick PLC Alema (Bishoftu), were widely adopted, and the expenses surpass those of on-farm mixed rations. Most farm-made feed contained ingredients like maize, wheat, barley, roasted soybean meal, and noug seed cake. Many producers could not provide specifics on feed amount, but roughly half noted feeding three times daily (morning, afternoon, evening). Water was made available regularly from piped sources in the morning, noon, evening, and midnight.

Generally, diseases were poorly identified, and few records were kept: the name of a specific disease was hardly mentioned by most producers, even though a few suspected coccidiosis is based on signs observed. Commonly reported signs included ruffled feathers, anorexia, depression, diarrhea, weight loss, paralysis, and twisted necks. Vaccination was carried out on all farms, with birds normally vaccinated against NCD, Gumboro, fowl pox, and fowl cholera/typhoid at least twice during the production cycle. Preventive measures and treatments were the main approaches to disease control, reflected in the relatively low average mortality of chicks at 7.7%. Almost half of the producers received training and extension services, but these interventions did not effectively address the producers' needs. Most farms kept basic records, most often production costs, feed usage, and mortalities but record quality and completeness were inadequate to support informed decision-making. Chicks were usually marketed at 45 days of age to other farmers and town consumers at the farm gate or local markets; when markets were limited, birds were kept up to an average of 78 days. Production was, however, constrained by several challenges: cost of feed, availability of improved birds, high cost of birds, lack of

financing, land/space availability, electric disturbances, high bird morbidity rates, unavailability of feed ingredients, disease outbreaks, and high mortality rates.”

In view of these, producers and sector experts voiced strong calls for support by the government and institutions to address such constraints. These measures include market linkage development and market promotion, practical training on poultry husbandry, land allocation, and access to credit, development of local commercial feed production, extension service enhancement, capacity building of experts through continuous training, improvement of transport, and ensuring adequate budgetary support for outreach activities. Finally, the dried blood-rumen content mixture had no adverse health effects on Sasso C44 broiler chicks during the starter and finisher phases of growth. Dried blood-rumen content mixture can replace roasted soybean meal in starter diets and finisher up to 60% without impairing body weight gain, feed conversion ratio, performance index, or carcass traits. The dried blood-rumen content mixture represents a promising, low-cost non-conventional feed ingredient for the economic efficiency of broiler production for Sasso C44 chickens.

10.2. Recommendations

The recommended actions from this study include strategic investment and coordinated development of the poultry sector. Providing a local feed processing plant capable of manufacturing balanced and affordable rations would reduce farmer production costs. Creating incentives for the expansion of large-scale commercial farms and a municipal hatchery will contribute to strengthening local chick supply systems, reducing reliance on sources located very far away. Continued research is called for especially on-farm performance studies of chicks distributed by commercial farms to guide evidence-based interventions. There is a need for government action in the form of short and long-term strategies aimed at addressing major constraints on commercial poultry operations. Improvement of feed innovation through mechanized collections and processing of blood and rumen contents can reduce labor and costs of production; slaughterhouses should be encouraged to integrate blood meal and rumen content processing to provide economical feed ingredients. Awareness creation and technology dissemination regarding the economic value of DBRCM is highly recommended for producers at all levels. Inclusion levels of DBRCM require validation in layer breeds before its official endorsement for layer rations, while further studies must test other blood-to-rumen content ratios

besides the 1:1 used here. Lastly, further research should consider inclusion levels higher than 60% in starter diets and finisher diets to fully understand the impacts of DBRCM on intake, growth performance, feed efficiency, carcass characteristics, and overall profitability.

Appendix A: Summary

This study evaluated Management Practices and Constraints of Commercial Poultry Farms, and Performance Evaluation of Sasso-C44 Broilers Fed on Diets Containing Graded Level Dried Blood Rumen-Content Mixture. Farm-level data were collected using structured questionnaires, focus group discussions, and on-site observations, while a feeding trial involving 200 broiler chicks was conducted using a completely randomized design. Results indicated that intensive production and deep-litter housing systems were predominant, with disease occurrence largely linked to management and environmental conditions. Substituting roasted soybean meal with DBRCM at levels up to 60% showed no significant effect ($P>0.05$) on feed intake, growth performance, feed conversion ratio, survivability, or carcass characteristics. Carcass yield and dressing percentage remained consistent across treatment groups. Economic analysis revealed improved profitability at 40–60% DBRCM inclusion levels. Overall, findings demonstrate that DBRCM is a viable, cost-effective alternative protein source that can reduce feed costs while maintaining optimal broiler performance under intensive production systems.

Key Terms: Broiler chickens, SASSO-C44, DBRCM, soybean meal substitution, alternative proteins, feed intake, feed efficiency, carcass traits, economic performance, intensive production

Appendix B: Similarity report

Similarity Report	
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College of Agriculture and Environmental Sciences _Animal REC

Date: 19/05/2025

Dear: Mr SORESA SHUMA ABDISA

NHREC Registration # : AREC-100818-024
Ref # : 2024/CAES_AREC/5937
Name: Mr SORESA SHUMA ABDISA
Student # : 21008590

**Decision: Ethics Approval from
19/05/2025 to 31/05/2026**

Researcher: Mr SORESA SHUMA ABDISA
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Co-Supervisor: Dr Dikeledi Petunia Malatji malatdp@unisa.ac.za

**MANAGEMENT PRACTICES AND CONSTRAINTS OF COMMERCIAL POULTRY FARMS AND
PERFORMANCE EVALUATION OF SASSO -C44 BROILERS FED ON DIETS CONTAINING GRADED LEVELS OF
DRIED BLOOD-RUMEN CONTENT MIXTURE**

Qualification: PhD Agriculture

Thank you for the application for research ethics clearance by the College of Agriculture and Environmental Sciences _Animal REC for the above mentioned research study. Ethics approval is granted for one year.

The **medium risk application** was **reviewed** by College of Agriculture and Environmental Sciences _Animal REC on 16 May 2025 in compliance with the Unisa Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.

The proposed research may now commence with the provisions that:

1. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.
2. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the College of Agriculture and Environmental Sciences _Animal REC.
3. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
4. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing, accompanied by a progress report.
5. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.

6. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data requires additional ethics clearance.
7. No field work activities may continue after the expiry date (31 May 2026). Submission of a completed research ethics progress report will constitute an application for renewal, for Ethics Research Committee approval.

Additional Conditions

1. Disclosure of data to third parties is prohibited without explicit consent from Unisa.
2. De-identified data must be safely stored on password protected PCs.
3. Care should be taken by the researcher when publishing the results to protect the confidentiality and privacy of the university.
4. Adherence to the National Statement on Ethical Research and Publication practices, principle 7 referring to Social awareness, must be ensured: "Researchers and institutions must be sensitive to the potential impact of their research on society, marginal groups or individuals, and must consider these when weighing the benefits of the research against any harmful effects, with a view to minimising or avoiding the latter where possible." Unisa will not be liable for any failure to comply with this principle.
5. Kindly note that the College of Agriculture and Environmental Sciences _Animal REC requires the submission of regular progress reports to be submitted annually in line with section 7.2 of the Unisa Policy on Research Ethics (2024).

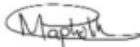
Note

The reference number 2024/CAES_AREC/5937 should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.

Kind regards,



Dr A Wilson
Chair of College of Agriculture and Environmental Sciences _Animal REC
E-mail: cheata@unisa.ac.za



Prof NO Mapholi
Executive Dean / By delegation from the Executive Dean of College of Agriculture and Environmental Sciences _Animal REC
E-mail: maphon@unisa.ac.za

Appendix D; Language Editing

Dambi Dollo University College of Social Science and Humanity Department of English Language and Literature	 <i>Empowering Generation</i> Dambi Dollo, Ethiopia ድምታ ዶሎ ዩኒቨርሲቲ	ድምታ ዶሎ ዩኒቨርሲቲ ኢንተርናሽናል ትምህርት ዘ/ኤ-ኤም-ኤም ትምህርት Ref.No/የጥር 04/DELL/2018 EC Date/4/6/2018 EC
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Letter of Professional Language Editor

To Whom It May Concern

I, Dr. Gedeon Melaku who is currently working at Dambi Dollo University as Associate/Assistant Professor in the department of English language and literature, has done the language edition for Assistant Professor. Soresa Shuma Abdisa, on his doctoral thesis titled, " *MANAGEMENT PRACTICES AND CONSTRAINTS OF COMMERCIAL POULTRY FARMS, AND PERFORMANCE EVALUATION OF SASSO-C44 BROILERS FED ON DIETS CONTAINING GRADED LEVEL DRIED BLOOD RUMEN-CONTENT MIXTURE.*" based on the professional assistance he requested. Thus, I confirm that the readability of the work in question is of a high standard. If you need more information, please do not hesitate to contact me.

(Phone: +25117816028)

(Email: gedeonmelaku@gmail.com).

With regards,

Signature 

Name of the editor Dr. Gedeon Melaku

Seal of the department



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