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ASSESSMENT OF BREEDING OBJECTIVES, PRODUCTION SYSTEMS AND
PHENOTYPIC CHARACTERISTICS OF INDIGENOUS CHICKEN IN NORTHERN
GHANA

BY

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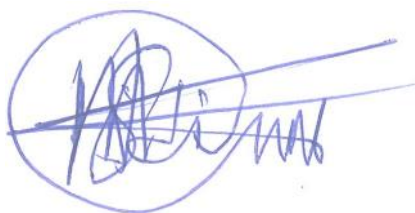
THESIS SUBMITTED TO THE DEPARTMENT OF ANIMAL SCIENCE, FACULTY OF
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JULY, 2025

DECLARATION

Student

I hereby declare that this thesis is the result of my original work and that no part of it has been presented for another degree in this University or elsewhere. All cited literature in the text has been well-referenced and any assistance received in writing the thesis is duly acknowledged.



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ABSTRACT

Indigenous chickens are vital to household economies and food security in rural Northern Ghana, yet systematic data on their breeding practices and characteristics remain limited. This study assessed breeding objectives, production systems, and morphological traits across five regions (Upper East, Upper West, Northern, Savannah, and North East). Methodologically, a mixed-methods approach was employed: (1) a cross-sectional survey of 150 randomly selected farmers using structured questionnaires on breeding practices and production constraints; and (2) phenotypic characterization of 1000 chickens (200/region), measuring live weight, linear traits (wingspan, body length, chest/shank circumference), and qualitative features (plumage/comb type). Data was analysed using Kruskal-Wallis, Chi-square, and Path coefficient analysis. Farmers prioritize meat, egg sales, and live bird sales, with preferences for productive traits like high egg yield and large body size, favouring resilient local breeds over high-maintenance exotic ones. Suboptimal sex ratios (1:3 male-to-female) risk inbreeding, with flock structures emphasizing chicks and hens. Morphological diversity shows regional variation in feather traits (frizzle in North East, naked necks in Savannah) and body measurements, with Savannah birds heaviest (1.28 kg) and Northern birds with the least weight (0.94 kg). Comb size and chest circumference predict body weight, offering breeding opportunities. Production systems are extensive, with 78% providing housing and 75% supplementary feed, but low vaccination (11%) and feed processing (37%) highlight disease and resource vulnerabilities. Recommendations include improved breeding practices, regional trait conservation, genetic studies, enhanced veterinary services, and market linkages to boost sustainability and preserve genetic resources.

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DEDICATION

This work is dedicated to the memory of my late father and late brother, Mr. John Amoro Abangtoh and Raymond Appasinaba, Mother, Veronica Yaro, My wife, Portia Adoba, and children, Apegeyine, Ayinedenaba, and Gracia Ayingura



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ACRONYMS

ICEM- International centre for Environmental Management

SNPs- Single Nucleotide Polymorphisms

WGS- Whole -Genome Sequencing

PMEL- Pacific Marine Environmental Laboratory

MCIR- Melanocortin Receptor-1

TRY- Tyrosinase

DXA- Dual – Energy X-Ray

BIA- Bioelectrical Impedance Analysis

NRC- National Research Council

QTL- Quantitative Trait Loci

AOAC- Association of Official and Analytical Chemist

AnGR- Animal Genetic resources



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CHAPTER ONE

1.0 INTRODUCTION

Chicken is widely recognized as a primary source of high-quality animal protein (Jalaludeen *et al.*, 2022; Randazzo *et al.*, 2021). Indigenous chickens play a vital role in supporting household incomes. Boosting their production can improve food security, reduce poverty, and lessen economic hardships for rural communities (Tadese *et al.*, 2024). Habimana *et al.* (2020) found that native chicken breeds are widespread in developing nations across Africa and Asia, accounting for over 80% of the total chicken populations in these regions. Ghana's poultry industry mainly features local chicken types, with a smaller number of mixed-breed chickens that serve two purposes that is for meat and sale of live ones (Naggujja *et al.*, 2020). The indigenous chicken populations in Ghana are estimated at 38 million (Ouma *et al.*, 2023) and are reared largely under the traditional production system (Obembe *et al.*, 2022).

Additionally, the traditional poultry farming system typically involves small-scale operations with minimal inputs, limited productivity, and frequent disease outbreaks that can decimate flocks. Despite facing numerous challenges, backyard chicken farming remains a vital source of high-quality protein for the rapidly increasing population in low-income, food-scarce regions. Backyard chicken farming also provides job opportunities for disadvantaged populations in various local communities (Fitsum, 2017). According to Fitsum (2017), backyard chicken farming serves as a critical livelihood strategy for low-income households, offering a pathway out of poverty. Notably, it empowers women by providing direct control over chicken and egg sales, enabling them to generate immediate income for household needs.

Brown *et al.* (2017) emphasized that characterizing local animal genetic resources (AnGR) is a foundational step in generating critical data for their conservation and sustainable utilization. This process involves assessing genetic diversity, population structure, and adaptive traits,



which are essential for designing targeted breeding programs and safeguarding biodiversity. Indigenous chicken breeds frequently possess key genetic traits that enhance their adaptability, disease resistance, and overall productivity in tropical environments (Birteeb & Boakye, 2020; Fayeye *et al.*, 2006). The characterization and identification of chicken genetic resources require comprehensive data on multiple factors: environmental adaptation patterns, population structures, presence of economically valuable traits (both current and potential), and sociocultural relevance. These critical parameters inform evidence-based decisions regarding conservation priorities and sustainable utilization strategies (Fitsum, 2017; Brown *et al.*, 2017; Hailemichael *et al.*, 2015; Weigend & Romanov, 2001). Kaleri *et al.* (2023) and De la Barra *et al.* (2019) emphasized that phenotypic and morphological characterisation forms the foundation for identifying and selecting superior indigenous chicken breeds. This process involves documenting adaptive traits and quantitative metrics to evaluate genetic potential and resilience in local environments. According to Kindie & Tamiru (2021), indigenous chickens can be characterised by molecular markers and morphological, however, morphological characterisation is a comparatively cheap and easy tool for the characterisation of indigenous chicken breeds. Despite their critical socioeconomic roles as income generators, cultural assets, and nutritional sources for rural households, indigenous chicken breeds face existential threats from modern agricultural pressures (Fitsum, 2017). Current evidence indicates that critical genetic traits in indigenous chicken populations are facing severe depletion, with carrier frequencies for major genes falling to alarmingly low levels (Birteeb & Boakye, 2020; Osei-Amponsah *et al.*, 2013). The decline of some local chicken breeds on small-scale farms is a serious concern, largely due to their replacement by exotic breeds or interbreeding with local populations (Fitsum, 2017).

Despite their significant contribution to the livelihoods of rural smallholders in Ghana, village chicken production systems have received limited attention in terms of research and



development (Yemane *et al.*, 2013). It is crucial to collect foundational data which will help in baseline information on the characteristics of these production systems and the performance of local chickens raised under scavenging conditions across the five regions of northern Ghana (Getu, 2021). Developing effective animal breeding programs for village settings hinges on a thorough understanding of local chickens. This involves characterizing the local breeds, defining their production environments, and identifying the specific breeding practices, production objectives, and preferred traits of rural farmers (Kindie & Tamiru, 2021; Fitsum, 2017). Consequently, to facilitate future improvements, it is essential to characterize these existing chicken breeds based on their overall merits (Fitsum, 2017).

Ouma *et al.* (2023) indicated that approximately 50% of Ghana's indigenous chicken population is concentrated in the Upper East and Northern regions. Northern Ghana holds significant promise for indigenous poultry production, boasting a variety of local chicken breeds. To fully leverage this potential, comprehensive research is essential. These studies should delve into the morphological, functional, and adaptive traits of these local chickens. This foundational study is crucial because it will directly inform effective conservation efforts, sustainable utilization, and the development of genetic improvement programs. With these goals in mind, this research was designed with the following specific objectives.

1.1 Specific Objectives

- ❖ To assess breeding objectives and breeding practices employed by indigenous chicken farmers in Northern Ghana
- ❖ To assess the morphological variability of indigenous chicken in Northern Ghana.
- ❖ To characterise the production systems of indigenous chicken in Northern Ghana.



CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 History and Distribution of Chicken

The history and distribution of chicken production reveal a complex evolution influenced by geographical, cultural, and economic factors. Chickens were domesticated in Central Asia around the third century BC, spreading along trade routes like the Silk Road, where they became integral to local diets (Peters *et al.*, 2024; Spengler *et al.*, 2022). In modern contexts, chicken production has expanded significantly, particularly in countries like the USA, Brazil, and China, which dominate global meat production (Uzundumlu & Dilli, 2022). Chickens were first raised in southern Central Asia, with archaeological evidence indicating their presence from the fourth century BC. They were primarily reared for eggs, as indicated by the abundance of eggshells found at various archaeological sites (Peters *et al.*, 2024; Spengler *et al.*, 2022).

Countries like Indonesia and India are expected to see substantial increases in chicken production, reflecting a shift in global poultry dynamics (Uzundumlu & Dilli, 2022). In Vietnam, chicken production is characterized by diverse networks, including small-scale farms and large vertically-integrated companies, highlighting the importance of local markets and consumer preferences (Dien *et al.*, 2023).

While the historical significance of chickens in diets is well-documented, contemporary challenges such as disease management and biosecurity in production networks remain critical for sustainable growth in the poultry industry.



2.2 Overview of Chicken Production

Chicken farming plays a vital role in worldwide food supply chains, delivering crucial protein to millions, especially in developing countries (Ngongolo & Chota, 2022). Chicken meat production has grown dramatically worldwide, increasing from 7.56 million tons in 1961 to a projected 139.19 million tons by 2025, reflecting higher consumption and evolving dietary preferences (Sipasi, 2024; Uzundumlu & Dilli, 2022). However, challenges such as climate change, disease prevalence, and economic factors threaten sustainability and productivity in various regions (Ngongolo & Mrimi, 2024).

The USA, Brazil, and China are the leading producers, with Brazil and China expected to close the gap with the USA by 2025 (Uzundumlu & Dilli, 2022). Climate change impacts, including temperature stress and water scarcity, pose significant risks to poultry farming (Ngongolo & Mrimi, 2024). In sub-Saharan Africa, low productivity and reliance on imports hinder local production growth despite rising demand (Erdaw & Beyene, 2022). Commercial poultry production systems are evolving, with increasing focus on animal welfare and consumer preferences shaping future practices (Pedersen, 2018). Despite the promising growth in chicken production, the industry faces substantial challenges that require innovative solutions and collaborative efforts to ensure sustainability and resilience.

In developing countries, chickens play a crucial role in economic growth. They provide essential nutrition and significantly support the livelihoods of many people, particularly in rural regions (Habimana *et al.*, 2020). Dagher (2009) reported that the poultry sector contributes significantly to the agricultural sector in the world. Fitsum (2017) observed a substantial increase in the demand for chicken products over recent years, with projections indicating a continued significant rise in the coming decades. Melesse (2014) reported that chicken products are the cheaper sources of protein as compared to other animal protein sources. Chicken meat



is considered a healthier option compared to other meats due to its low saturated fat content and abundance of essential micronutrients (Food and Agriculture Organization (FAO) 2013; Audsley, 2006). According to Habimana *et al.* (2020), indigenous chicken breeds dominate poultry populations in developing nations across Asia and Africa, accounting for over 80% of the total poultry stock. While conventional large-scale chicken production systems continue to dominate commercial meat production, shifting consumer preferences have prompted the adoption of alternative rearing methods. In response to growing demand for ethically produced and higher-quality chicken products, producers are increasingly implementing pasture-raised and free-range systems. These alternative approaches allow birds greater mobility and access to outdoor environments, aligning with consumer expectations for animal welfare and natural production methods (Jeni *et al.*, 2021; Shi *et al.*, 2019; Ricke, 2017).

2.3 Characteristics of Chicken

Research indicates that indigenous chicken breeds typically exhibit slower growth rates and lower egg production capacity compared to commercial hybrid varieties (Kindie & Tamiru, 2021). Indigenous chicken breeds are known to be more resilient than broilers and other commercial breeds. They exhibit strong disease resistance, thrive in challenging environmental conditions, and tolerate poor nutrition and high temperatures well, as reported by Liswaniso *et al.* (2023), Kaleri *et al.* (2023) and Odjakova *et al.* (2022). According to Neupane *et al.* (2017) and Alabi *et al.* (2019), indigenous poultry breeds are robust and produce meat and eggs that are more flavourful than those from exotic breeds. Sah & Yadav (2021) stated that, indigenous chicken breeds are well-suited for scavenging and low-input environments. They are also valued for their dual purpose, providing both high-quality meat and eggs. Desha *et al.* (2016) reported that indigenous poultry birds have unique characteristics such as early maturity with a higher fertility rate, better disease resistance, and good scavengers.



Different morphological traits in poultry species impact their growth, behaviour, and overall performance. For instance, broiler chickens grow larger and quicker than layer hens (Leeson & Summers, 2005). Compared to chickens, turkeys have larger bodies and longer legs (Havenstein *et al.*, 2003). Compared to chickens and turkeys, ducks and geese have larger bodies and more noticeable plumage (Cherry & Morris, 2008). Chickens are social animals that engage in pecking, scratching, and dust-bathing behaviours. Those behaviours are controlled by both genetic and environmental variables (Lay *et al.*, 2011). Due to their propensity for foraging, ducks and geese are frequently employed in free-range agricultural systems (Cherry & Morris, 2008). As a result of high metabolic rate, chickens need a meal high in energy to sustain growth (Leeson & Summers, 2005). Turkeys have a lesser level of polymorphism but a similar genomic organisation (Reed *et al.*, 2007). Huang *et al.*, (2013) highlighted that, ducks and geese have a more complex gene organisation with a larger degree of polymorphism. Compared to layer hens, broiler chickens produce more meat and have less fat (Leeson & Summers, 2005). Turkeys yield more meat and have less fat than chickens (Havenstein *et al.*, 2003).

2.3.1 Production Systems of Chicken

Generally, there are three main production systems for keeping chickens in Ghana. The extensive production system allows total exposure of chickens to sunlight and pasture. In contrast, the intensive production system practically reduces the exposure of chicken, and in between these two systems of production is the semi-intensive system of production (Brown *et al.*, 2017). The management of chicken production is influenced by the type of housing system which will depend on the availability of space (Fitsum, 2017; Bailey *et al.*, 2010). For small-scale chicken production, the extensive or free-range system is ideal, allowing chickens unrestricted movement. In contrast, the intensive system keeps birds entirely confined, often in setups like a deep-litter system. A semi-intensive system offers a middle ground, where



chickens are partially housed but have occasional access to the outdoors (Ifeduba *et al.*, 2020). The extensive or free-range system of chicken production is regarded as animal welfare friendly (Mramba *et al.*, 2025; Conraths *et al.*, 2005; Appleby, 2003).

The intensive production system, also referred to as the commercial production system, typically involves larger flock sizes than the extensive system (Ndung'u, 2021). The intensive system of chicken production practices basic biosecurity systems, and a semi-automatic system of feeding (Birhanu *et al.*, 2021). As stated by Birhanu *et al.* (2021) in the extensive system of chicken production, birds obtain their feed mainly from scavenging the surroundings and hardly get feed waste. In the extensive system of production, chicken do not get access to an improved housing system, good health care, and supplemented feeding (Munyaneza *et al.*, 2021).

2.3.2 Effects of Production Systems on the Productivity of Chicken

The extensive or free-range chicken management system offers a compelling approach that aligns environmental sustainability, economic viability, and strong animal welfare, making it a suitable choice for meeting organic agriculture standards and potentially providing a fully organic diet (Jeni *et al.*, 2021; Chen *et al.*, 2018; Rodenburg & Turner, 2012). According to Plessis (2012) and Pedersen *et al.* (2003), the free-range or extensive system of chicken production can significantly enhance the health of the birds' gastrointestinal tract and overall welfare. The free-range or extensive management system allows chickens to express their natural behaviours like scratching, dust bathing, running, flying, and foraging. This system also helps reduce the incidence of pecking due to decrease stocking density tract and overall welfare (Chilemba, 2023; Bestman *et al.*, 2018). An extensive or free-range system of chicken production promotes grass ingestion behaviour which is beneficial to the birds as some grasses contain high concentrations of potassium which can enhance feed conversion rate and weight gain (Blair, 2018). Jeni *et al.* (2021), Dhama *et al.* (2015) and Mikulski *et al.* (2011) reported



that chickens raised under semi-extensive and free-range or extensive systems showed similar body weight gained and feed conversion efficiencies. Ipek and Sozcu (2017), Brown *et al.* (2017), Stadig *et al.* (2016), Moyle *et al.* (2014) and Pavlovski *et al.* (2009) indicated that chickens raised in an extensive production system tend to exhibit poorer feed conversion rates and lower body weight gain.

2.3.3 Effects of Production Systems on Reproductive Traits of Chicken

Several researchers stated that, chickens raised under the free range system of production recorded lower live body weight gain as compared to chickens raised under the intensive system of production (Ahizo *et al.*, 2023; Kuźniacka *et al.*, 2014; Castellini *et al.*, 2002). Mengesha *et al.* (2022) and Guteta (2017) highlighted that, the average egg-laying performance of indigenous chicken reared under the free range system in Ethiopia was 76.3 eggs/year/hen, while pullets at first egg, and cockerels at first mating were 24.2 weeks. Mekonnen *et al.* (2023), Fitsum (2017) and Melesse and Negesse (2011) reported that indigenous chickens reared under extensive systems have low productivity, producing about 40-60 small-sized eggs annually with a different degrees of hatchability, and a low chance of chick survival under extensive systems of production. Mekonnen *et al.* (2023) reported distinct sexual maturation timelines for indigenous chickens in Ethiopia, with males reaching sexual maturity at 23.48 weeks and females at 23.6 weeks. The study further documents a notable gender disparity in first mating age, where females commence breeding at 27.5 weeks compared to males at 24.6 weeks. Indigenous chicken breeds, according to Mekonnen *et al.* (2023) and Fitsum (2017) begin laying eggs later than exotic and hybrid breeds. Indigenous chickens typically lay their first egg between 24 and 28 weeks of age, averaging 27.2 weeks, while exotic and hybrid chickens start earlier, at an average of 25.7 and 25.4 weeks, respectively. Mekonnen *et al.* (2023) and Kibret (2008) reported that indigenous chickens have a longer productive lifespan compared to exotic breeds. Mekonnen *et al.* (2023) found that in the Metekel zone of Northwest



Ethiopia, female chickens had a reproductive lifespan of 3.79 years, while males had a slightly shorter lifespan of 3.56 years. The hatchability potential of indigenous chickens is an essential economic parameter in the poultry sector as it greatly impacts chicken output (Mekonnen *et al.* 2023). Okeno *et al.* (2012) and Moges *et al.* (2010) found that, natural hatchability percentage of indigenous chicken in Northern Ethiopia Bure district was 82.83%. Mekonnen *et al.* (2023), Yemane *et al.* (2013) and Kirunda (2011) noted that hatchability of the indigenous chickens could be affected by several factors such as nutrition, egg quality, genetic factors, age, the condition of incubation, hygiene, and laying season. Halima *et al.* (2007) reported that the brooding period for indigenous hens reared under the extensive system of production was 56 days in Northern Ethiopia.

2.4 Importance of Chicken Production

Indigenous chicken production contributes beneficially to human nutrition by providing meat, and eggs with high-quality nutrients and micronutrients (Ibrahim *et al.*, 2018). Selling chicken products provides a key source of income, particularly for women, helping them address immediate financial needs and reduce economic instability. Chicken production offers significant benefits, including livelihood, food security, and nutritional support for millions of farmers with limited resources (Ahmed *et al.*, 2021; De Bruyn *et al.*, 2015; Alders & Pym, 2009). Rural chicken farming offers a vital source of protein (from eggs and meat), beneficial minerals, and essential vitamins for millions of malnourished individuals, especially impoverished children and pregnant women (Tixier-Boichard & Duclos, 2022; Ahmed *et al.*, 2021; Grace *et al.*, 2018; Farrell, 2013; Alders & Pym, 2009). Apart from the nutritional, and economic benefits, rural chicken production serves as socio-cultural, and religious functions for smallholder livelihoods (Ahmed *et al.*, 2021; Farrell, 2013). Indigenous chickens are excellent foragers, have good mothering ability, and are well-recognised for their disease resistance, and tropical adaptability while the colour of their plumage aids in protecting them



against predators (Alagawany *et al.*, 2021; D'Andre *et al.*, 2019). According to Hailemichael *et al.* (2016), extensive or free-range systems of poultry production provide essential sources of income to poor households. Chicken farming offers high-quality protein through its meat and eggs. Sonaiya and Swan (2004) highlighted that chicken rearing plays a substantial role in enhancing food security for households across the developing world. Higenyi *et al.* (2014) indicated that indigenous chicken meat serves a dual purpose for households in developing countries, particularly for low-income peri-urban and rural families, by providing a cost-effective source of protein and a valuable income stream. Chicken production provides income diversification as it serves a source of food, fertilizer, and renewable energy in over 80% of rural households (Alhassan *et al.*, 2021). Chicken meat provides essential sources of nutrients such as vitamins, minerals, and protein with low fat levels and highly unsaturated fatty acids rendering a more preferable meat choice for consumers (Zhang *et al.*, 2021; Jin *et al.*, 2018).

2.5 Challenges of Chicken Production

Chicken diseases pose a significant challenge in chicken farming, manifesting in two primary forms: subclinical infections, which reduce productivity and cause unnoticeable health issues, and clinical infections, which lead to visible illness and increased mortality (Jeni *et al.*, 2021; Scott *et al.*, 2018; Fitsum, 2017; Weeks *et al.*, 2016; Whay *et al.*, 2007). Heat stress reduces feed intake in chickens by disrupting adipokine function, a key regulator of feeding behaviour (Abass, A. 2021; Bernabucci *et al.*, 2009). Abass (2021), Rostagno (2020) and Wu *et al.* (2018) found that, heat stress disrupts feed intake, immune function, and physiological processes in the gastrointestinal tract, leading to compromised intestinal integrity and inflammation in chickens. Exposure of chickens to elevated environmental temperatures triggers the hypothalamic-pituitary-adrenal (HPA) axis, leading to reduced growth performance, impaired immune responses, and alterations in intestinal mucosa integrity (Jeni *et al.*, 2021; Rostagno, 2020; Opoku-Mensah, 2017; Lara & Rostagno, 2013). Pius *et al.* (2021), Vernooij *et al.* (2018),





Opoku-Mensah, (2017) and De Bruyn *et al.* (2015) stated that, the African poultry industry faces numerous interconnected challenges. These include, but are not limited to, the poor genetic quality of indigenous chicken breeds, an unreliable supply of quality feed, and inconsistent availability of day-old chicks. The sector also suffers from high mortality rates due to prevalent diseases, limited access to credit facilities, inputs, and services, and a lack of organized market infrastructure and supply chains. Furthermore, inadequate production methods, insufficient investment capacity, and a lack of modern production technology hinder growth. Finally, a weak transportation system, unfavourable government policies, and shrinking agricultural budgets further compound this issue. Feed resources are recognised as the most challenging factor affecting the poultry production sector (International Livestock Research Institute (ILRI), 2017). Mahoro *et al.* (2017) stated that market fluctuation is the challenge facing the chicken production sector in Rwanda. The extensive system of chicken production has an unimproved biosecurity system, and great risk of communicable diseases such as Newcastle diseases (Erdaw & Beyene, 2022; Snoeck *et al.*, 2013). Ouma *et al.* (2023) highlighted several hurdles in Ghana's Northern Region chicken production sector. These include insufficient knowledge and skills in chicken management, limited access to financial resources and capital, and a shortage of veterinary and agricultural extension services. The region also grapples with restricted access to vaccines, the prevalence of diseases, and a dearth of quality feed. Furthermore, extreme weather conditions impacting feed availability and a lack of household-level involvement in decisions about how chicken sales income is used also pose significant challenges.

2.6 Definition of Breed Characterisation

Breeders and geneticists realised early in the 20th century that domesticated animals needed to be categorised and described according to their physical and genetic traits (Lush, 1946). The concept of breed characterization initially emerged through the classification of livestock

breeds based on distinct morphological traits, including body size, coat colour, and horn shape (Mekonnen *et al.*, 2023). Breed characterisation is the process of characterising and recording a breed's genetic and phenotypic traits, together with its history, origin, and distribution, according to the FAO (2015). Breeding programmes, conservation priorities, and genetic diversity documentation all depend on breed characterisation (Hailu & Getu, 2015). Modern breed characterization has been transformed by the application of genetic markers, particularly single nucleotide polymorphisms (SNPs) and microsatellites, which provide precise molecular tools for differentiation (Tribudi *et al.*, 2024). These markers were made possible by the invention of molecular genetics. To determine genetic variations between breeds and piece together their evolutionary history, genetic characterisation entails the examination of DNA markers (Toro *et al.*, 2009).

2.6.1 Types/Categories of Breed Characterisation

Breed characterisation is an important aspect of animal genetics and breeding as it enhances the description and identification of distinct breeds facilitating their improvement, conservation, and utilisation. Characterisation of animal breeds can be grouped into different types each focusing on specific aspects of a breed's characteristics. Mason (1966) defined breed characterisation as the recording of physical traits like facial features, body proportions, coat colour, and horn configuration. Toro *et al.* (2009) stated that morphological characterisation of animal breeds provides an accurate understanding of a breed's traits which is frequently combined with other techniques such as genetic characterisation. The determination of genetic variations between breeds together with their evolutionary history, and genetic characterisation entails the examination of DNA markers (Araújo *et al.*, 2010). Rege *et al.* (2011) emphasized that, systematic categorization of animal genetic resources (AnGR) is fundamental for their effective preservation and sustainable utilization. Phenotypic characterization includes measuring growth rates and feed efficiency. For instance, a study on native turkeys highlighted



the correlation between feed conversion ratio (FCR) and growth traits, indicating that selecting for FCR can enhance overall growth performance (Pezeshkian *et al.*, 2023). The creation of breeding plans and the enhancement of animal productivity depend heavily on phenotypic characterisation (Safari *et al.*, 2005). Behavioural traits involve the description of a breed's behaviour such as temperament and social behaviour. Animal welfare and the creation of breeding strategies that put animal welfare first depend on behavioural characterisation. The creation of breeding plans and the enhancement of animal productivity depend on this kind of characterisation (Jarvis *et al.*, 2011). Breeds are categorised according to their traits such as dairy or beef breeds in a process known as categorical characterisation (FAO, 2015). Both the creation of breeding programmes and the preservation of animal genetic resources benefit from this kind of classification.

Multivariate characterisation of animal breeds involves the use of multiple variables such as genetic, phenotypic, and morphological traits to describe a breed's characteristics (Toro *et al.*, 2009). Contemporary livestock characterization and classification increasingly utilize multivariate statistical methods, as demonstrated by multiple studies (Aziz & Al-Hur, 2013; Birteeb *et al.*, 2012; Yakubu & Akinyemi, 2010; Traore *et al.*, 2008). Multivariate statistical methods serve as powerful analytical tools for simultaneously evaluating comprehensive morphological datasets, enabling precise quantification of both inter- and intra-population variation (Yakubu & Ibrahim, 2011). Discriminant function analysis (DFA) represents a particularly valuable multivariate statistical approach, demonstrating significant efficacy in both predicting categorical membership and classifying populations through simultaneous evaluation of multiple parameters (Egbo & Bartholomew, 2017; Long, 2013). This type of characterisation provides a comprehensive understanding of a breed's characteristics and is essential for the development of breeding programs.



2.6.2 Methods of Breed Characterisation

Breed characterization serves as a fundamental prerequisite for both the preservation and genetic enhancement of animal genetic resources (AnGR). It involves describing a breed's unique characteristics including its performance, genetic, and phenotypic traits (FAO, 2015). For a breed to be successfully identified, classified, and registered as well as for breeding plans to be developed, it must be accurately characterised (Mwacharo *et al.*, 2013). Breed characterization has been accomplished through the use of morphometric analysis, genetic analysis, and performance testing, among other techniques. Measurements of an animal's height, length, and weight are all part of the morphometric analysis process (P. Kumar *et al.*, 2017). Animal features that can be directly measured and observed, such as coat colour, skin structure, body shape, and anatomical features are known as morphological markers. Particularly in developing nations, morphological markers are employed in the characterisation, identification, and classification of the genetic development of various populations or species (Gizaw *et al.*, 2007). Breed associations can be studied and breeds with distinct body types can be identified using morphological markers (Ajmone-Marsan *et al.*, 2010). For instance, morphometric analysis was used by Kumar *et al.* (2017) to describe Jamunapari breed of Indian goats. The breed was shown to have a distinct body type, with a larger body size and better milk output than other breeds.

Also, genetic analysis looks at genetic composition of breeds including its genetic diversity and DNA markers (Toro *et al.*, 2009). Breeds with distinctive genetic traits can be identified using this method which is also helpful for researching the genetic links between different breeds (Mwacharo *et al.*, 2013). Modern genetic analysis utilizes complementary techniques including, comprehensive whole genome sequencing (WGS) for full variant detection, microsatellites for population genetics, and single nucleotide polymorphism SNP arrays for high-density genotyping, each serving distinct characterization needs (Bertolini *et al.*, 2018).



Single nucleotide polymorphism (SNP) markers are frequently utilized for genotyping because they are numerous throughout the genome and are well-suited for efficient, automated high-throughput analysis (Vignal *et al.*, 2002).

SNPs are ubiquitously distributed across functional and regulatory genomic regions, facilitating comprehensive genetic analysis (Syvänen, 2001). Benefits of SNPs include their extensive distribution across the genome, high genetic stability, excellent reproducibility, and high precision, enabling rapid and efficient genotyping (Primmer *et al.*, 2002; Tsuchihashi & Dracopoli, 2002). Hailu & Getu (2015) demonstrated that whole-genome sequencing (WGS) represents the most exhaustive approach for genetic variation analysis. Ankole breed of cattle in Africa was characterised by Mwacharo *et al.* (2013), using genetic analysis, and the results showed that the breed was unique from other breeds in the area and possessed a high degree of genetic diversity. Performance testing involves the evaluation of a breed's performance traits including its growth rate, milk production, and reproductive performance (P. Kumar *et al.*, 2017). According to Michalska *et al.* (2016), performance testing serves as a critical component in genetic selection programs, particularly for sire evaluation. Breeds with superior performance qualities can be found through performance testing, and breeding strategies that enhance these traits can be developed (Mwacharo *et al.*, 2013). Breed characterisation using omics technologies including transcriptomics, proteomics, and genomes has garnered more attention in the last few years (Bertolini *et al.*, 2018). According to Toro *et al.* (2009), these technologies make it possible to analyse the genetic composition and gene expression of a breed, which might reveal important information about its biology and performance attributes.

2.6.3 Characterisation of Livestock Breed

Livestock breeds are important to agricultural production providing, fibre, food, and income for millions of people worldwide. Livestock breed characterisation is essential for their improvement, conservation, and sustainable use. Phenotypic characterization entails detailing



a breed's observable functional and physical attributes, including features like body coat colour, size, and milk production (Kumar *et al.*, 2017). According to FAO (2011), accurate assessment of animal genetic resource diversity and the determination of whether it is diminishing or not depends on phenotypic characterisation. Studying a breed's genetic composition, including its DNA markers and genetic diversity is known as genetic characterisation (Toro *et al.*, 2009). Molecular characterization employs DNA-based genetic markers, including microsatellites and single nucleotide polymorphisms (SNPs), to analyse the genomic composition of animal breeds (Bertolini *et al.*, 2018). Studies by Wu *et al.* (2018) reported that highly polymorphic molecular genetic markers such as microsatellites are important techniques for studying genetic diversity owing to their exceptional genome-wide random distribution, variability, and lack of selective bias. Kumar *et al.* (2017) reported that functional characterisation of animal breeds involves the evaluation of a breed's functional traits such as its ability to adapt to different environments and its resistance to diseases. Characterisation of breeds with unique traits can facilitate their utilisation in breeding programs and improve animal productivity (Notter, 2012).

2.6.4 Non-Genetic Factors of Chicken

The reproductive and productive potential of chickens is controlled by two factors such as non-genetic or environmental (like ecological condition, health care, feeding, and shed) and genetic factors (Sah & Yadav, 2021). Studies by Hossen (2010) and Ochieng *et al.* (2011) demonstrated that, environmental and managerial factors substantially influence poultry productivity. Management interventions play a crucial role in enhancing the production capabilities of indigenous chickens, thereby making a substantial contribution to the livelihoods of impoverished rural households (Sarkar, 2012; Hossen, 2010). According to Ochieng *et al.* (2011) strategic management interventions can significantly improve both the productivity and market viability of indigenous chicken production systems. Desha *et al.* (2016) found that non-genetic elements significantly influenced the varying growth potentials of indigenous day-old



chicks. These factors included the brooding system, the specific batch of chicks, the farm environment, the feeding system, and the sex of the chick. Sogunle *et al.* (2016) reported that, feeding is the most critical non-genetic factor in chicken production, and the availability of either high-quality feed or affordable feed is crucial for the growth of the chicken sector. According to Uddhav *et al.* (2016), a deficiency of protein and vitamins in chicken feed compromises the immune system of chicks, making them susceptible to diseases and predators, which ultimately results in high mortality rates. High energy and protein diets lead to increased body weight gain and improved feed conversion ratios. For instance, chicks receiving 22% crude protein and 2900 Kcal/kg metabolizable energy exhibited the highest weight gain and feed efficiency (Kumar *et al.*, 2009).. In a similar vein, Kidd *et al.* (2004) demonstrated that supplementing layer hens' diets with calcium and phosphorus improved both egg production and bone quality. Yahav *et al.* (2005) found that broilers raised at a cooler temperature (24°C) experienced increased mortality and reduced growth rates compared to those kept in warmer conditions (32°C). Lewis *et al.* (2010) discovered that layer hens housed in low-light settings produced fewer eggs and had worse feather quality. According to Mench *et al.* (2011), broilers kept at higher stocking densities (30 kg/m²) exhibited reduced growth rates and increased mortality compared to those housed at lower densities (20 kg/m²). Bilgili *et al.* (2006) discovered that broiler hens housed in dirty litter had worse feather quality than hens housed in clean litter. According to Zhang *et al.* (2013), broiler growth and productivity can be impacted by the way nutrition and the environment interact.

2.8 Characterisation of Animal Genetic Resources

Sass *et al.* (2020) emphasize that animal genetic resources are essential for both rural development and ensuring food security. The extensive history of livestock domestication, marked by processes of selection, adaptation, and migration, has fostered a vast array of breeds. Key evolutionary forces such as selective breeding, genetic drift, isolation, mutation, and



adaptation have significantly contributed to the rich diversity observed in local livestock populations. Over centuries, this continuous process has led to the emergence of numerous distinct breeds, each uniquely suited for particular purposes and demonstrating varying performance levels across diverse production environments (Weigend *et al.*, 2009). Livestock genetic resources have diverged from their wild ancestral species, adapting and evolving across diverse environments. These resources have been shaped by processes such as genetic drift, mutation, and both artificial and natural selection, resulting in characteristic genes that determine their adaptive and productive capabilities. The genetic diversity found within domestic livestock breeds is crucial for animal breeders, enabling them to develop new traits in response to evolving market demands, disease challenges, and environmental changes (Joshi *et al.*, 2012). Characterising animal genetics is a foundational step for understanding evolution, managing genetic resources, establishing taxonomy, developing conservation strategies, and comprehending domestication processes for their effective utilization (Jansen *et al.*, 2002; Groves & Ryder 2000; Oakenfull *et al.*, 2000). The initial phase of characterizing local genetic resources necessitates a thorough understanding of their morpho-biometrical traits both within and across populations (FAO, 2012). Livestock genetic resources encompass a remarkable array of domestic livestock breeds and their populations, which have adapted and evolved over centuries to various environmental conditions. Experts at the FAO define farm animal genetic resources as all livestock species and populations that can be used for agricultural or food production (Tanchev, 2015). Animal genetic resources have been characterised using a variety of techniques, such as morphological, biochemical, and molecular methods (P. Kumar *et al.*, 2012). Physical characteristics like body size, coat colour, and horn shape are evaluated as part of morphological characterisation (Mwacharo *et al.*, 2013). Blood proteins, enzymes, and other biomarkers are analysed as part of the biochemical characterisation process (P. Kumar *et al.*,

2012). A more exact and accurate way to estimate genetic diversity is through molecular characterisation which includes genotyping and DNA sequencing (Luikart *et al.*, 2001).

2.9 Genes that Control Colours (white)

The genetic control of colour in animals and plants is a complex process involving multiple genes and environmental factors. In horses, the ASIP and MC1R genes are pivotal in determining base coat colours by regulating the type and distribution of melanin pigments. A specific locus upstream of ASIP has been identified as influencing the shade of bay coat colour, highlighting the genetic intricacies involved in pigmentation (Corbin *et al.*, 2020). In humans, over 125 pigmentary genes are known to affect skin colour, influencing processes from melanocyte development to melanin turnover (Ortonne, 2009).. Melanin, specifically, is responsible for the expression of red (pheomelanin) and black (eumelanin) colours, with its production facilitated by tyrosinase (Lamoreux & Wakamatsu, 2001). The PMEL17 gene at locus I is associated with dominant white, having alleles for dominant white I, dun I D, and smoky I S (Kerje *et al.*, 2004). According to Sato *et al.*, (2007), The tyrosinase (TYR) gene at the C locus is linked to albinism. The recessive allele for this gene is c^a , which, when present in a homozygous state, results in the albino phenotype, often referred to as red-eyed white or recessive white depending on the species. Schütz (2015) noted that the Agouti signalling protein, a ligand to the melanocortin receptor-1 (MC1R), plays a vital role in coat colour. The genetic basis of chicken feather colour is a complex trait that has been extensively studied (Cooke *et al.*, 2017). Furthermore, dominant white, smoky, and dun colours are linked to PMEL17 polymorphism (Kerje *et al.*, 2004). Vaez *et al.* (2008) Stated that, while mutations in MLPH can lead to the dilution of brown/red pheomelanin and black eumelanin pigments. The Tyrosinase (TYR) gene and SLC45A2 are also implicated in determining white colour (Gunnarsson *et al.*, 2007; Chang *et al.*, 2006).



2.10 Colour Varieties of Chicken

The feather colour pigmentation in indigenous chickens is shaped by genetic variations and the presence of gonadotropic hormones (Bell, 2011). The same author further noted that the distribution, differentiation, and mixture of melanocytes contribute to the diverse colour patterns observed in chickens. Several studies (Cabarles, 2013; Akinola & Essien, 2011; Dana *et al.*, 2010; Moges *et al.*, 2010) suggest that most indigenous chicken producers favour chickens with dull or non-bright colours, this preference is practical, as these colours provide camouflage from predators when the chickens scavenge under extensive production systems. Razuki *et al.* (2022) outlined the different morphological colour varieties of the indigenous chicken in Iraq such as brown, black, barred, brown naked-neck, white naked-neck, and white coloured feathers in Indigenous chicken.

2.11 Phenotypic and Morphological Characterisation of Indigenous Chicken

Weigend and Romanov (2001) asserted that the characterization and identification of chicken genetic resources are primarily depended on understanding their unique traits with current or future economic value, their capacity to adapt to specific environments, and their socio-cultural benefits. This information is crucial for making informed decisions regarding their utilization and conservation. Indigenous chickens have evolved through adaptation to diverse agroclimatic conditions, leading them to possess distinct gene combinations and unique adaptive features not commonly found in modern, improved chicken breeds (Egahi *et al.*, 2010). Halima *et al.* (2007) reported significant variation in morphological traits among indigenous chicken populations, including feather contours, body conformation, productivity, shank and earlobe colour, plumage colour, and comb type. Several studies (Usman *et al.*, 2014; Ahmad *et al.*, 2014; Melesse & Negesse, 2011) indicated that white and red-white earlobe colours are the most prevalent in indigenous chickens. Apuno *et al.* (2011) noted that large comb sizes are highly effective for heat resistance. The differences in chicken earlobe colour



are attributed to breed-specific characteristics influenced by nutritional factors (Dana *et al.*, 2010). Sørensen (2010) found that indigenous frizzled chickens perform better in high-temperature regions due to their superior ability to regulate body heat compared to normal-feathered chickens. Indigenous chicken breeds with feathered shanks are generally considered less appealing than non-feathered shank breeds, which have feathers only on the outer toes, hocks, and tarsometatarsus (Ikeobi *et al.*, 2001). The same author also highlighted that a chicken's comb plays a vital thermoregulatory role during scavenging, as chickens do not sweat. Chickens with a single comb also show improved body weight gain and egg-laying ability (Ikeobi *et al.*, 2001). Egahi *et al.* (2010) and Stettenheim (2000) also reported that the chicken's earlobe serves an essential thermoregulatory function. Habimana *et al.* (2020) further stated that earlobe coloration is a breed-specific trait influenced by the bird's nutrition. The white earlobe colour commonly seen in mature indigenous chickens is closely linked to the bird's sexual maturity hormone (Youssao *et al.*, 2010). Finally, the shank colour of indigenous chickens provides insights into their foraging ability, immune and nutritional status, and sexual desirability (Eriksson *et al.*, 2008; Blas *et al.*, 2006; Blount *et al.*, 2003).

2.12 Body Weight Characterisation of Chicken

Body weight is a crucial factor in chicken production, directly impacting growth rate, feed efficiency, and ultimately, the profitability of poultry farming (Leeson & Summers, 2001). Wang *et al.* (2024) highlighted that body weight is an essential economic trait primarily influenced by minor genes that interact with functional genes and also serve as molecular markers, which are extensively studied for their association with body weight gain. Precise characterization of body weight is vital for optimizing breeding programs, forecasting growth performance, and identifying genetic markers linked to desirable traits (Dekkers, 2003). Various methods are employed to characterize chicken body weight, including linear measurements such as body length and shank length (Hocking & Robertson, 1999) and non-

invasive techniques like dual-energy X-ray absorptiometry (DXA) and bioelectrical impedance analysis (BIA) (Sorensen & Su, 2002). Yilmaz *et al.* (2013) noted that body weight and linear body measurements are frequently used in scientific research and selection applications. However, Yakubu *et al.* (2009) pointed out that measuring animal body weight often requires weighing scales, which may not always be accessible in smallholder management settings. Machine learning algorithms have been utilized to predict body weight from easily measurable traits like wing length and breast circumference (Zhang & Chen, 2019). Chicken body weight is shaped by a complex interaction of genetic and environmental factors. Genetic elements, including breed, sex, and genotype, significantly influence body weight (Siegel, 2014). Environmental factors such as nutrition, management practices, and climate also play a critical role (National Research Council (NRC), 1994). NRC found that broilers on a high-energy diet had considerably higher body weights than those on a low-energy diet. Similarly, birds raised in hot climates had lower body weights than those in temperate climates (Yahav & Hurwitz, 2003). Genetic variation in body weight is a key component of poultry breeding programs. Several quantitative trait loci (QTL) linked to body weight have been identified in chicken populations (Abasht *et al.*, 2006). Jeong *et al.*, (2016) demonstrated the value of genetic analysis and pattern recognition in identifying origin-specific breeds or providing information about their characteristic traits. For example, Tuiskula-Haavisto *et al.* (2002) identified a QTL on chromosome 1 associated with body weight at 35 days of age. The body weight of chickens is indicative of their size, overall weight, and general condition (Daikwo *et al.*, 2011). Kaleri *et al.* (2023) and Msoffe *et al.* (2002) observed that male chickens are generally heavier than females, a difference attributed to hormonal influences that promote rapid body growth and a larger frame in males. Kindie and Tamiru (2021) further reported that male chickens are significantly superior in all linear body measurements.



2.13 Measuring the Body Weight of Animals

Accurately measuring an animal's body weight is essential for evaluating its growth, development, and health, as well as determining the appropriate amounts of food and medicine it requires (Council *et al.*, 2011). Over time, numerous methods have been developed for measuring animal body weight, each possessing its own benefits and drawbacks. Scales and balances are two common tools used in traditional body weight assessment techniques (Association of Official Analytical Chemists, 2012). These techniques are easy to use, affordable, and generally accessible yet they necessitate handling or restraint of the animal which can be distressing and compromise the measurement's precision (Grandin, 2017). Recently, additional techniques for determining body weight have emerged, including dual-energy X-ray absorptiometry (DXA) and bioelectrical impedance analysis (BIA) (Deurenberg & Deurenberg-Yap, 2002; Toombs & Collins, 2017). Kyle and Bosaeus (2003) further explained that BIA assesses the body's resistance to electrical currents. This measurement can be used to estimate lean and fat mass. Conversely, DXA measures body composition and bone density using X-rays (Blake & Fogelman, 2010). Both BIA and DXA are trustworthy and accurate ways to estimate body weight however, they may be more expensive than conventional techniques and call for specific equipment (Speakman, 2013). Beyond these methods, researchers have also explored using computer vision techniques and machine learning algorithms to estimate animal body weight directly from photographs (Chen & Zhang, 2020; Wang & Li, 2019). These techniques could be very effective and precise, but they need big image datasets and can be impacted by things like illumination and animal posture (Li & Wang, 2020).

2.14 Use of Body Measurements to Forecast Body Weight in Chicken

The application of linear body measurements in farm animals can serve as a fundamental tool in livestock and chicken production for determining animal prices and selecting chickens for



breeding (Muumin *et al.*, 2020; Abdel-Latif, 2019). The use of linear body measurements and body weight determination has been established for various poultry, such as narrow and broad helmeted French broiler guinea fowl in semi-arid Nigeria (Dzungwe *et al.*, 2018). Several studies, including those by Khan *et al.* (2015) have successfully used linear body measurements to predict the weight of farm animals.

Numerous studies have investigated the correlation between body measurements and body weight in chicken. For instance, Narinc *et al.* (2013) found a statistically significant positive relationship between body weight and linear body parameters like body length, shank length, and wing length in broiler chickens. Similarly, Khan *et al.* (2015) reported a significant connection between body weight and morphometric characteristics such as keel length, breast breadth, and thigh length in native chicken breeds. Oladele *et al.* (2017) developed a highly accurate prediction model (92% accuracy) for estimating body weight in broiler chicks using morphometric parameters including body length, shank length, and wing length. Adeyinka *et al.* (2019) utilized a multiple linear regression model with a high coefficient of determination (R^2) of 0.85 to predict body weight from morphometric parameters like body length, breast width, and thigh length in indigenous Nigerian chicken breeds. Ojedapo *et al.* (2018), noted that morphometric features provided higher accuracy in body weight prediction for broiler chickens compared to layer chickens. Furthermore, Ajayi *et al.* (2020) demonstrated that the accuracy of body weight prediction using morphometric traits in broiler chickens improved with age.

2.15 Morphological Traits characterisation of Chicken

Morphological and phenotypic traits of indigenous chickens, such as frizzled feathers, large wattles, naked necks, long legs, and large combs, have been extensively researched. Studies have indicated that some of these traits are linked to tropical adaptability and productivity, as reported by Assan (2015). Habimana *et al.* (2020) specifically identified frizzle, silky, and



normal as three distinct feather morphological types in indigenous Rwandan chickens. Maharani *et al.* (2021) and Tadele *et al.* (2018) also confirm that indigenous chicken breeds commonly exhibit differences in their morphological traits, especially in backyards, and rural production systems ranging from skin colour, plumage colour, and distribution, body shape, and shank colour to type of comb. Razuki *et al.* (2022) reported that indigenous chickens are raised in Iraq to produce fresh eggs as a first choice in some households, and comb type, feather-legged, plumage colour as a second choice, and some other desirable traits. Razuki *et al.* (2022) identified egg production and body weight as the most crucial economic traits, serving as primary sources of livelihood for chicken producers. In tropical regions, indigenous chickens are predominantly reported to have a single comb type (Cabarles, 2013; Aklilu *et al.*, 2013). Hailemichael *et al.* (2015) and Dana *et al.* (2010) found that rose and pea combs were the most common comb types among indigenous chickens in Ethiopia, whereas Moges *et al.* (2010) observed that rose and single comb types were the most predominant in Northwestern Ethiopia. While Fotsa *et al.* (2010), Faruque *et al.* (2010) and Keambou *et al.* (2007) reported white shank colour as the primary colour for indigenous chicken shanks. El-Safty (2012) and Egahi *et al.* (2010) observed black shank colour to be the most common in these chickens.

2.16 Correlation Among Morphological Traits in Chicken

Morphological traits and chicken weight, such as shank length and body length, significantly impact the growth potential of broilers. These factors positively influence slaughter yield at market age (Patbandha *et al.*, 2017). The chicken's skeletal structure determines its body shape, accommodating its musculature. The correlation between linear body measurements and body weight is crucial for accurately predicting body weight and can be rapidly utilized in breeding and selection programs (Ukwu & Okoro, 2014). The relationships among linear body parameters offer valuable insights into an animal's potential and carcass value (Musah *et al.*, 2015). Variedades (2010) reported that morpho-structural characteristics have been used to



determine the weight of three varieties of grey-breasted helmeted guinea fowl in Nigeria. Sadick *et al.* (2020) found that shank length and shank circumference are excellent predictors of body weight, whereas beak length is a poor predictor. Abdel-Latif, (2019) specifically highlighted shank diameter and length as outstanding predictors of body weight in white leghorn chickens, with prediction coefficients of 66% and 80%, respectively. Shank length is recognized as a reliable morphological trait for accurately determining the body weight of indigenous chickens and French broiler guinea fowl in Nigeria (Dzungwe *et al.*, 2018; Ukwu & Okoro, 2014). Variedades (2010) also noted that heart girth was a good predictor of body weight for helmeted guinea fowl in Sudan. Tadesse *et al.* (2013) found a substantial association between body weight and morphometric features such as wing length, keel length, and shank length in native chicken breeds. Olori *et al.* (2002), observed that male broilers showed a stronger correlation between body weight and body length compared to females. Similarly, Niu *et al.* (2017) discovered that in a layer breed, the relationship between body weight and shank length strengthened the egg. Zhang *et al.* (2018) reported significant relationships between egg production and morphometric characteristics like body and wing length. Mrode *et al.* (2018) noted that selecting for morphometric features like body length and shank length significantly improved a broiler breed's growth rate and carcass quality.

2.17 Egg Characterisation of Chicken

The primary goal of genetic and economic improvement in egg-laying hens is chicken egg production. While direct selection for total or partial egg numbers or laying rates has led to positive genetic improvement in egg production, this approach can reduce genetic variability, narrow the range of selective outcomes, and limit future genetic progress (Wolc *et al.*, 2019). Islam *et al.* (2001) reported that the internal and external egg quality traits of breeds impact their performance and that of future generations. Tumova *et al.* (2007) stated that a chicken's genotype significantly influences egg yolk, albumin, yolk index, and egg shape index. Yakubu



et al. (2008) recorded a significant difference in most egg parameters between normal and naked-neck feathered chickens, with the exception of yolk index and shell weight.

Jones *et al.* (2010) indicated that egg weight was a significant predictor of egg quality in layer chicken breeds. According to Narinc *et al.* (2013), the shape and size of an egg are related to its hatchability, eggshell strength, and overall egg quality in broiler and layer breeders. Costa *et al.* (2019) utilized machine learning algorithms to determine egg quality based on biochemical and physical characteristics, achieving an 85% accuracy level. Similarly, Wang *et al.* (2020) employed machine learning algorithms to predict egg hatchability based on egg weight and shape, reaching 90% accuracy.

Hutt (2003) reported that a chicken's egg production traits result from multiple genes influencing numerous biochemical processes, which in turn control a wide range of physiological and anatomical traits. These traits are also affected by both environmental conditions and genetics. Egg production traits in chickens, such as egg mass, egg weight, body weight at sexual maturity, and egg number, are regulated by the age at which chickens reach sexual maturity (Camci *et al.*, 2002).

2.18 Production Performance of Chicken

Indigenous chickens are highly adapted to harsh local environments, making them a valuable genetic resource for conservation and small-scale farming systems (Razuki *et al.*, 2022). However, village-level free-range rearing systems often result in low productivity, characterized by poor reproductive performance and high wastage compared to intensive production systems (Pedersen *et al.*, 2003). Studies by Moges *et al.* (2010) highlighted that indigenous chickens under extensive systems produce fewer eggs per year, smaller egg sizes, and lower body weights than exotic chicken breeds. Despite these challenges, indigenous hens exhibit strong maternal instincts and higher broodiness than exotic breeds (Dana *et al.*, (2010).



Research by Moges *et al.* (2010) shows that indigenous hens in Ethiopia, Ghana, and Tanzania lay an average of 17.0, 20.9, and 24.8 eggs per clutch in their top three laying periods, respectively. Additionally, Mekonnen *et al.* (2023) found that indigenous hens have better fertility rates than exotic breeds. In Southern Ethiopia, these hens produce around 4.6 clutches annually, averaging 15.4 eggs per clutch (Alemu, 2020). Metanne & Afardual (2015) reported that Moroccan hens had improved productivity, laying an average of 78 eggs per year with an egg size of 44.1 grams. Aklilu *et al.* (2013) suggested that variations in clutch numbers may be due to genotype-environment interactions. However, Hailu & Getu (2015) noted that traditional household management systems contribute to low productivity due to high chick mortality rates before hatching.



CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Outline of Study

This research was conducted across the five regions of northern Ghana, focused on three key areas related to indigenous chicken farming; farmers' breeding objectives -the traits farmers are aiming for when breeding their chickens; production systems- methods that are used to raise indigenous chickens in these regions; and morphological variations- analysing physical differences among and within indigenous chicken populations in these regions.

3.2 Location of Study

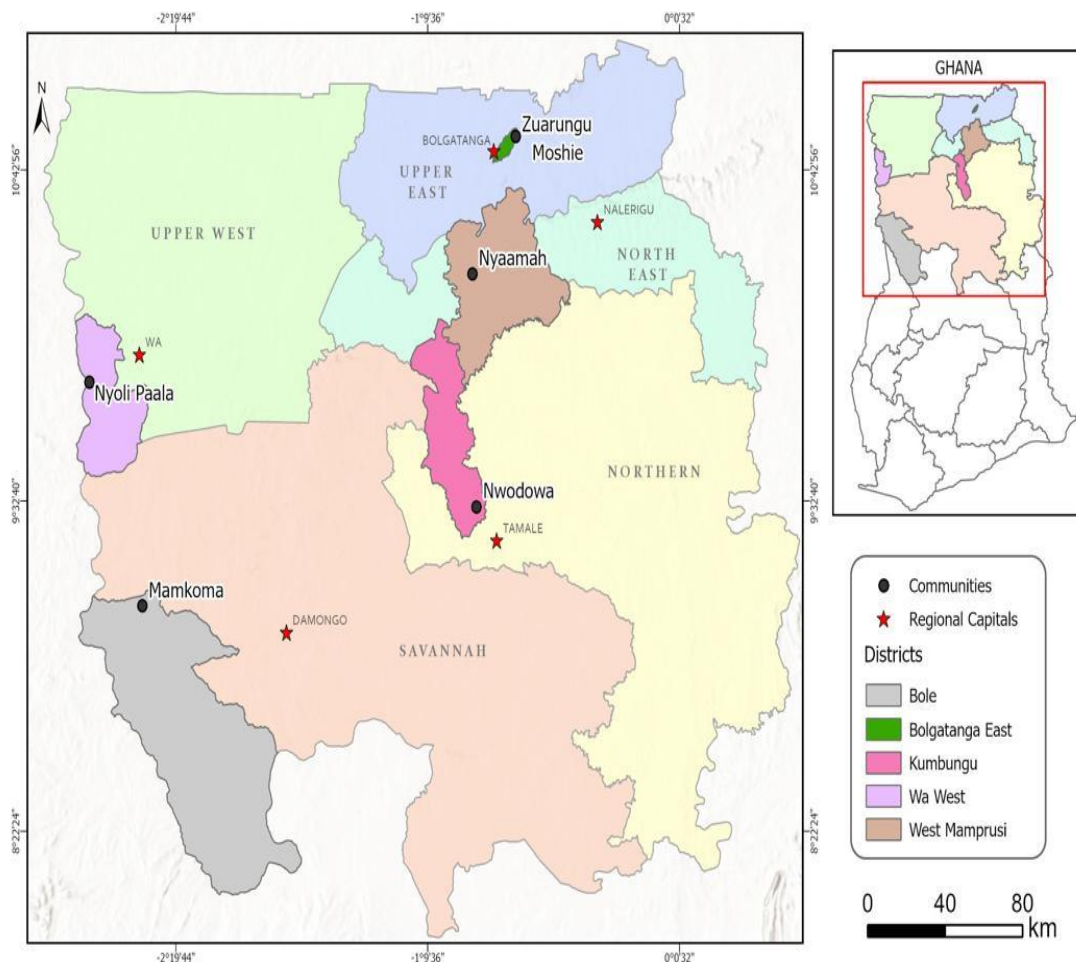


Figure 3.1. A map of the study areas where the survey was conducted

This study took place across five regions in Northern Ghana: Upper East, Upper West, Northern, Savannah, and North East.

The Upper East Region is located in the northeastern part of Ghana, specifically between latitudes 10°30' North and 11° North, and longitudes 0° and 1° West. It experiences a single, distinct rainy season, making it a relatively dry area. The rains come down between May and October, bringing much-needed water. Then, from November to April, it's dry, cold, and dusty due to the harmattan winds. Between March and May, the temperatures are quite high, hitting around 45°C. In December and January, the temperatures drop to around 13°C ("Upper East Region", 2020).

The North East Region experiences even drier conditions compared to other parts of northern Ghana. Its terrain is predominantly grassland, interspersed with drought-resistant trees such as *Adansonia digitata* (baobab) and Acacia species. The region has a distinct seasonal pattern with the dry season spanning from December to April, wet season from June to November. Annual rainfall is 750–1050 mm. Temperatures exhibit significant diurnal and seasonal variations with peak heat just before the rainy season, coolest months are December and January and daily temperature range from 17°C (night) to 47°C (day). Geographically, the region lies between Latitude 10°30'N to 11°N and Longitude 0°W to 1°W ("North East Region", 2025).

The Savannah Region shares a similar landscape with the North East, characterized by vast grasslands and resilient, drought-resistant trees. Like its neighbouring regions, the Savannah experiences a prolonged dry season from December to April, followed by a wet season that runs from July to November. Annual rainfall typically ranges from 750 to 1050 mm. Temperatures in the Savannah Region fluctuate significantly, ranging from approximately 14°C at night to a high of 40°C during the day. The hottest periods occur just before the onset



of the rainy season, while the coolest months are December and January. Geographically, the Savannah Region is situated between latitudes 7°30' North and 11°03' North, and longitudes 0°45' East and 2°02' West ("Savannah Region", 2025).

The Northern Region experiences a hot, arid climate with a single rainy season, primarily influenced by its closeness to the Sahara and Sahel. Temperatures are typically high, while rainfall remains low. The dry season spans from January to March, followed by the wet season from April to October. Daily temperatures can vary significantly, reaching up to 40°C during the day and dropping to around 14°C at night. Geographically, the region lies approximately between 8°N to 10°N latitude and 0°W to 2°E longitude ("Northern Region", 2025).

The Upper West Region is located in Ghana's northwestern corner, sharing a border with Burkina Faso. It extends between latitudes 9.8°N to 11.0°N and longitudes 1.6°W to 3.0°W. The region has a tropical climate, characterized by a brief rainy season from May to October and a prolonged dry season from October to April. Temperatures typically vary from 22.5°C to 45°C ("Upper West Weather and Climate", 2025).

3.2.1.1 Sampling and Sampling Techniques

The research was carried out in five regions of northern Ghana: Upper East, Upper West, Northern, Savannah, and North East. A total of 150 indigenous chicken farmers were randomly selected from these regions, with 30 farmers representing each area. The procedure for selecting 150 indigenous chicken farmers, with 30 farmers from each of 5 regions, followed a stratified random sampling approach: The study area was divided into 5 regions based on administrative regions to ensure diverse representation of indigenous chicken farmers.

30 farmers were randomly selected from each region. This number balanced statistical reliability enabling with logistical feasibility (cost, time, enumerator capacity).



The total of 150 farmers was calculated as 5 regions × 30 farmers per region. Equal allocation across regions prioritizes balanced comparisons over proportional sampling. Within each region, farmers were chosen randomly from extension lists to minimize bias. Data collection took place between October 2023 and May 2024 using structured questionnaires guided by FAO guidelines on phenotypic characterisation of chicken's data collection instrument.

The study examined key aspects of local poultry production, including breeding practices, feeding methods, health management, and housing conditions. Questionnaires were administered either to the head of the household or the primary caretakers of the chickens. Baseline surveys, supported by the structured questionnaire, were used to gather relevant information. Households were chosen through simple random sampling before being enrolled in the study.

Sample size n was calculated using Cochran's formula. The sample size for the study was determined using the following formula $n_0 = \frac{Z^2 \cdot p \cdot q}{e^2}$, where n_0 is the minimum required sample size, Z = Z-score (critical value from the standard normal distribution for the desired confidence level for 95% confidence), p = estimated proportion of the population with the characteristic (if unknown, use $p=0.5$ for maximum variability), and e = margin of error (expressed as a decimal, e.g., 0.05 for ±5%). The sample size was 150 houses.

3.2.1.2 Data Collection

Farmers participated in the study by answering questions using a structured questionnaire. A sample of it can be found in Appendix A. This questionnaire was designed to gather insights into several key aspects of their indigenous chicken farming practices such as breeding objectives, breeding practices, traits of preference of local chickens and the production systems of indigenous chickens.



A total of 200 mature chickens (≥ 12 months old) were randomly selected from farmers' flocks across the study regions for biometric evaluation. Following established protocols (Okruszek *et al.*, 2006) the following morphometric traits were measured: Live body weight (BWT), Wingspan (WIS), Body length (BDL), Head length (HL), Neck length (NKL), Beak length (BKL), Shank length (SKL), Wattle length (WAL), Chest circumference (CC), and Thigh circumference (THC).

Weight measurements were taken using an electronic digital weighing scale with a maximum capacity of 5 kg. For linear measurements, a calibrated measuring tape was used to determine body length, neck length, wingspan, shank length, and thigh circumference. Callipers were specifically used for precise measurements of beak length and wattle length. All these measurements were recorded in centimetres, following the methodologies detailed by Yakubu *et al.* (2011). The quantitative traits of the indigenous chickens were precisely measured as follows:

Body Weight (BWT) - This was the live weight of the chicken, obtained using a weighing scale.

Body Length (BDL) - Measured by fully stretching the bird, this was the length from the tip of the rostrum maxilla (beak) to the cauda (tail, excluding feathers).

Shank Length (SKL) - This measurement extended from the hock joint to the spur of either leg.

Chest Circumference (CC) - This was taken around the widest part of a chicken's breast area, typically measured behind the wings.

Wingspan (WIS) - Determined by fully stretching both the right and left wings and measuring the length between their tips.



Thigh Circumference (THC) - Measured as the circumference of the drumstick at the coxa region.

Neck Length (NKL) - This was the distance between the occipital condyle and the cephalic borders of the coracoids.

Beak Length (BKL) - Measured as a straight line from the rostral angle of the nares to the tip of the beak.

Wattle Length (WL) - This was the longest distance perpendicular to the wattle's basal occurrence site.

Head Length (HL) - Defined as the distance between the occipital bone and the insertion of the beak into the skull.

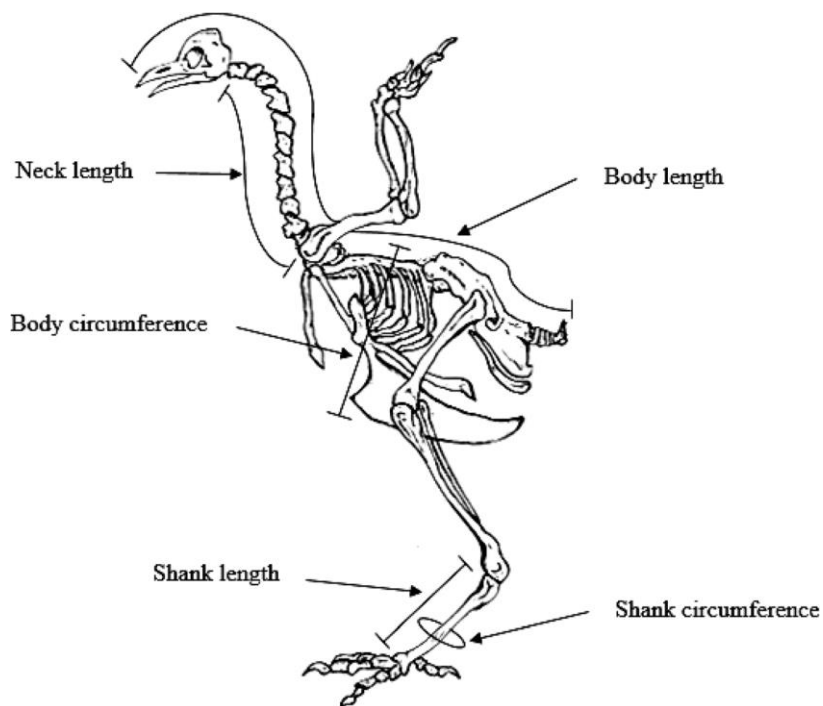


Figure 3.2. A Picture of a bird showing some body measurements (Tadele et al., 2018)



Qualitative morphological characteristics were evaluated through direct visual appraisal using standardized descriptors from the FAO guidelines for chicken genetic resources (FAO, 2011).

Feather Morphology - Birds were grouped by their feather structure as normal, frizzle (curled or ruffled feathers), or silky (soft, down-like feathers).

Feather Distribution - This described how feathers were distributed on the bird, classified as normal, naked neck (lack of feathers on the neck), feathered shanks and feet, muffs and beard crest, or vulture hocks (dense feathering on the hocks).

Plumage Pattern - The design on the feathers was noted as plain (solid colour), barred (alternating bands of colour), laced (feathers outlined with a contrasting colour), or mottled (irregular spots of different colours).

Plumage Colour - This simply referred to the main colour(s) of the feathers, categorized as white, black, blue, red, or wheaten.

Comb Size - Combs were visually assessed and classified as small, medium, or large.

Comb Type - Variations in comb shape included pea, rose, single, walnut, cushion, strawberry, duplex, V-shaped, and double.

Skeletal Variants - The skeletal structure was described as either normal, crested (a tuft of feathers on the head due to a skull abnormality), polydactyl (having more than the usual number of toes), or extra toes.

Skin Colour - Observed variations included white, yellow, and blue-black.

Shank Colour - Chickens showed diverse shank colours such as yellow, black, white, green, and brown.

Earlobe Colour - Earlobe colours were classified as white, red, or white and red.



Presence of Wattles - A simple observation of whether wattles were present or not.

Beak Types - Variations in beak shape included normal, parrot (short and curved), and scissors (crossed mandibles).

3.2.1.3 Data Analyses

Data pertaining to breeding objectives and the purpose of production were analysed using the Kruskal-Wallis test. This is a powerful, rank-based non-parametric test, often referred to as a One-way ANOVA on ranks. The Kruskal-Wallis test is specifically employed to ascertain if there are statistically significant differences among three or more independent groups with respect to a continuous or ordinal dependent variable.

The test statistic for the Kruskal-Wallis test is given as:

$$H = \frac{12}{N(N+1)} \sum_{i=1}^k \frac{R_i^2}{n_i} - 3(N+1)$$

The formula calculates a value based on:

The total number of observations from all groups combined (N).

The number of groups you're comparing (k).

The sum of ranks for each individual group (R_i^2).

The sample size of each individual group (n_i).

The test statistic in this study, traits were ranked based on farmer preference: higher numbers were assigned to the most preferred traits, and lower numbers to the least preferred. This ranked data was then uploaded into SPSS version 27.0 (IBM, Armonk, NY, USA) for analysis.



To summarize the data on various qualitative traits, descriptive statistics like frequencies and percentages were employed. The Chi-squared test of goodness of fit was then utilized to test the hypothesis that all variant phenotypes for these qualitative traits were equally distributed.

The Chi-square statistic is given as: $\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}$

Where: χ^2 = is Chi-square, O_i = Observed frequency in category i , E_i = Expected frequency in category i .

The strength of associations between categorical variables was assessed using Cramér's V , a robust effect size measure derived from Pearson's chi-squared statistic. This nonparametric test evaluates the null hypothesis of no association between nominal variable pairs.

Cramér's V is calculated as:

$$V = \sqrt{\frac{\chi^2}{nt}}$$

Where: χ^2 is the chi-squared statistic, n is the sample size, r is the number of rows in the contingency table, c is the number of columns, and $t = \text{minimum}(r - 1, c - 1)$. Cramér's V ranges from 0 (no association) to 1 (perfect association), independent of table dimensions or sample size. This allows for comparing association strength across different tables, with higher values indicating stronger relationships. In this study, association strength was categorized as: $\leq 0.3 \rightarrow$ Weak, $0.31 - 0.7 \rightarrow$ Moderate, $\geq 0.7 \rightarrow$ Strong. (Birteeb & Boakye, 2020).

The quantitative traits were analysed using a General Linear Model (GLM). To identify specific mean differences among groups, the LSD (Least Significant Difference) method was applied under the Post Hoc Multiple Comparison option.



The quantitative traits were analysed using the General Linear Model (GLM), with mean comparisons conducted via Fisher's Least Significant Difference (LSD) under the Post Hoc Multiple Comparisons option. The GLM's fixed-effects model was specified as:

$$Y_i = \mu + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \beta_5 X_{5i} + \beta_6 X_{1i} X_{2i} + \beta_7 X_{1i} X_{3i} + \beta_8 X_{2i} X_{3i} + \beta_9 X_{1i} X_{4i} + \beta_{10} X_{2i} X_{4i} + \beta_{11} X_{3i} X_{5i} + \beta_{12} X_{1i} X_{2i} X_{3i} + \varepsilon_i; \quad (1)$$

Model Components: Y_i : Morphological trait of the i th bird ($i=1, 2, \dots, n$). μ : Overall mean of the sampled birds. β_j : Regression coefficients for fixed effects ($j=1, 2, \dots, 12$).

Fixed Factors: X_{1i} : Region of the i th bird. X_{2i} : Plumage colour of the i th bird. X_{3i} : Comb size of the i th bird. X_{4i} : Feather morphology of the i th bird. X_{5i} : Feather distribution of the i th bird.

Interaction Terms: $X_{1i} X_{2i}$: Region $\times$ Plumage colour. $X_{1i} X_{3i}$: Region $\times$ Comb size. $X_{2i} X_{3i}$: Plumage colour $\times$ Comb size. $X_{1i} X_{4i}$: Region $\times$ Feather morphology. $X_{2i} X_{4i}$: Plumage colour $\times$ Feather morphology. $X_{3i} X_{5i}$: Comb size $\times$ Feather distribution. $X_{1i} X_{2i} X_{3i}$: Region $\times$ Plumage colour $\times$ Comb size. ε_i : Random error associated with each observation Y_i .

The study utilized the correlate-bivariate option in SPSS to calculate Pearson correlation coefficients between pairs of body traits.

As outlined by Birteeb *et al.* (2024), a path analysis was conducted to assess the direct and indirect effects of linear body traits on the live body weight of chickens. To determine the path coefficients, the data was standardized and analysed using a multiple linear regression model, where live body weight served as the dependent variable and the linear body measurements as the independent variables. The regression coefficients obtained from this model represented the direct path coefficients. Subsequently, indirect path coefficients for each body trait in



relation to live body weight were calculated by combining these regression coefficients with Pearson correlation coefficients.

A simplified path analysis model was provided as:

$$Y = \mu + \sum_{i=0} \sum_{j=1} \rho_{ij} X_j; \quad (2)$$

Model Components: Y: Live body weight (response variable). μ : Overall mean/intercept term. X_j : The j th linear body measurement ($j=1, 2 \dots 10$), representing 10 distinct morphometric traits. ρ_{ij} : Correlation coefficient between the i th and j th linear body traits ($i=0, 1 \dots 9$). This model quantifies the relationship between live body weight (Y) and multiple linear body measurements (X_j) accounting for pairwise correlations among predictors (Birteeb *et al.*, 2024).



CHAPTER FOUR

4.0 RESULTS

The purpose and objectives for which farmers breed indigenous chicken in Northern Ghana are given in Table 4.1. There were no notable differences found ($p > 0.05$) in farmers' preferences among the purposes for breeding indigenous chickens in each region, except in the Upper West and Savannah regions where the data shown significant differences ($p < 0.05$). The results indicated that farmers in the Upper West region bred indigenous chicken mostly for meat consumption and egg sales, while in the Savannah region chick and live adult bird sales were the most preferred breeding objectives among farmers. This is because meat consumption and egg sales recorded higher mean ranks compared to other regions. North East region for egg consumption, Upper East and Northern region for egg sale. Farmers in North East region also bred their chickens for festival/ceremonies and to give away while those in Upper East did not consider these as breeding objectives. Also, farmers in the Savannah region did not consider egg sale, festivals and give aways as important breeding objectives.

The empty spaces in the table means farmers in those regions did not consider these purposes as breeding objectives. The p value is within the columns and a comparison of production objectives within the region.



Table 4.1: Purpose and objectives for which farmers breed indigenous chicken in Northern Ghana

Production Objectives	Region					Overall
	Upper West	North East	Upper East	Savannah	Northern	
Meat consumption	2.88±0.81 ^a	2.63±0.66	2.33±0.19	1.55±0.25 ^b	2.00±0.21	2.32±0.94 ^a
Egg consumption	1.87±0.64 ^b	2.33±0.67	1.50±0.22	1.61±0.64 ^b	1.33±0.21	1.69±0.99 ^b
Egg sale	2.33±0.33 ^{ab}	1.80±0.25	3.00±0.00		3.00±0.00	2.07±0.23 ^{ab}
Chick sale	1.35±0.33 ^b	1.67±0.33	2.20±0.37	2.36±0.14 ^{ab}	2.00±0.21	1.97±0.15 ^b
Festival/ceremonies	1.20±0.64 ^b	2.0±0.33	1.60±0.63		2.00±0.31	1.74±0.14 ^b
Give away	1.00±0.00 ^b	2.00±0.00	1.00±0.00		2.33±0.67	1.64±0.24 ^b
Live adult sale	1.64±1.19 ^b	1.58±0.16	2.37±0.19	2.36±0.14 ^{ab}	2.07±0.22	2.03±0.85 ^{ab}
P-value	<0.001	0.15	0.14	0.01	0.45	<0.001

Smaller values represent least preferred for breeding objectives within the region while higher values represent most preference for breeding objectives within the region...

The results for farmers' ranking of the purpose of breeding indigenous chicken are presented in Figure 4.1. The ranked data revealed that farmers preferred breeding for meat consumption, followed by egg sale, live adult sales, and egg consumption, with breeding to give away being the lowest preference across the five regions of northern Ghana.

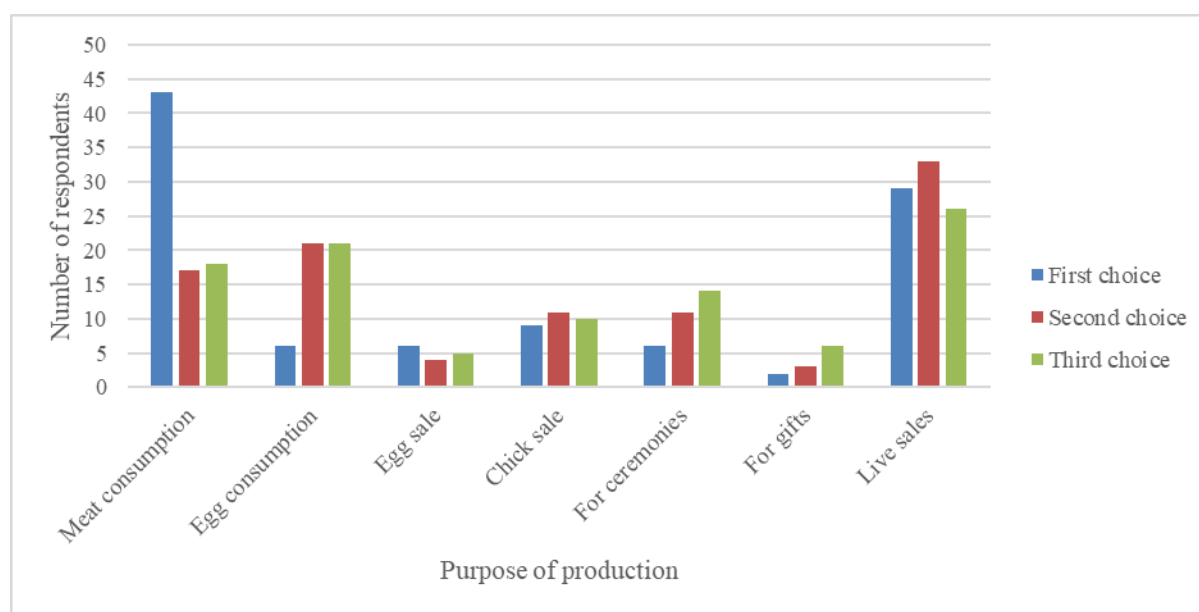


Figure 4.1: Purpose for which farmers breed Indigenous chicken according to their choices



Table 4.2. Illustrates farmers' breed preference. The analysis revealed significant statistical distinctions ($p < 0.001$) in the preferences of farmers for chicken breeds in all regions except in Upper West and Northern regions. The results indicate that farmers in the North East, Upper East, and Savannah Regions had high preference for local and exotic breeds of chicken as against improved local chicken. Clearly, there was no preference for improved local chicken (Table 4.2). Only farmers in the Upper West and Northern regions preferred raising improved exotic breeds of chicken. Crossbreeds of chicken were the least preferred among the breeds raised by farmers in the five Northern regions.

The empty spaces in the table means, farmers in those regions did not prefer those breeds. The p value is within the columns and a comparison of farmers breed preferences within the region.

Table 4.2. Farmers preference for different chicken breeds in Northern Ghana

Breed	Region					Overall
	Upper West	North East	Upper East	Savannah	Northern	
Local	2.38±0.19	3.00±0.00 ^a	2.95±0.53 ^a	2.95±0.50 ^a	1.80±0.21	2.61±0.07 ^a
Improved local	2.06±0.10	2.10±0.07 ^b	2.05±0.53 ^b	2.05±0.5 ^b	2.00±0.16	2.05±0.04 ^{ab}
Exotic	1.85±0.02	2.25±0.08 ^a	2.34±0.00 ^a	2.34±0.00 ^a	1.44±0.01	2.01±0.07 ^a
Improved exotic	2.50±0.50				2.00±0.00	2.33±0.33 ^b
Crossbred	1.67±0.42	1.00±0.00 ^c			1.50±0.50	1.38±0.21 ^c
P – value	0.168	<0.001	<0.001	<0.001	0.855	<0.001

Smaller values represent least preference for breeding within the region while higher values represent most preference for breeding within the region

The summary of farmers' preferred chicken breed choices, ranked as first, second, or third, is presented in Figure 4.2. Most farmers preferred local chicken as the first choice, while improved local chicken was considered the second preferred breed (Figure 4.2). Clearly, the



improved exotic and crossbred chicken were not regarded as important breeds for rearing in the study area, as farmers did not rank any of them as first, second or third preference.

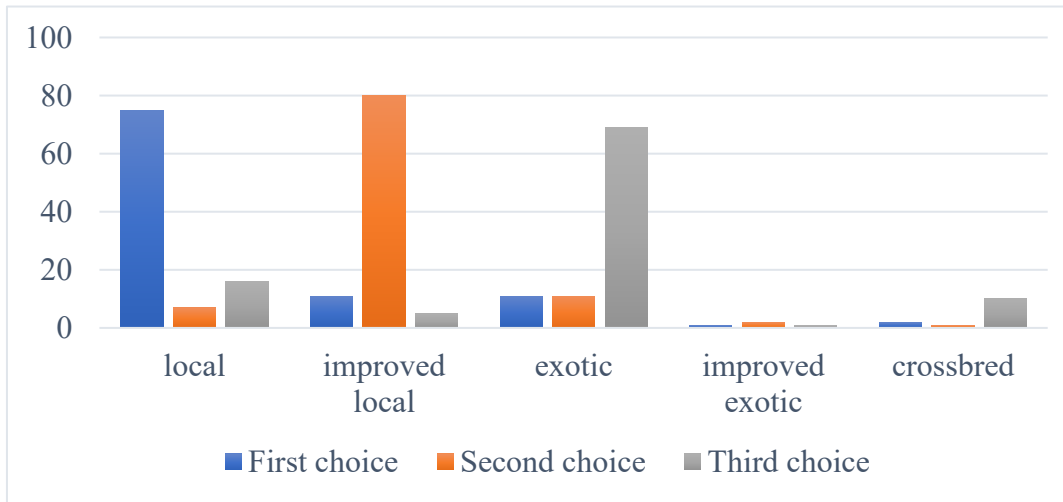


Figure 4.2: Farmers preference for different chicken breeds in Northern Ghana according to their choice

The results regarding the traits that farmers prefer in chickens and the reasons for these preferences are presented in Table 4.3. For the combined (overall) data, there were statistically significant variations ($p < 0.001$) in farmers' preferences for traits. The outstanding reasons were the production of many eggs and large body size, while the ability to fight was the least of the reasons (Table 4.3). Farmers in northern Ghana's five regions showed a clear preference for productive traits in chickens. Specifically, they favoured birds with a large body size, better-tasting meat, and high egg production, which are crucial for economic and productivity benefits. No statistically significant difference was found ($p > 0.05$) in farmers' reasons for trait preferences in all the other regions except in the Savannah region, where physical traits like good appearance, fighting ability, and longevity were significantly less favoured when selecting chickens for breeding. Farmers in the savannah region did not prioritize traits like better-tasting eggs, feed efficiency, and fighting ability (Table 4.3).

The empty spaces in the table means, farmers did not prefer these traits in chicken. The p value is within the columns and a comparison of traits farmers prefer in chicken within the region.



Table 4.3. Traits farmers prefer in chicken and their reasons

Reasons	Region					Overall
	Upper West	North East	Upper East	Savannah	Northern	
Produces many eggs	2.43±0.29	2.75±0.14	2.67±0.33	3.00±0.00 ^a	2.13±0.29	2.54±0.12 ^a
Produces better-tasting eggs	2.20±0.37	2.00±0.00	1.50±0.50		2.00±0.32	2.00±0.19 ^{bc}
Produces harder/thicker-shelled eggs	1.33±0.33	2.00±1.00	2.50±0.50	3.00±0.00 ^a	2.33±0.67	2.08±0.26 ^{bc}
Has a large body size/weight	2.40±0.27	2.14±0.90	2.80±0.20	2.93±0.67 ^a	2.29±0.19	2.53±0.90 ^a
The meat tastes better	2.44±0.18	2.00±0.62	2.08±0.26	2.12±0.81 ^b	1.82±0.23	2.09±0.09 ^b
Its chicks have high survival rate	2.11±0.26	1.80±0.63	1.67±0.42	1.50±0.50 ^c	2.33±0.42	1.94±0.14 ^{bc}
It is feed efficient	1.00±0.00	2.00±0.00	1.50±0.50		3.00±0.00	1.80±0.37 ^{bc}
Has good physical appearance	1.25±0.25	1.50±0.84	1.63±0.18	1.29±0.19 ^c	1.50±0.34	1.42±0.11 ^c
It is a good fighter	2.00±0.00	1.00±0.00				1.33±0.33 ^c
Has less illnesses	1.57±0.37	1.71±0.76	2.00±0.23	1.17±0.17 ^c	1.75±0.96	1.71±0.14 ^{bc}
Lives a long time	1.75±0.25	1.33±0.58	1.8±0.37	1.00±0.00 ^c	1.00±0.00	1.57±0.17 ^{bc}
P – value	0.88	0.11	0.22	<0.001	0.42	<0.001

^{abc} Within each column, average values accompanied by different superscript letters indicate a statistically significant difference ($p < 0.05$) in farmers' preferences for that particular chicken breeding trait.

Figure 4.3 represents the results of trait preference by farmers. Farmers selecting chickens for breeding highly value productive traits. These include characteristics like high egg production, a large body size and weight, better-tasting meat, and a good physical appearance.

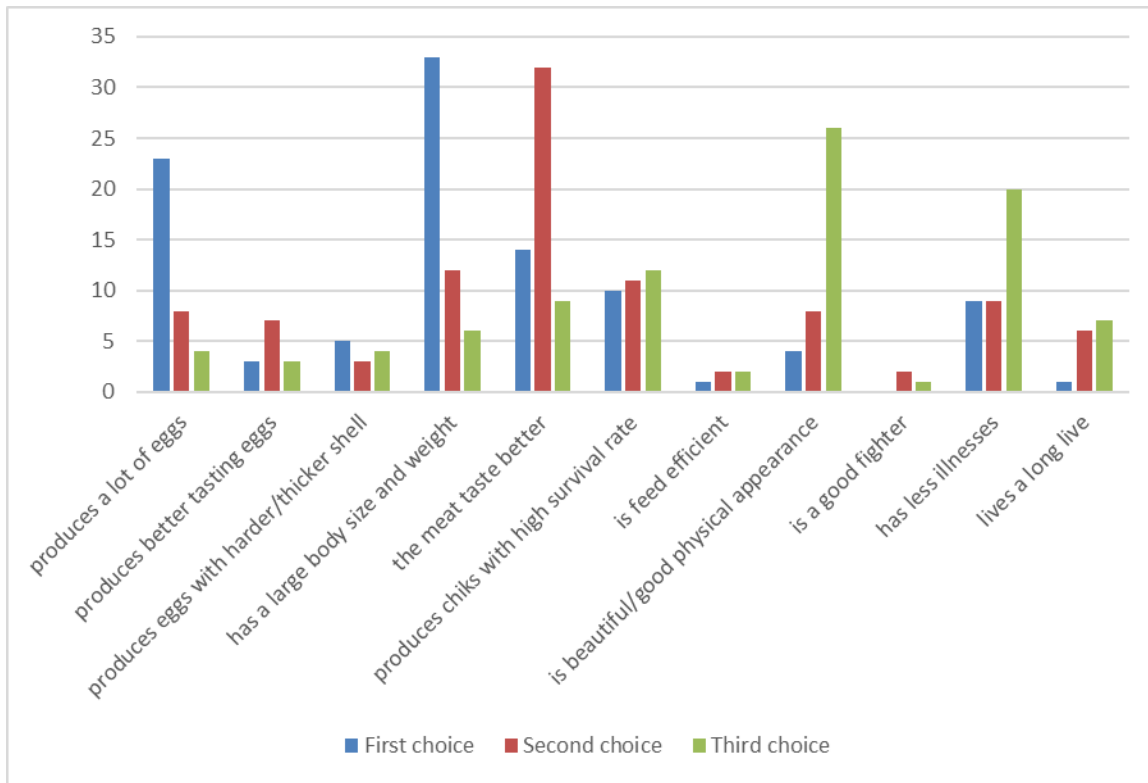


Figure 4.3 Trait preference by farmers and their choices for these traits

The results of the traits that farmers consider when selecting hens for breeding are presented in Table 4.4. Except for the Northern Region ($p < 0.001$), there were no statistically significant variations ($p > 0.05$) in farmers' preference of breeding traits among hens. This indicates that farmers from each region greatly preferred a mixture of productive, physical environmental adaptability and behavioural traits of hens when selecting chicken for breeding. Farmers in Ghana's Northern Region prioritize body size when selecting hens, a preference that is less pronounced among farmers in the Upper West and Upper East regions. Farmers in Northern region, North East, Savannah and Upper East preferred growth rate when selecting hens, while

farmers in Upper West region, Upper East, North East, and Savannah most preferred chick production rate when selecting hens.

Then Upper West did not consider traits such as cold tolerance, heat tolerance, temperament and scavenging ability when selecting hens for breeding. Feed requirement was considered only in the Upper West region; while scavenging ability was considered only in the North East region, Northern region did not also consider chick production rate as a basis for selecting hens.

The empty spaces in the table means, farmers in those regions did not prefer those traits when selecting hens. The p value is within the columns and a comparison of traits farmers prefer when selecting hens within the region.



Table 4.4. Traits farmers prefer when selecting hens for breeding

Whether hens are selected for breeding	Region					Overall
	Upper West	North East	Upper East	Savannah	Northern	
Body size/weight	4.00±0.00	2.89±0.67	3.45±0.43	3.33±0.67	5.00±0.00 ^a	3.32±0.31
Growth rate	3.25±1.00	3.40±0.43	2.89±0.35	3.75±0.25	3.88±0.29 ^a	3.40±0.20
Feed requirement	1.00±0.00					1.00±0.00
Body /feather colour	2.50±0.50	2.44±0.44		3.00±0.00	3.50±0.50 ^{ab}	3.00±0.30
Leg length	3.00±0.00	3.00±1.00		4.00±1.00		3.40±0.51
Comb shape/type			2.00±0.00	4.33±0.33		4.00±0.41
Chick production rate	5.00±0.00	3.25±0.75	4.00±0.00	2.50±0.5		3.20±0.41
Clutch length	3.00±0.00	1.75±0.48	2.00±1.00	2.60±0.51	4.43±0.29 ^a	3.00±0.33
Egg size/shape	4.00±0.00	4.00±1.00	3.00±0.00	2.14±0.34	5.00±0.00 ^a	2.92±0.38
Cold tolerance		3.67±0.33	2.5±0.50	2.75±0.75	2.00±0.00 ^b	2.90±0.35
Heat /drought tolerance		3.50±0.50	3.00±0.00	1.00±0.00	2.00±0.00 ^b	2.60±0.51
Temperament		3.00±0.00	2.00±0.00		3.29±0.42 ^{ab}	3.11±0.35
Scavenging ability		2.67±0.33				2.67±0.33
Brooding /hatching ability	4.50±0.50	2.63±0.53	3.40±0.66	1.00±0.00	2.00±0.00 ^b	2.94±0.36
Egg productivity	2.33±0.88	3.33±0.88	2.33±0.88		2.00±0.03 ^b	2.28±0.31
Rearing /mothering ability	2.00±0.58	3.80±0.44	2.44±0.56	2.00±0.00	1.56±0.34 ^b	2.56±0.28
P -value	0.50	0.59	0.71	0.15	<0.001	0.28

^{ab} Within each column, average values accompanied by different superscript letters indicate a statistically significant difference ($p < 0.05$) in farmers' preferences for that particular chicken breeding trait.

The ranking of each trait as first, second, etc. by farmers when selecting breeding hens is shown in Figure 4.4. The data showed that farmers across the five regions of northern Ghana ranked body size as the first trait of preference, followed by growth rate and feather colour. For the second preferred trait, growth rate was the highest followed by brooding ability (Figure 4.4). Feed requirements and scavenging ability were ranked the least preferred when selecting hens for breeding.

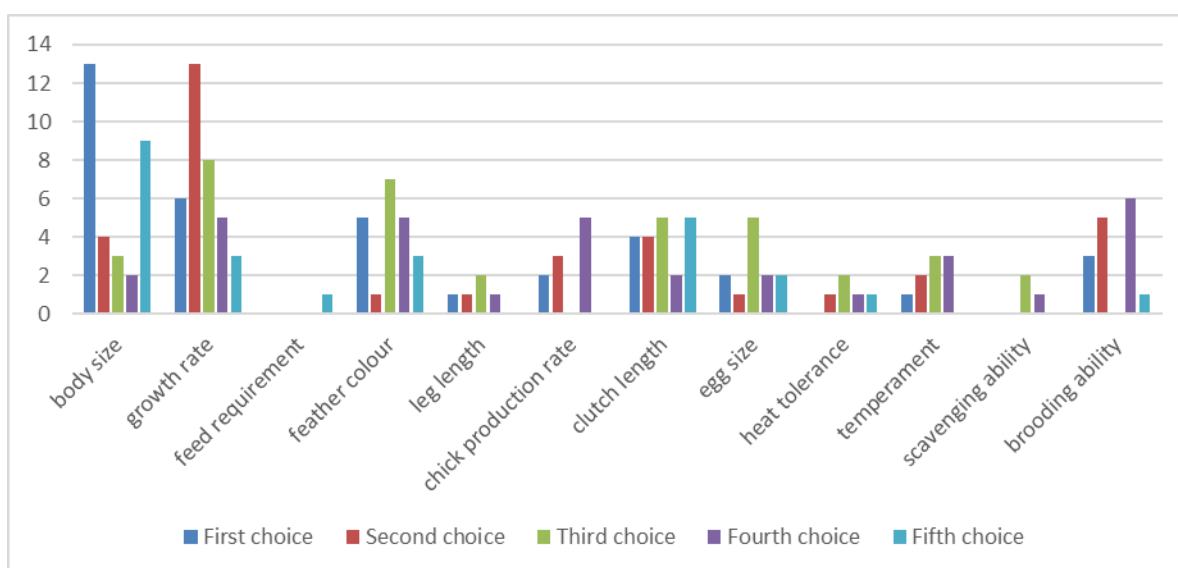


Figure 4.4: Traits farmers prefer when selecting hens for breeding according to their choice

The results for traits farmers prefer when selecting cocks for breeding are presented in Table 4.5. The observed differences were statistically significant ($p < 0.05$) in farmer's preference of breeding traits among cocks in North East, Savannah and Northern region, except for Upper West and Upper East. In the North East region of Ghana, farmers prioritize body size/weight as the most important trait when selecting hens. This preference is also observed, though to a lesser extent, in the Upper West and Upper East regions while farmers in North East and Savannah breed for homestead recognition.

Notably farmers in the Upper West region and Upper East region selected cocks whose female offspring had good mothering ability. Farmers in all the regions did not consider egg

productivity as a trait when selecting cocks. Also, Northern and Upper East did not select cocks based on their wingspan.

The empty spaces in the table means, farmers in those regions did not prefer those traits when selecting cocks. The p value is within the columns and a comparison of traits farmers prefer when selecting cocks within the region

.



Table 4.5. Traits farmers prefer when selecting cocks for breeding

Whether cocks are selected for breeding	Region					Overall
	Upper West	North East	Upper East	Savannah	Northern	
Body size/weight	4.67±0.33	4.71±0.22 ^a	4.10±0.28	3.89±0.31 ^b	4.33±0.33 ^a	4.33±0.14 ^a
Growth rate	3.75±0.48	3.50±0.27 ^b	3.50±0.27	2.88±0.35 ^c	4.14±0.34 ^{ab}	3.56±0.15 ^b
Feed requirement	4.00±0.00	2.67±0.33 ^{bc}	3.00±2.00		1.00±0.00 ^c	2.71±0.57 ^{bcde}
Body /feather colour	2.50±0.65	3.00±0.32 ^{bc}	3.86±0.74	2.67±0.28 ^c	2.00±0.46 ^c	2.83±0.22 ^{bcde}
Leg length	2.00±0.00	1.80±0.37 ^c	2.00±0.31	1.63±0.49 ^c	2.50±0.50 ^{abc}	1.87±0.21 ^{cde}
Comb shape/type	2.00±1.00	3.00±1.00 ^{bc}	2.50±0.29	5.00±0.00 ^a	4.00±0.00 ^{abc}	3.60±0.36 ^{ab}
Wing span	1.00±0.00	1.00±0.00 ^c		2.00±0.00 ^c		1.33±0.33 ^e
Homestead recognition		3.00±0.00 ^{bc}				3.00±0.00 ^{bc}
Chick production rate		2.00±0.41 ^{bc}	2.50±1.50			2.17±0.45 ^{bcde}
Clutch length		1.00±0.00 ^c	2.00±0.00		3.38±0.26 ^{abc}	3.00±0.33 ^{bc}
Egg size/shape		3.00±0.00 ^{bc}	4.00±0.00		2.00±0.00 ^{abc}	3.00±0.58 ^{bcd}
Cold tolerance	1.00±0.00	2.00±1.00 ^{bc}			2.00±0.00 ^{abc}	1.75±0.48 ^{de}
Heat /drought tolerance	2.00±0.00	1.50±0.38 ^c	2.00±0.54	1.67±0.67 ^c	2.00±0.00 ^{abc}	1.76±0.24 ^{de}
Temperament		2.00±0.00 ^{bc}	2.67±0.88		1.33±0.21 ^c	1.82±0.29 ^{cde}
Scavenging ability		2.00±0.00 ^{bc}	3.00±0.00			2.50±0.50 ^{bcde}
Brooding /hatching ability			2.00±0.00		2.00±0.00 ^{abc}	2.00±0.00 ^{bcde}
Egg productivity						
Rearing /mothering ability	5.00±0.00		1.00±0.00			3.00±2.00 ^{bcde}
P -value	0.12	<0.001	0.080	<0.001	0.002	<0.001

^{abcde} Within each column, average values accompanied by different superscript letters indicate a statistically significant difference ($p < 0.05$) in farmers' preferences for that particular chicken breeding trait.

Farmer's cock trait preferences are presented in Figure 4.5. The data show that farmers ranked body size and growth rate higher, while scavenging ability, hatching ability, mothering ability, wing span, and homestead recognition recorded the least preference ranked by farmers across the five regions of northern Ghana.

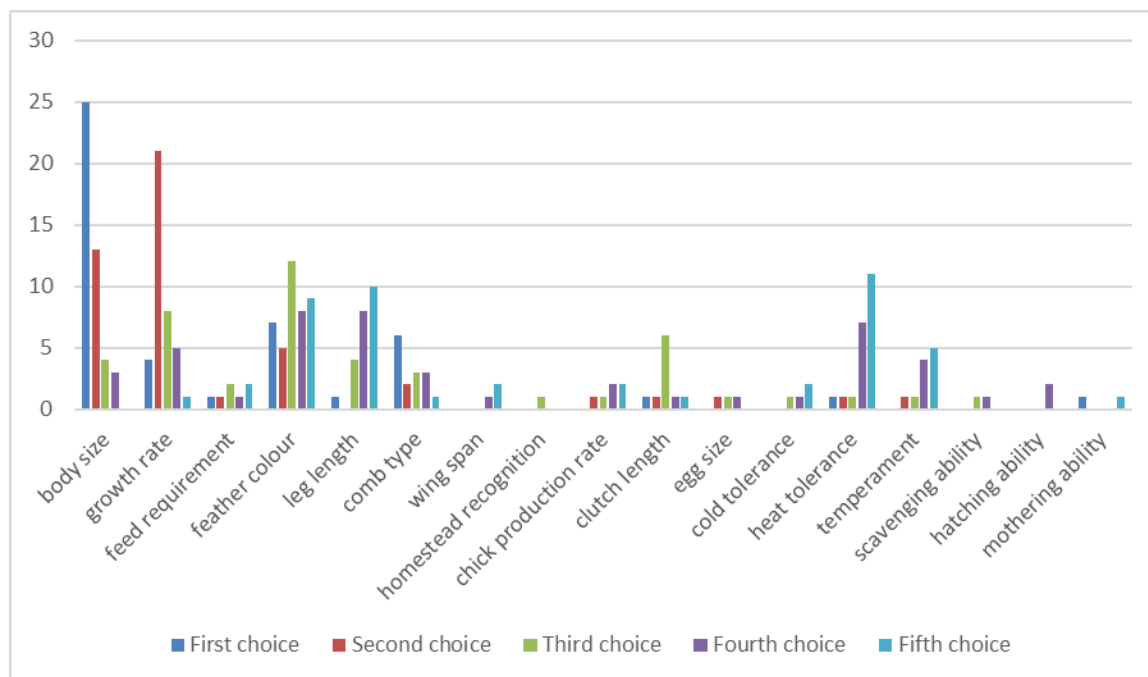


Figure 4.5 Traits farmers prioritize when selecting cocks for breeding according to their choice

The results of farmers general preference of traits among breeding hens are presented in Table 4.6. A statistically significant difference was found ($p < 0.05$) in farmer's preference of breeding traits among hens in all the regions. In Ghana's Upper West region, farmers mainly choose hens based on their egg-laying ability, the survival rate of their chicks, and how efficiently they use feed. Traits like, is a good fighter and physical appearance were Less preferred, indicating a strong focus on egg quantity for the general flock. In the North East Region, trait selection was Similar to Upper West, the production of a lot of eggs, hens with large body sizes and feed efficiency were the most traits preference by farmers in this region. While egg production, chick survival, and feed efficiency are top priorities, farmers in the Upper West region give less importance to longevity and physical appearance when selecting hens. In the Upper East

actively dislike aggressive traits (like being a good fighter) and place very low importance on lives a long live. They also preferred hens that produced a lot of eggs, better tasting eggs and those that had large body sizes. Producing a lot of egg, better tasting eggs, eggs with thicker shells and lives a long time emerged as the most preferred general trait for hens in Savannah region, reflecting a strong emphasis on economic viability. The most preferred trait in the Northern region was for hens that produce a lot of eggs. Physical appearance and aggressive behaviour (is a good fighter) were significantly the least preferred traits, while egg and meat taste were moderately considered.



Table 4.6. Farmers general preference of traits among breeding hens

Irrespective of Whether hens are selected for breeding	Region					Overall
	Upper West	North East	Upper East	Savannah	Northern	
Produces a lot of eggs	4.07±0.38 ^a	4.60±0.25 ^a	4.67±0.14 ^a	4.63±0.22 ^a	3.75±0.42 ^a	4.34±0.14 ^a
Produces better-tasting eggs	2.75±0.41 ^{ab}	2.75±0.75 ^b	3.33±0.49 ^b	3.50±0.34 ^b	2.60±0.25 ^{ab}	3.00±0.19 ^b
Produces harder/thicker-shelled eggs	2.70±0.34 ^{ab}	1.00±0.00 ^b	2.67±0.88 ^b	3.33±0.88 ^b	3.00±0.63 ^{ab}	2.71±0.26 ^{bc}
Has a large body size	2.64±0.36 ^{ab}	3.00±0.26 ^b	3.45±0.43 ^b	2.67±0.33 ^b	3.20±0.58 ^{ab}	2.93±0.17 ^b
The meat tastes better	3.00±0.58 ^{ab}	2.57±0.37 ^b	2.60±0.43 ^b	2.77±0.26 ^b	3.25±0.21 ^{ab}	2.88±0.15 ^b
Its chicks have high survival rate	3.69±0.29 ^{ab}	2.65±0.31 ^b	2.36±0.34 ^b	3.00±0.32 ^b	3.17±0.32 ^{ab}	2.97±0.15 ^b
Is feed efficient	2.71±0.64 ^{ab}	3.80±0.20 ^b	2.75±0.25 ^b	2.00±0.00 ^b	4.00±0.00 ^a	3.10±0.26 ^b
Has good physical appearance	1.00±0.00 ^b	2.20±0.28 ^b	2.50±0.42 ^b	2.08±0.45 ^b	2.29±0.18 ^{ab}	2.18±0.18 ^c
Is a good fighter	2.33±0.88 ^{ab}	2.33±0.33 ^b	2.29±0.47 ^b	1.00±0.00 ^b	2.00±0.00 ^{ab}	2.06±0.26 ^c
Has less illnesses	2.58±0.39 ^{ab}	2.69±0.47 ^b	2.43±0.48 ^b	2.78±0.47 ^b	2.00±0.37 ^b	2.46±0.19 ^{bc}
Lives a long time.	2.67±0.47 ^{ab}	2.14±0.46 ^b	1.86±0.40 ^b	3.33±0.88 ^b	2.44±0.53 ^{ab}	2.40±0.23 ^{bc}
P – value	0.031	<0.001	<0.001	<0.001	0.039	<0.001

^{abc} Within each column, average values accompanied by different superscript letters indicate a statistically significant difference ($p < 0.05$) in farmers' preferences for that particular chicken breeding trait.

Figure 4.6 shows farmers general preference of traits among breeding hens. When selecting hens, farmers prioritize egg-laying ability above all others. This is followed by the hen's capacity to produce chicks with a high survival rate. Other important traits, in descending order of preference, include better-tasting meat, large body size, good physical appearance, and resistance to illness. The least preferred trait for farmers is a hen's ability to produce eggs with thicker shells.

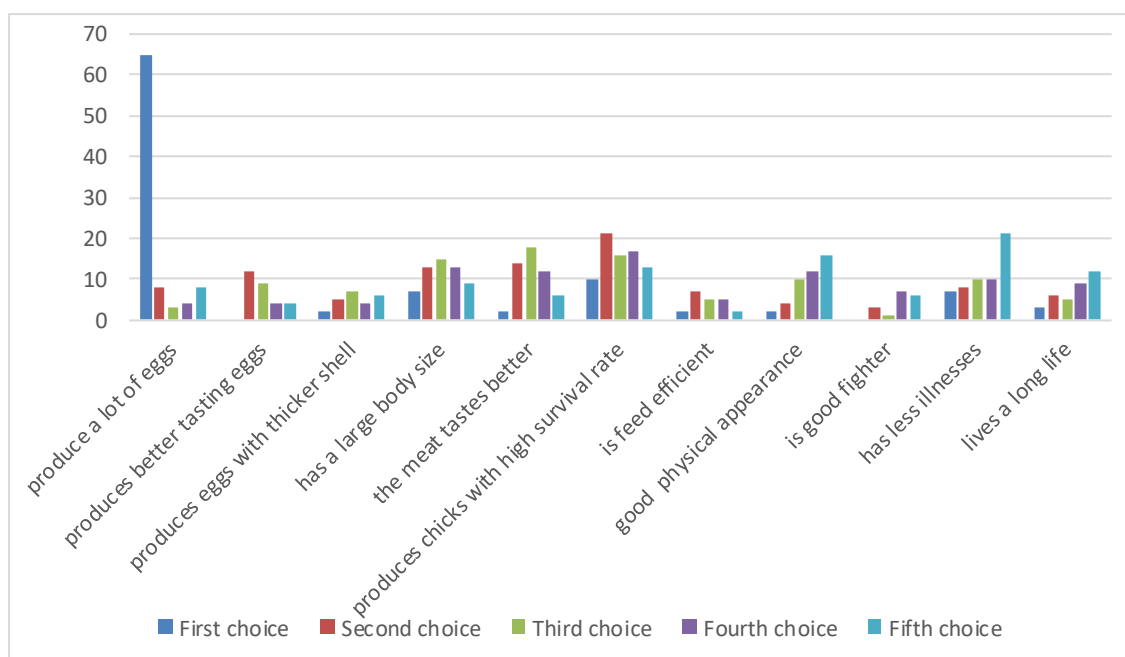


Figure 4.6 Farmers general preference of traits among breeding hens according to their choice

The results in Table 4.7 represent Farmers general preference of traits among breeding cocks. There were significant differences ($p < 0.05$) in the breeding traits farmers preferred for cocks across the Upper West, Upper East, Savannah, and Northern regions. However, this variation in preference did not extend to the North East region. Farmers in the Upper West overwhelmingly prioritize cocks believed to contribute to high egg production in the flock, large body sizes and cocks which were feed efficient. Egg shell quality, however, was a very low concern for cock selection in this region. In the North East region, the most preferred traits here were cocks that contributed to the production of a lot of eggs whose taste were better, cocks that had large body sizes and live a long time. Traits related to chick survival rate, were

less preferred. Farmers in the Upper East region also preferred cock's which had large body sizes and cocks which contributed to the production of a lot of eggs, cocks whose meat tasted better and good physical appearance were also highly valued, while feed efficiency and longevity were less important. Farmers in Savannah were most concerned with a cock's ability to contribute to the production of hard egg shells. They also preferred a large body size, fighting ability and longevity were significantly less preferred.

Traits such as is a good fighter and longevity were less preferred. In the Northern region, farmers highly value breeding cocks that are expected to sire chicks with a high survival rate. They also show strong preference for cocks that possess a large body size, exhibit a good physical appearance, and demonstrate feed efficiency.

The empty spaces in the table means, farmers in those regions did not prefer those traits when selecting cocks. The p value is within the columns and a comparison of traits farmers prefer when selecting cocks within the region.



Table 4.7. Farmers general preference of traits among breeding cocks

Irrespective of Whether cocks are selected for breeding	Region					Overall
	Upper West	North East	Upper East	Savannah	Northern	
Produces a lot of eggs	4.00±0.00 ^a	5.00±0.00	4.00±1.00 ^{ab}	-	-	4.40±0.40 ^a
Produces better-tasting eggs	2.00±1.00 ^b	4.00±0.00	-	-	-	2.67±0.88 ^{bc}
Produces harder/thicker-shelled eggs	1.00±0.00 ^b	-	-	5.00±0.00 ^a	1.00±0.00 ^c	3.00±1.15 ^{bc}
Has a large body size	3.94±0.36 ^a	3.17±0.41	4.21±0.26 ^a	3.65±0.27 ^{ab}	3.63±0.37 ^{ab}	3.76±0.15 ^a
The meat tastes better	2.38±0.27 ^b	2.82±0.27	3.36±0.33 ^{ab}	2.78±0.33 ^{abc}	3.11±0.29 ^{abc}	2.90±0.14 ^{bc}
Its chicks have high survival rate	2.25±0.63 ^b	2.00±1.00	2.00±0.00 ^{bc}	-	5.00±0.00 ^a	2.78±0.52 ^{bc}
Is feed efficient	3.67±0.33 ^{ab}	3.00±0.41	2.30±0.47 ^{bc}	2.17±0.31 ^c	4.00±0.00 ^{ab}	2.91±0.23 ^{bc}
Has good physical appearance	2.33±0.41 ^b	3.15±0.37	3.40±0.25 ^{ab}	3.61±0.27 ^{abc}	3.42±0.22 ^{ab}	3.27±0.14 ^b
Is a good fighter	3.50±0.40 ^{ab}	3.57±0.61	2.00±0.00 ^{bc}	3.00±0.00 ^{abc}	1.80±0.37 ^c	3.08±0.29 ^{bc}
Has less illnesses	2.44±0.32 ^b	2.65±0.32	2.63±0.26 ^{bc}	2.65±0.33 ^{bc}	2.53±0.31 ^{ab}	2.58±0.14 ^{bc}
Lives a long time.	2.85±0.42 ^{ab}	3.13±0.39	1.88±0.33 ^c	2.47±0.42 ^{bc}	2.27±0.36 ^c	2.51±0.18 ^c
P – value	0.010	0.478	<0.001	0.016	0.007	<0.001

^{abc} Within each column, average values accompanied by different superscript letters indicate a statistically significant difference ($p < 0.05$) in farmers' preferences for that particular chicken breeding trait.

The results of Farmers general preference of traits among breeding cocks are shown in Figure 4.7. The data reveal that farmers across the five regions of northern Ghana had almost similar preference ranks for traits such as better tasting meat, good physical appearance, less illness, and lives long life, with large body size being the highest ranked. Farmers across all five regions of northern Ghana consistently ranked traits related to egg production specifically, producing many eggs, better-tasting eggs, or eggs with thicker shells as their least preferred when selecting cocks for breeding.

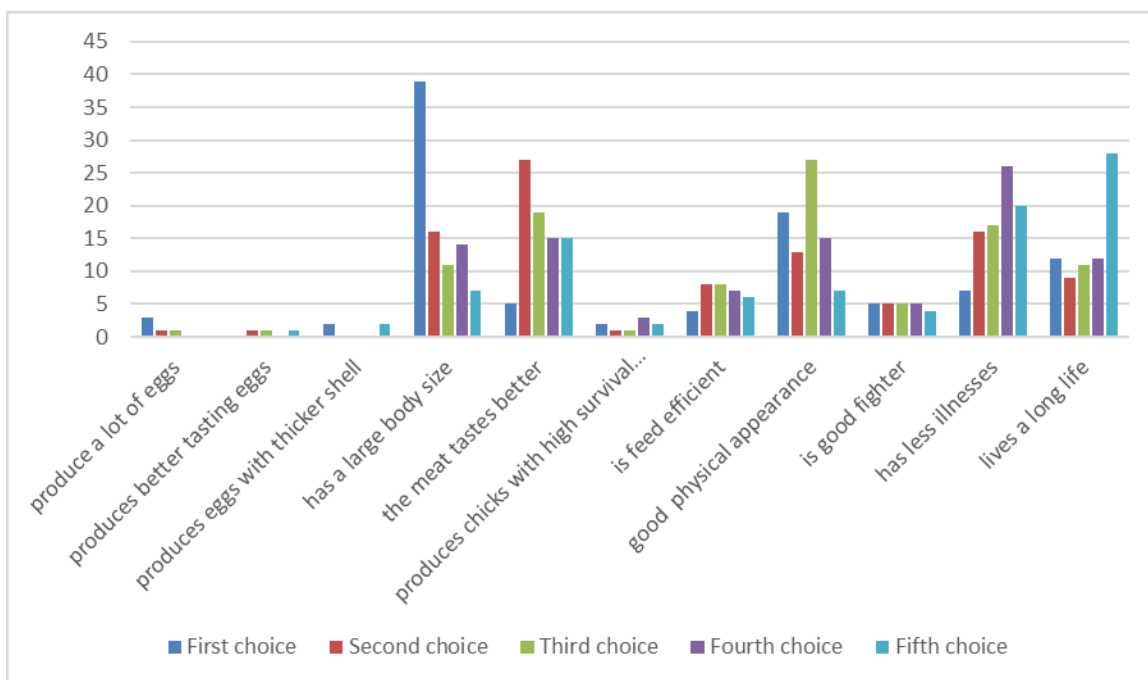


Figure 4.7 Farmers general preference of traits among breeding cocks according to their choice

The results of the test of hypothesis for sex ratio are presented in Table 4.8. For each region, a test of the male-to-female ratio against the standard ratio of 1:10 was statistically significant ($p < 0.001$). The test of the extreme case of equal proportions (1:1) of male-to-female was also highly significant in all regions (Table 4.8). The data implied an unequal distribution of males and females across the regions. Further analysis revealed that existing proportions of male-to-female were 1:3 in Upper West, within 1:2 and 1:3 in North East, within 1:3 and 1:4 in Upper East and Savannah, and 1:2 in Northern region (Table 4.8). This means that about 25% of the

birds in a famer's flock were males in all the regions except in Northern region where the proportion of males was about 33%. These variations in sex ratios across the five regions could indicate traditional, ecological conservation, and breeding practice preferences.

Table 4.8. Test of Hypothesis on Sex

Region	Sex ratios					Standard breeding ratio (1:10)
	1:1	1:2	1:3	1:4	1:5	
Upper West	<0.001	0.032	2.223	<0.001	<0.001	<0.001
North East	<0.001	0.352	0.184	0.003	<0.001	<0.001
Upper East	<0.001	<0.001	0.279	0.532	0.050	<0.001
Savannah	<0.001	<0.001	0.305	0.473	0.038	<0.001
Northern Region	<0.001	0.829	0.003	<0.001	<0.001	<0.001
Overall	<0.001	<0.001	0.103	<0.001	<0.001	<0.001

Figure 4.8 presents the data on flock sizes owned by chicken farmers. The finding indicates that the chick population was higher, followed by a hen, pullets, and cockerels, while cock numbers being the least populated.

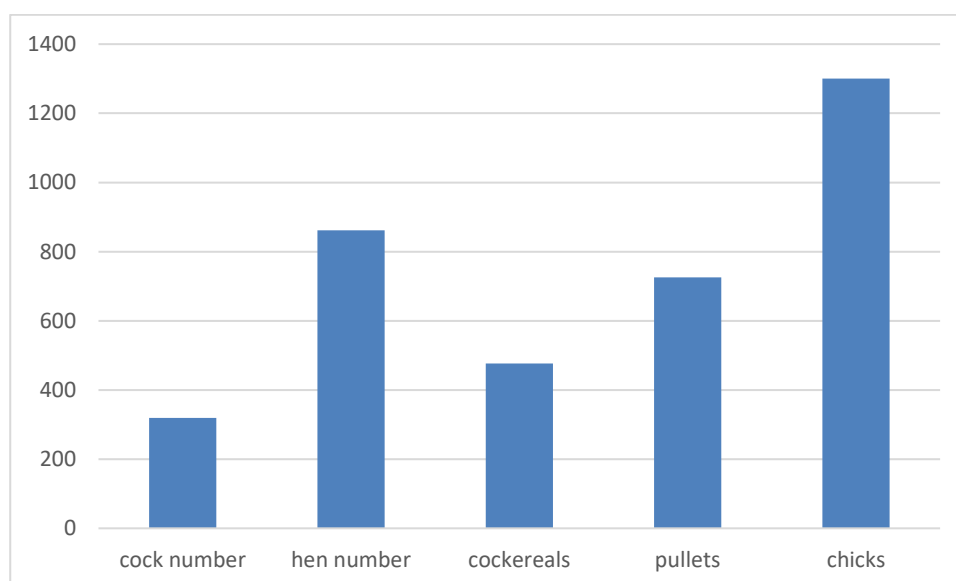


Figure 4.8. Flock data



The number of farmers who supplemented their flock's feed throughout the year are shown in Figure 4.9. The results indicated that the Savannah region recorded consistent number of farmers feeding their birds throughout the year, while the Northeast, Northern, Upper East, and Upper West recorded inconsistent feeding patterns throughout the year.

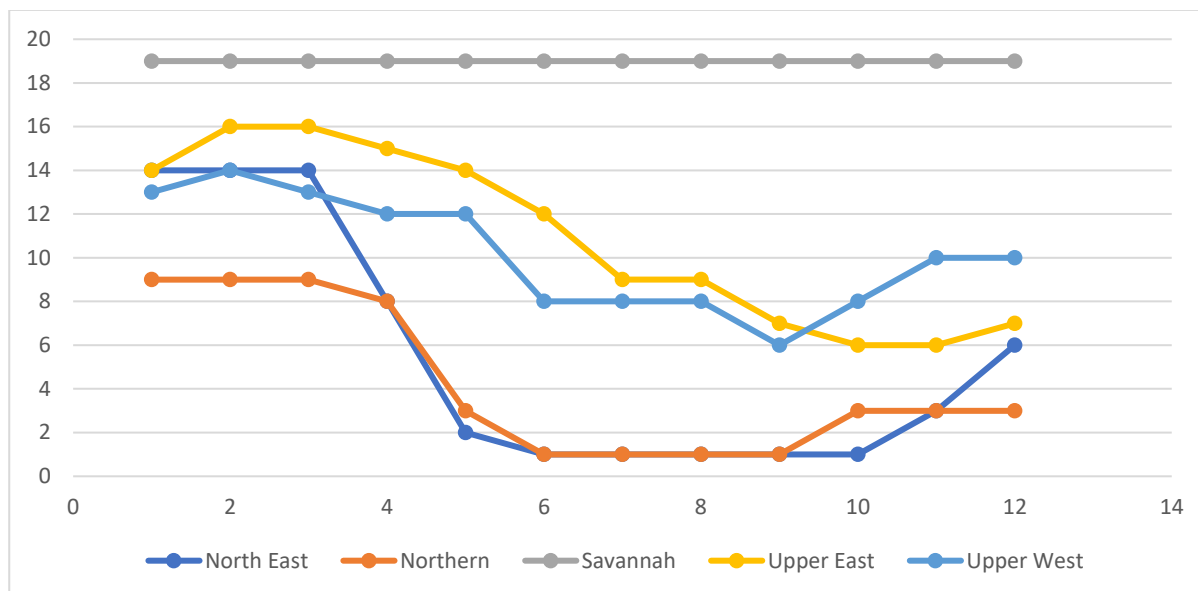


Figure 4.9 The months during which farmers provide supplemental feed to their flock.

Table 4.9 presents the association between qualitative traits of local chickens and regions in Northern Ghana. Traits like comb type (Cramer's $V = 0.488$), plumage pattern (0.381), skin colour (0.286) and plumage colour (0.286) showed the most significant differences across the regions. North East and Upper East were dominated by rose combs, barred plumage, and red feathers. Northern Region had high occurrence of plain plumage, white feathers, and single combs. Savannah region had naked necks population of (24%) and single combs populations (96%). The Upper West was distinct for yellow skin (40.5%) and yellow shanks (43%). Some common traits across the regions shown were normal feathers (72.5–97.5%) of chickens sampled, while red earlobes (52.5–63.4%) were consistently dominant across all regions. Wattles were present in >98% of chickens in all regions, the North East had 10% of chickens with frizzle feathers, Northern had 8% of chickens with silky feathers, Upper East had 10.8%

of chickens with extra toes, and Upper West had 34% of chickens with parrot beaks. The data shows genetic adaptation, environmental influences, or selective breeding practices shaping regional traits. Which are useful for conservation, breeding programs, and studying genetic diversity in local chickens. Northern Ghana's chicken populations exhibited clear regional distinctions, with some traits nearly universal and others highly localized. This study analysed the variance of weight and quantitative traits in local chickens from Northern Ghana, revealing several key factors influencing their physical characteristics.



Table 4.9.a Regional variation in morphological traits of indigenous chicken populations across Northern Ghana

Trait	Region (n=200 in each Region)						Cramer's V	P.Value
	North East	Northern	Savannah	Upper East	Upper West	Total		
Feather Morphology								
Frizzle	20(10) ^a	14(7) ^a	2(1) ^b	5(2.6) ^b	5(2.5) ^b	46(2.6)	0.133	<0.001
Normal	176(88) ^a	170(84.6) ^b	195(97.5) ^b	188(96.5) ^b	188(94) ^b	917(92.2)		
Silky	4(2) ^a	16(8) ^b	3(1.5) ^a	1(0.5) ^a	6(3) ^a	30(3)		
Other		1(0.5) ^a			1(0.5) ^a	2(0.2)		
Feather Distribution								
Feathered shanks	2(1) ^{ab}		7(3.5) ^a	3(1.3) ^{ab}	4(2) ^{ab}	16(1.6)	0.211	<0.001
Naked Neck	2(1) ^a	20(10) ^b	48(24) ^c	4(2.1) ^a	21(10.5) ^b	95(9.5)		
Normal	196(98) ^a	181(90) ^b	145(72.5) ^c	187(96.4) ^a	175(87.5)	884(88.8)		
Plumage Pattern								
Barred	105(52.5) ^a	14(7) ^b	5(2.5) ^c	127(65.5) ^d	78(39) ^c	329(33.1)	0.381	<0.001
Laced	191.5) ^a	18(9) ^b	1(1.5) ^a	3(1.5) ^a		23(2.3)		
Mottled		31(15.4) ^b	4(2) ^c			35(3.5)		
Plain	94(47) ^a	136(67.7) ^b	120(60) ^{bc}	63(32.5) ^d	111(55.5)	524(52.7)		
Other		2(1) ^a	70(35) ^b	1(0.5) ^a	11(5.5) ^c	84(8.4)		
Plumage Colour								
Black	40(20) ^a	42(20.9) ^a	20(10) ^b	28(14) ^{ab}	30(15) ^{ab}	160(16.1)	0.286	<0.001
Blue	7(3.5) ^a		1(0.5) ^b			8(0.8)		
Red	115(57.5) ^a	22(11) ^b	77(38) ^c	130(67) ^a	52(26) ^d	396(39.8)		
White	38(19) ^a	83(41) ^b	30(15) ^a	31(16) ^a	30(15) ^a	212(31.3)		
Other		54(26.9) ^b	72(36) ^c	5(2.5) ^d	88(44) ^c	219(22)		
Skin Colour								
Blue	1(0.5) ^a				1(0.5) ^a	2(0.2)	0.286	<0.001
White	194(97) ^a	183(91) ^a	171(85.5) ^b	187(96.4) ^a	118(59) ^c	853(85.7)		
Yellow	5(2.5) ^a	18(9) ^b	29(14.5) ^b	7(3.5) ^a	81(40.5) ^c	140(14.1)		

^{abc} Within each row, average values accompanied by different superscript letters indicate a statistically significant difference ($p < 0.05$) in regional variation in morphological traits across each row.

Table 4.9.b Regional variation in morphological traits of indigenous chicken populations across Northern Ghana

Trait	Region (n=200 in each Region)						Cramer's V	P.Value
	North East	Northern	Savannah	Upper East	Upper West	Total		
Shank Colour								
Black	106(53) ^a	94(46.8) ^a	59(29.5) ^b	106(54.6) ^a	56(28) ^a	421(42.3)	0.179	<0.001
Blue	3(1.5) ^{ab}	4(2) ^b		3(1.5) ^{ab}		10(1)		
Green	2(1) ^a					2(0.2)		
White	66(33) ^{ab}	81(40.3) ^b	77(38.5) ^b	51(26.3) ^a	58(29) ^a	333(33.5)		
Yellow	23(11.5) ^a	22(10.9) ^a	64(32) ^b	33(17) ^a	86(43) ^c	228(22.9)		
Other				1(0.5) ^a		1(0.1)		
Earlobe Colour								
Red	126(63) ^a	105(52.5) ^b	119(59.5) ^{ab}	123(63.4) ^a	108(54) ^{ab}	581(58.4)	0.124	<0.001
White	1(0.5) ^a					1(0.1)		
White and Red	1(0.5) ^a	1(0.5) ^a		3(1.5) ^a		5(0.5)		
Other			10(5) ^b			10(1)		
Comb Type								
Cushion	3(1.5) ^a					3(0.3)	0.488	<0.001
Pea	31(15.5) ^a	23(11.4) ^a	7(3.5) ^b	9(4.6) ^b	10(5) ^b	80(8)		
Rose	165(82.5) ^a			180(90.2) ^c	1(0.5) ^b	346(34.8)		
Single		172(85.6) ^b	192(96) ^c	5(2.6) ^d	187(93.5) ^c	556(55.9)		
Strawberry					2(1) ^a	2(0.2)		
V. Shape	1(0.5) ^a					1(0.1)		
Walnut		6(3) ^b	1(0.5) ^{ab}			7(0.7)		
Comb Size								
Large	27(13.5) ^{abc}	20(10) ^c	55(27.5) ^d	37(19.1) ^b	22(11) ^{ac}	161(16.2)	0.167	<0.001
Medium	63(31.5) ^{ab}	35(17.4) ^c	55(27.5) ^b	53(27.3) ^b	74(37) ^a	280(28.1)		
Small	110(55) ^a	146(72.6) ^b	90(45) ^c	104(53.6) ^{ac}	104(52) ^{ac}	554(55.7)		

^{abc} Within each row, average values accompanied by different superscript letters indicate a statistically significant difference ($p < 0.05$) in regional variation in morphological traits across each row.

Table 4.9.c Regional variation in morphological traits of indigenous chicken populations across Northern Ghana

Trait	Region (n=200 in each Region)						Cramer's V	P.Value
	North East	Northern	Savannah	Upper East	Upper West	Total		
Skeletal Variants								
Crested	4(2) ^a	1(0.5) ^{ab}	4(2) ^a		3(1.5) ^{ab}	12(1.2)	0.095	0.003
Dwarf					1(0.5) ^a	1(0.1)		
Extra Toes	14(7) ^a	3(1.5) ^b	11(5.5) ^{ac}	21(10.8) ^a	4(2) ^{bc}	53(5.3)		
Normal	182(91) ^a	197(98) ^b	184(92) ^{ac}	173(89.2) ^a	192(96) ^{ab}	928(93.3)		
Polydactyl			1(0.5) ^a			1(0.1)		
Presence of Wattles								
No	2(1) ^a		3(1.5) ^a	2(1) ^a		7(0.7)	0.072	0.267
Yes	198(99) ^a	200(100) ^a	197(98.5) ^a	192(99) ^a	200(100) ^a	988(99.3)		
Beak Types								
Normal	142(71) ^a	177(88.1) ^b	147(73.5) ^a	173(89.2) ^b	132(66) ^a	771(77.5)		
Parrot	45(22.5) ^a	15(7.5) ^b	49(24.5) ^a	18(9.3) ^b	68(34) ^c	195(19.6)		
Scissors	13(6.5) ^a	9(4.5) ^{ab}	4(2) ^b	3(1.5) ^{bc}		29(2.9)		

^{abc} Within each row, average values accompanied by different superscript letters indicate a statistically significant difference ($p < 0.05$) in regional variation in morphological traits across each row.

The findings regarding correlations between qualitative traits in Northern Ghana's indigenous chicken populations are presented in Tables 4.10.a and 4.10.b. Sex was strongly associated with skin colour. This is the most significant relationship observed. Feather distribution was moderately associated with plumage pattern. Plumage pattern was moderately associated with plumage colour. Skin colour was moderately associated with shank colour. While weak associations were also observed in some traits. Sex with shank colour, earlobe colour, comb size, and feather morphology were associated with both plumage colouration and skin pigmentation. Additionally, plumage colour demonstrated weak but consistent association with multiple characteristics, including skin colour, shank colour, earlobe colour, comb type, and comb size, skeletal variants, presence of wattles, and beak types. Feather distribution showed weak association with plumage colour, skin colour, and comb type. Plumage pattern with beak types, skin colour with comb type, comb size, and beak types, shank colour with comb type and comb size. Earlobe colour with comb type, comb size, and presence of wattles. Comb type with skeletal variants, presence of wattles, and beak types. skeletal variants with presence of wattles.



Table 4.10.a Occurrences of association among qualitative characteristics indigenous chicken populations in Northern Ghana

Trait	Cramer's. V	P. Value	Remarks
Sex- Feather Morphology	0.27	0.960	No association
Sex- Feather distribution	0.57	0.171	No association
Sex- Plumage pattern	0.082	0.102	No association
Sex- Plumage colour	0.061	0.502	No association
Sex- Skin colour	0.86	0.005	strong association
Sex- Shank colour	0.170	<0.001	Weak association
Sex- Earlobe colour	0.179	<0.001	Weak association
Sex- Comb type	0.080	0.393	No association
Sex- Comb size	0.452	<0.001	Weak association
Sex- Skeletal variants	0.056	0.609	No association
Sex- Presence of wattles	0.052	0.258	No association
Sex- Beak types	0.63	0.091	No association
Feather morphology- feather distribution	0.60	0.297	No association
Feather morphology- plumage pattern	0.89	0.24	No association
Feather morphology-plumage colour	0.096	0.007	Weak association
Feather morphology-skin colour	0.105	<0.001	Weak association
Feather morphology-shank colour	0.078	0.264	No association
Feather morphology-earlobe colour	0.051	0.796	No association
Feather morphology-comb type	0.075	0.547	No association
Feather morphology-comb size	0.057	0.366	No association
Feather morphology-skeletal variants	0.069	0.286	No association
Feather morphology-presences of wattles	0.041	0.641	No association
Feather morphology-beak type	0.044	0.692	No association
Feather distribution-plumage pattern	0.437	<0.001	Moderate association
Feather distribution-plumage colour	0.284	<0.001	Weak association
Feather distribution-skin colour	0.132	<0.001	Weak association
Feather distribution-shank colour	0.047	0.927	No association
Feather distribution-earlobe colour	0.060	0.517	No association

Table 4.10.b Occurrences of association among qualitative characteristics indigenous chicken populations in Northern Ghana

Trait	Cramer's V	P. Value	Remarks
Feather distribution-comb type	0.177	<0.001	Weak association
Feather distribution-comb size	0.058	0.153	No association
Feather distribution-skeletal variants	0.085	0.073	No association
Feather distribution-presences of wattles	0.055	0.220	No association
Feather distribution-beak types	0.031	0.763	No association
Plumage pattern-plumage colour	0.447	<0.001	Moderate association
Plumage pattern-presences of wattles	0.063	0.411	No association
Plumage pattern-beak types	0.093	0.027	Weak association
Plumage colour-skin colour	0.099	0.012	Weak association
Plumage colour-shank colour	0.181	<0.001	Weak association
Plumage colour-earlobe colour	0.099	<0.001	Weak association
Plumage colour-comb type	0.302	<0.001	Weak association
Plumage colour-comb size	0.103	0.007	Weak association
Plumage colour-skeletal variants	0.109	<0.001	Weak association
Plumage colour-presences of wattles	0.136	<0.001	Weak association
Plumage colour-beak types	0.128	<0.001	Weak association
Skin colour-shank colour	0.481	<0.001	Moderate association
Skin colour-earlobe colour	0.054	0.667	No association
Skin colour-comb type	0.197	<0.001	Weak association
Skin colour-comb size	0.070	0.043	Weak association
Skin colour-skeletal variants	0.057	0.589	No association
Skin colour-presences of wattles	0.034	0.556	No association
Skin colour-beak types	0.016	0.016	Weak association
Shank colour-earlobe colour	0.062	0.764	No association
Shank colour-comb type	0.118	<0.001	Weak association
Shank colour-comb size	0.143	<0.001	Weak association
Shank colour-skeletal variants	0.047	0.986	No association
Shank colour-presences of wattles	0.016	0.999	No association
Shank colour-beak type	0.079	0.250	No association
Earlobe colour-comb type	0.296	<0.001	Weak association
Earlobe colour-comb size	0.209	<0.001	Weak association
Earlobe colour-skeletal variants	0.073	0.181	No association
Earlobe colour-presences of wattle	0.113	0.013	Weak association
Earlobe colour-beak type	0.057	0.593	No association
Comb type-comb size	0.069	0.650	No association
Comb type-skeletal variants	0.210	<0.001	Weak association
Comb type-presences of wattles	0.378	<0.001	Weak association
Comb type-beak types	0.108	0.025	Weak association
Comb size-skeletal variants	0.051	0.731	No association
Comb size-presences of wattles	0.041	0.430	No association
Comb size-beak types	0.056	0.182	No association
Skeletal variants-presences of wattle	0.212	<0.001	Weak association
Skeletal variants-beak type	0.036	0.960	No association
Presence of wattles-beak types	0.062	0.150	No association





Table 4.11 displays the outcome of a General Linear Model (GLM) analysis, illustrating how qualitative characteristics affect the quantitative traits of indigenous chickens found in Northern Ghana. Region stands out as the most crucial factor, influencing almost every measured trait in chickens. This includes live body weight, wingspan, head and body length, chest and thigh circumference, shank length, and wattle length, clearly demonstrating the strong impact of geographical location on chicken morphology. This shows a strong influence of geographical location on chicken morphology. Feather characteristics significantly influenced the chicken's body length and chest circumference. The size of the comb had an effect on multiple traits, including live body weight, wingspan, chest circumference, wattle length, and thigh circumference. The analysis revealed significant sexual dimorphism, with sex having a pronounced effect on shank length and a measurable influence on wingspan. Skeletal variants were strongly linked to neck length. Characteristics such as plumage patterning, skin pigmentation, shank colouration, earlobe hue, comb morphology, wattle presence, and beak structure showed no significant influence on the majority of measured parameters. Overall, the findings suggest that environmental factors (region) and specific morphological characteristics (feather morphology, comb size, sex, skeletal variants) play crucial roles in shaping the physical traits of local chickens in Northern Ghana.

Table 4.11. An analysis of variance was conducted to evaluate weight and other quantitative traits among indigenous chicken populations in Northern Ghana

Source of Variation	Mean Squares and levels of significance										
	DF	BW	WIS	BEL	HL	NL	BL	CC	SL	WAL	THC
Region	4	1.530*	55.894*	1.727 ^{ns}	37.217*	40.5533**	135.617*	143.581*	403.794*	9.965*	14.973*
Feather Morphology	3	0.352 ^{ns}	3.503 ^{ns}	0.686 ^{ns}	1.211 ^{ns}	12.722 ^{ns}	22.664*	39.966*	154.135 ^{ns}	0.319 ^{ns}	1.426 ^{ns}
Feather Distribution	2	0.043 ^{ns}	3.535 ^{ns}	0.470 ^{ns}	0.018 ^{ns}	4.151 ^{ns}	4.784 ^{ns}	4.106 ^{ns}	8.060 ^{ns}	0.173 ^{ns}	0.005 ^{ns}
Plumage pattern	2	0.200 ^{ns}	4.391 ^{ns}	0.665 ^{ns}	0.462 ^{ns}	11.527 ^{ns}	11.399 ^{ns}	3.111 ^{ns}	149.051 ^{ns}	0.062 ^{ns}	0.770 ^{ns}
Plumage colour	4	0.240 ^{ns}	7.955*	0.686 ^{ns}	1.009 ^{ns}	19.384 ^{ns}	21.492*	8.319	162.39 ^{ns}	3.26 ^{ns}	0.700 ^{ns}
Skin colour	2	0.010 ^{ns}	3.772 ^{ns}	0.007 ^{ns}	0.585 ^{ns}	28.813 ^{ns}	1.743 ^{ns}	0.570 ^{ns}	24.004 ^{ns}	1.792 ^{ns}	1.730 ^{ns}
Shank colour	5	0.102 ^{ns}	10.389 ^{ns}	0.442 ^{ns}	1.544 ^{ns}	17.251 ^{ns}	6.016 ^{ns}	3.499 ^{ns}	58.485 ^{ns}	1.934 ^{ns}	1.408 ^{ns}
Earlobe colour	4	0.173 ^{ns}	1.315 ^{ns}	1.525 ^{ns}	0.192 ^{ns}	2.190 ^{ns}	6.681 ^{ns}	3.245 ^{ns}	150.548 ^{ns}	0.491 ^{ns}	0.831 ^{ns}
Comb type	6	0.092 ^{ns}	4.885 ^{ns}	0.225 ^{ns}	0.443 ^{ns}	20.391 ^{ns}	7.633 ^{ns}	9.035 ^{ns}	55.097 ^{ns}	0.847 ^{ns}	0.995 ^{ns}
Comb size	2	3.513*	28.264*	0.956 ^{ns}	0.948 ^{ns}	20.758 ^{ns}	109.007 ^{ns}	214.476*	1270.513 ^{ns}	112.053*	34.516*
Skeletal variants	3	0.029 ^{ns}	5.759 ^{ns}	0.212 ^{ns}	0.555 ^{ns}	341.304*	3.484 ^{ns}	3.742 ^{ns}	16.804 ^{ns}	0.325 ^{ns}	1.566 ^{ns}
Presence of wattles	1	0.423 ^{ns}	0.388 ^{ns}	0.089 ^{ns}	0.433 ^{ns}	34.721 ^{ns}	4.182 ^{ns}	19.954 ^{ns}	8.553 ^{ns}	1.155 ^{ns}	2.355 ^{ns}
Beak types	2	0.378 ^{ns}	4.545 ^{ns}	0.244 ^{ns}	1.264 ^{ns}	9.088 ^{ns}	3.647 ^{ns}	12.348 ^{ns}	65.189 ^{ns}	3.171 ^{ns}	2.703 ^{ns}
Sex	1	0.012 ^{ns}	125.469	2.052 ^{ns}	0.301 ^{ns}	71.986 ^{ns}	11.462 ^{ns}	9.563 ^{ns}	1653.457**	28.765 ^{ns}	3.572 ^{ns}

*

Significance levels: ** $p < 0.01$, * $p < 0.05$, ^{ns}=not significant. BW=body weight, WIS=wingspan, BEL=beak length, NL=neck length, BL=body length, CC=chest circumference, SKL=shank length, WAL=wattle length and THC=thigh circumference across the rows of the table

Table 4.12 displays the path analysis and phenotypic correlations between body weight and linear body measurements. Path analysis revealed chest circumference (CC) has the most influential direct predictor of live body weight (BW), demonstrating the highest path coefficient among all morphometric traits. Body length (BL), wingspan (WIS), wattle length (WAL), and thigh circumference (THC) also show great positive direct effects on body weight, but their overall influence is further amplified through strong indirect pathways through other traits. Contrasting with CC's strong influence, beak length (BEL), head length (HL), neck length (NL), and shank length (SL) demonstrated negligible predictive value for body weight. The phenotypic correlations generally endorse these findings, with chest circumference and body length showing the strongest positive associations with body weight.



Table 4.12. Path coefficients and phenotypic correlations between body weight (BW) and morphometric traits

Trait	Path Coefficient		Phenotypic correlation matrix for body weight and morphometric traits								
	Direct	Indirect	BW	WIS	BEL	HL	NL	BL	CC	SL	WAL
WIS	0.140	0.2092	0.354*	1							
BEL	-0.002	0.011	0.019 ^{ns}	0.011*	1						
HL	0.001	0.071	0.072*	0.016**	0.000 ^{ns}	1					
NL	0.012	0.1545	0.139*	0.0329**	-4.034E-05 ^{ns}	-1.184E-06 ^{ns}	1				
BL	0.143	0.254	0.405*	0.052**	-8.099E-05 ^{ns}	5.867E-05*	0.002**	1			
CC	0.252	0.1884	0.450*	0.045**	4.003E-06 ^{ns}	7.629E-05**	0.002**	0.071**	1		
SL	-0.015	0.006	-0.008 ^{ns}	0.009*	-0.000 ^{ns}	0.000 ^{ns}	0.000 ^{ns}	-0.003 ^{ns}	-0.006 ^{ns}	1	
WAL	0.099	0.226	0.329*	0.049**	-3.153E-05 ^{ns}	7.86E-05*	0.002**	0.059**	0.079**	-0.000 ^{ns}	1
THC	0.100	0.238	0.341*	0.054**	-1.547E-05 ^{ns}	0.000**	0.002**	0.048**	0.098**	-0.000 ^{ns}	0.036**

Significance levels: ** $p < 0.01$, * $p < 0.05$, ns=not significant. BW=body weight, WIS=wing span, BEL=beak length, NL=neck length, BL=body length, CC=chest circumference, SKL=shank length, WAL=wattle length, THC=thigh circumference.

Table 4.13. Least square means ($\pm$ SE) of body weight and linear measurements in indigenous chickens affected by region, plumage colour, and comb size. Savannah region dominates with highest body weight (1.28kg), largest body length (20.36cm), broadest chest circumference (26.48cm). Northern region shows unique adaptations with the lightest weight (0.94kg) and longest shanks (10.54cm), the Upper West had largest wingspan (17.63cm), Plumage colour shows some, but less consistent, influence while variations exist (chickens with blue plumage generally tend to be smaller across many traits, and "other" plumage types are often associated with larger measurements), the impact of plumage colour is not as uniform across all traits as that of comb size. Comb size is a major determinant of chicken size. The study identified comb size as a reliable indicator of somatic growth, where chickens possessing larger combs uniformly exhibited enhanced body weight and proportional increases in all measured linear traits. This strong correlation suggests that comb size could be a practical indicator for selecting larger, more robust birds.

Table 4.13. Least Square Means ($\pm$ SE) of Body Weight and Linear Measurements in Indigenous Chickens as Affected by Region

Trait	Overall	Location				
		Upper East	Upper West	Northern	Savannah	North East
BW	1.09 $\pm$ 0.01	1.08 $\pm$ 0.04	1.18 $\pm$ 0.04	0.94 $\pm$ 0.01	1.28 $\pm$ 0.03	0.99 $\pm$ 0.02
WIS	16.73 $\pm$ 0.07	16.69 $\pm$ 0.13	17.63 $\pm$ 0.15	16.40 $\pm$ 0.13	17.28 $\pm$ 0.16	15.64 $\pm$ 0.13
BEL	2.44 $\pm$ 0.04	2.38 $\pm$ 0.02	2.38 $\pm$ 0.00	2.45 $\pm$ 0.02	2.40 $\pm$ 0.04	2.56 $\pm$ 0.13
HL	5.35 $\pm$ 0.03	5.53 $\pm$ 0.05	5.07 $\pm$ 0.06	6.15 $\pm$ 0.06	5.22 $\pm$ 0.67	4.78 $\pm$ 0.06
NL	13.71 $\pm$ 0.13	13.31 $\pm$ 0.10	14.52 $\pm$ 0.17	13.175 $\pm$ 0.10	14.43 $\pm$ 0.13	13.12 $\pm$ 0.56
BL	18.42 $\pm$ 0.08	18.25 $\pm$ 0.14	18.47 $\pm$ 0.13	17.07 $\pm$ 0.14	20.36 $\pm$ 0.18	17.94 $\pm$ 0.16
CC	24.32 $\pm$ 0.10	23.31 $\pm$ 0.18	25.18 $\pm$ 0.25	23.22 $\pm$ 0.17	26.48 $\pm$ 0.19	23.38 $\pm$ 0.18
SL	8.02 $\pm$ 0.73	7.03 $\pm$ 0.08	7.64 $\pm$ 0.13	10.54 $\pm$ 3.63	8.06 $\pm$ 0.34	6.81 $\pm$ 0.08
WAL	1.53 $\pm$ 0.05	1.13 $\pm$ 0.09	1.44 $\pm$ 0.08	1.39 $\pm$ 0.05	2.41 $\pm$ 0.10	1.27 $\pm$ 0.17
TC	7.49 $\pm$ 0.04	6.72 $\pm$ 0.08	8.054 $\pm$ 0.76	7.75 $\pm$ 0.77	8.09 $\pm$ 0.96	6.81 $\pm$ 0.76

Body weight (BW), wingspan (WIS), beak length (BEL), head length (HL), neck length (NL), body length (BL), chest circumference (CC), shank length (SKL), wattle length (WAL), and thigh circumference (THC).

Table 4.14. Least Square Means ($\pm$ SE) of Body Weight and Linear Measurements in Indigenous Chickens as affected by Plumage colour, and comb Size

The table presents the least square means ($\pm$ SE) of body weight and linear measurements in indigenous chickens, as affected by plumage colour and comb size. The data shows that both factors affect these traits, but comb size has a more pronounced and consistent effect.

Plumage Colour, chickens' body weight (BW) and linear measurements show minor variations based on plumage colour, but these differences are generally small. For instance, body weight ranges from 1.08 kg in white chickens to 1.16 kg in red chickens, indicating that plumage colour is not a primary factor for these traits. Comb size shows a strong, positive correlation with body size. Chickens with larger combs consistently have greater body weight and larger linear measurements than those with medium or small combs.

Chickens with large combs are significantly heavier (1.39 kg) than those with medium (1.12 kg) or small combs (1.00 kg). This trend is consistent across all linear measurements, including wingspan (WIS), body length (BL), and chest circumference (CC). Chickens with large combs have a body length of 20.42 cm, much greater than the 17.81 cm seen in chickens with small combs.



Table 4.14. Least Square Means ($\pm$ SE) of Body Weight and Linear Measurements in Indigenous Chickens as affected by Plumage colour, and comb Size

Trait	Overall	Plumage Colour					Comb Type		
		White	Black	Blue	Red	Other	Small	Medium	Large
BW	1.09 $\pm$ 0.013	1.08 $\pm$ 0.017	1.10 $\pm$ 0.026	1.11 $\pm$ 0.128	1.10 $\pm$ 0.02	1.16 $\pm$ 0.037	1.00 $\pm$ 0.019	1.12 $\pm$ 0.016	1.39 $\pm$ 0.030
WIS	16.73 $\pm$ 0.066	16.48 $\pm$ 0.13	16.72 $\pm$ 0.143	15.0 $\pm$ 0.59	16.83 $\pm$ 0.099	16.86 $\pm$ 0.166	16.18 $\pm$ 0.75	16.86 $\pm$ 0.118	18.39 $\pm$ 0.18
BEL	2.44 $\pm$ 0.037	2.43 $\pm$ 0.028	2.47 $\pm$ 0.13	2.07 $\pm$ 0.142	2.47 $\pm$ 0.072	2.37 $\pm$ 0.037	2.36 $\pm$ 0.039	2.51 $\pm$ 0.10	2.58 $\pm$ 0.030
HL	5.35 $\pm$ 0.031	5.57 $\pm$ 0.072	5.39 $\pm$ 0.079	4.80 $\pm$ 0.206	5.16 $\pm$ 0.35	5.47 $\pm$ 0.083	5.377 $\pm$ 0.4	5.24 $\pm$ 0.060	5.45 $\pm$ 0.62
NL	13.71 $\pm$ 0.125	13.49 $\pm$ 0.128	14.23 $\pm$ 0.70	12.62 $\pm$ 0.42	13.46 $\pm$ 0.92	14.06 $\pm$ 0.135	13.75 $\pm$ 0.078	13.98 $\pm$ 0.40	14.86 $\pm$ 0.155
BL	18.42 $\pm$ 0.076	17.92 $\pm$ 0.15	18.67 $\pm$ 0.202	18.62 $\pm$ 0.82	18.55 $\pm$ 0.12	18.48 $\pm$ 0.144	17.81 $\pm$ 0.88	18.49 $\pm$ 0.138	20.42 $\pm$ 0.194
CC	24.32 $\pm$ 0.097	23.83 $\pm$ 0.212	24.40 $\pm$ 0.26	23.62 $\pm$ 0.679	24.14 $\pm$ 0.152	25.09 $\pm$ 0.19	23.62 $\pm$ 0.10	24.56 $\pm$ 0.189	26.29 $\pm$ 0.29
SL	8.02 $\pm$ 0.73	10.55 $\pm$ 3.43	7.56 $\pm$ 0.42	6.62 $\pm$ 0.794	7.22 $\pm$ 0.075	7.42 $\pm$ 0.099	6.94 $\pm$ 0.053	10.15 $\pm$ 2.61	8.06 $\pm$ 0.928
WAL	1.53 $\pm$ 0.049	1.44 $\pm$ 0.717	1.64 $\pm$ 0.22	1.33 $\pm$ 0.54	1.47 $\pm$ 0.068	1.64 $\pm$ 0.066	0.960 $\pm$ 0.029	1.53 $\pm$ 0.056	3.49 $\pm$ 0.209
TC	7.49 $\pm$ 0.041	7.45 $\pm$ 0.076	7.51 $\pm$ 0.119	6.81 $\pm$ 0.312	7.30 $\pm$ 0.070	7.88 $\pm$ 0.067	7.19 $\pm$ 0.047	7.51 $\pm$ 0.075	8.48 $\pm$ 0.114

Body weight (BW), wingspan (WIS), beak length (BEL), head length (HL), neck length (NL), body length (BL), chest circumference (CC), shank length (SKL), wattle length (WAL), and thigh circumference (THC).

Data presented in Table 4.15.a demonstrated that most surveyed farmers maintained dedicated housing facilities for their poultry flocks. Survey data indicated that most farmers supplemented their chickens' natural foraging with additional feed provisions. The majority of the farmers across the five northern regions of Ghana provide feed for all types of chicken, indicating a comprehensive approach to nutrition. Again, the majority of the farmers feed their chickens in the morning and evening (Table 4.15a). The results further indicated that, the majority of the farmers do not process their feed before feeding (Table 4.15b). Throwing feed on the ground was the commonest method of feeding practised by the farmers across the five regions of northern Ghana. The study revealed that most farmers did not vaccinate their chicken flocks against any disease outbreak. More than half of the farmers did not record disease outbreaks within their flock. Nearly all, about 98% of farmers across the five regions of northern Ghana provided drinking water for their chicken flocks (Table 4.15b).



Table 4.15.a: Husbandry practices of some farmers in Northern Ghana

Practice	Number of responds		Tested Hypothesis					
	Frequency	Percentage	Equal proportions	Chi-square	P-Value	Unequal Proportions	Chi-square	P-Value
Housing Provision/ Provision of Housing								
No Housing	3	2	1	94.64	<0.001	1	0.009	0.996
Chicken House	117	78	1			40		
Kept in Kitchen	30	20	1			8		
Total	150	100						
Supplying Supplementary	87	77.68	1			78		
feed								
No	38	25.33	1	25	<0.001	1	0.00	1
Yes	112	74.667	1			3		
Total	150	100						
Afternoon Only	4	3	1			3		
Evening Only	2	2	1			1		
Morning /Afternoon	2	2	1			1		
Morning/Evening	46	41	1			41		
Afternoon/ Evening	2	2	1			1		
Morning, Afternoon/ Evening	28	25	1			25		
Always available/ad libitum	4	4	1			4		
Total	150	100						

Table 4.15.b: Husbandry practices of some farmers

Practice	Number of responds		Tested Hypothesis					
	Frequency	Percentage	Equal proportions	Chi-square	P-Value	Unequal Proportions	Chi-square	P-Value
Any Processing before feeding before feeding								
No processing	94	63	1	30.320	<0.001	63	0.008	0.996
Chopped	20	13	1			13		
Ground	36	24	1			24		
Total	150	100						
Method of feeding								
Put into containers	26	17	1	155.333	<0.001	17	0.006	0.939
Thrown on the ground for collective feeding	124	83	1			83		
Total	150	100						
Have you carried out any routine vaccination of your chicken in the past twelve (12) Months								
No	134	89	1	59.889	<0.001	5	2.200	0.138
Yes	16	11	1			1		
Total	150	100						
Did you experience any chicken disease in the past twelve (12) Months								
No	83	55	1	1.000	0.317			
Yes	67	45	1					
Did you provide your chickens with water								
No	3	2	1	92.160	<0.001	2	0.000	1.000
Yes	147	98	1			98		
Total	150	100						

Figure 4.10 shows the results of reasons farmers do not provide supplementary feed. From Figure 4.10, the results show that the high cost of feed was a major reason farmer do not provide supplementary feed for their flock, followed by unavailability of feed, lack of awareness about supplementary feed, and lack of money to buy food, with time shortage being the least challenge.

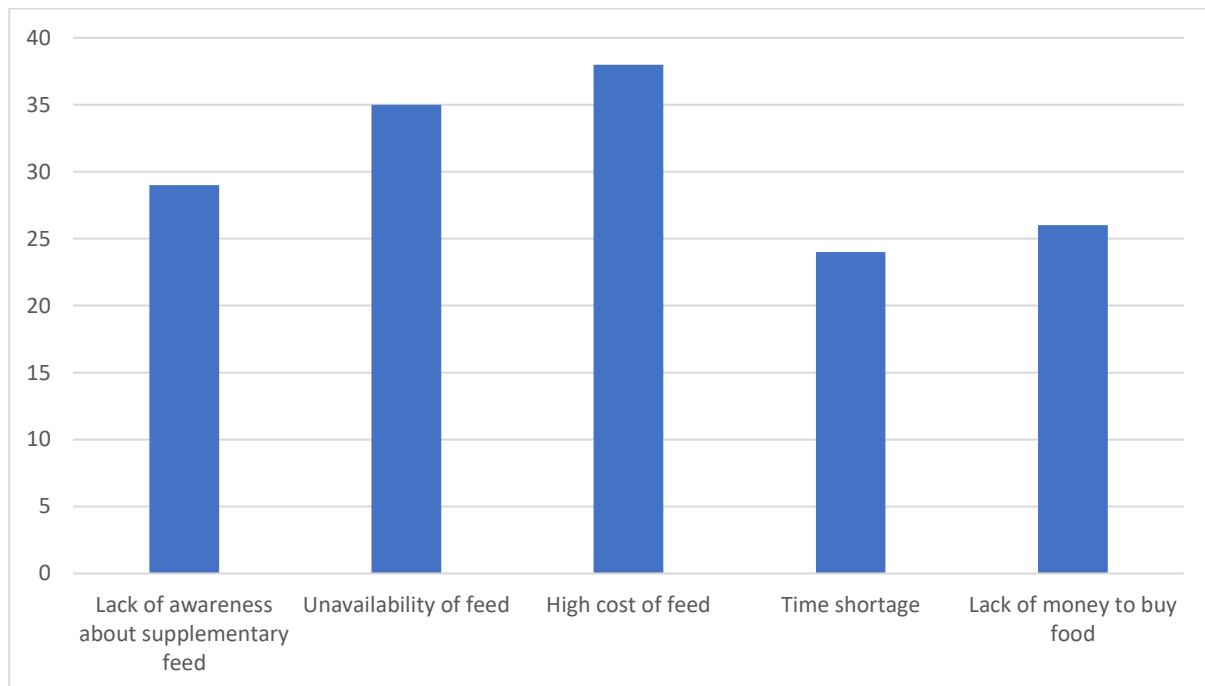


Figure 4.10 Illustration of the various reasons why farmers in the regions of Northern Ghana do not offer supplementary feed to their chickens

Figure 4.11. Seasonal patterns of supplementary feeding provision among chicken farmers

Data revealed that months such as January, February, March, and April are the highest supplementary feeding months. Farmers significantly reduced supplementary feeding from May to September, compared to October-April, reflecting seasonal resource availability patterns. Lastly, months such as October, November, and December are the months with moderate supplementary feeding. Clearly, provision of supplementary feeding peaks in the months of February-March and then declines in a systematic manner through the following months, reaching a minimum in September and begins to rise again.

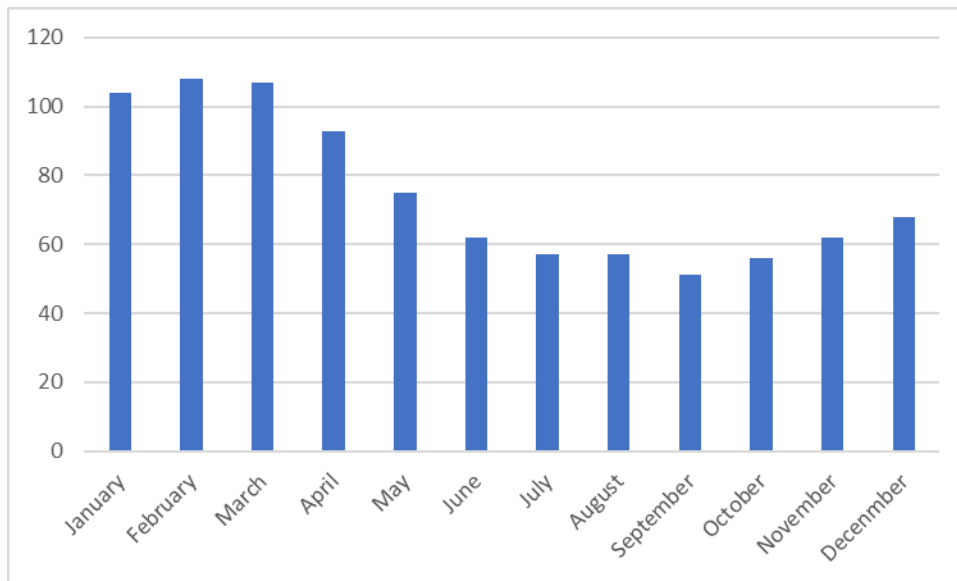


Figure 4.11: Months in which farmers provide supplementary feed to their birds



CHAPTER FIVE

5.0 DISCUSSION

Production Objectives of farmers in the five regions of northern Ghana

The observed trends in why farmers raise indigenous chickens in the five regions of northern Ghana could have been influenced by several factors such as resource availability, consumer preferences, and environment, health, socioeconomic, and cultural factors. These elements may shape the priorities in local chicken farming objectives in Ghana's northern regions. Raphulu and van Rensburg, (2018) and Gebreselassie *et al.* (2015), highlighted that indigenous chickens plays a crucial economic role by providing a reliable source of income while also serving as a vital animal protein source for rural communities in sub-Saharan Africa. This finding agrees with farmers across the five regions of northern Ghana concerning live adult live sales of indigenous chickens as a major productive objective in raising indigenous chickens. The Upper West region recorded the highest significance in meat consumption and egg sale; Savannah region recorded the highest significance in chick and live adult sale these productive objectives indicates that indigenous chicken production forms a major economic role in these regions. This outcome shows that farmers in this region are more reliant on chicken production for their sources of livelihood and income through the sales of live adult chicken. Malatji *et al.* (2016) emphasized that indigenous chickens serve multiple socioeconomic and cultural functions, including income generation, supplying high-quality animal protein, fulfilling ceremonial obligations (such as gift-giving and payments), and playing significant roles in various traditional and religious practices. Gabanakgosi *et al.* (2013) stated that the donation of chickens is expressed by many words such as socialisation, love, support, togetherness, care, teamwork, encouragement, self-reliance, sharing, pass-o-gift, and appreciation and this agrees with the findings in this study as give away was a productive objectives practice by farmers across the regions.



The finding in this survey suggests that the Northern regions' environmental conditions favour raising indigenous breeds of chickens for meat and egg consumption. Indigenous chickens demonstrate remarkable environmental adaptability, thriving in diverse and often harsh conditions while making significant contributions to rural livelihoods and nutritional security (Assan, 2022). The survey findings indicate that meat and egg consumption were highly prioritized by farmers as productive objectives in raising indigenous chicken across the regions and this finding agrees with Lan Phuong *et al.* (2015) and Moula *et al.* (2011) both reported that a primary motivation for raising chickens, particularly indigenous breeds, is for home consumption. Meat consumption was ranked as the first preferred purpose of breeding by farmers across the five Northern regions of Ghana, indicating its high demand and economic importance. Birhanu *et al.* (2023) found that farmers prioritize meat consumption, egg consumption, and the sale of meat or adult birds as the main objectives for their chicken production.

Preferences of chicken breeds by farmers in the five regions of northern Ghana

The preference for breeds of chickens could be influenced by various factors such as socioeconomic benefits, market demand, cultural practices, resource availability, and health considerations. Okpeku *et al.* (2019) found that indigenous chicken breeds demonstrate superior adaptability to Africa's demanding ecological conditions compared to exotic varieties. The findings of this survey indicate that farmers across the Northern regions of Ghana highly prefer the local and improved breeds of chickens and this could be a result of their better adaptability to local climatic conditions and their resistance to disease conditions which often make them well-integrated into local farming systems. Desta and Wakeyo (2012) observed that indigenous chicken breeds maintain significant popularity across developing nations owing to two key adaptive advantages: their natural disease resistance and remarkable tolerance to fluctuating feed conditions.





Smallholder farmers prefer indigenous breeds of chicken as a result of their resilience, adaptation, scavenging ability, taste of meat or eggs, brooding behaviour, low cost of production, socio-cultural reasons, and premium output prices (Nguyen Van *et al.*, 2020; Lan Phuong *et al.*, 2015; Moula *et al.*, 2011). This preference trend may also result from farmers' familiarity and associated cultural values of the local breeds of chickens. The preference for local breeds of chickens can also be attributed to the availability of local feed resources, as exotic breeds of chicken management require better feed and more intensive management systems. Tabler *et al.* (2018) demonstrated that while improved chicken breeds (including exotic and crossbred varieties) offer enhanced genetic potential for productivity, their adoption remains constrained by substantial input requirement. Farmer preference for indigenous and locally improved chicken breeds serves as a dynamic conservation mechanism, safeguarding valuable genetic diversity essential for climate resilience. Assan (2022) highlighted the critical socioeconomic role of indigenous chicken breeds as vital animal genetic resources in Africa, demonstrating their multidimensional contributions to poverty alleviation and food security. Preference for exotic breeds of chicken across the Northern regions of Ghana could be due to their high production potential, in areas of meat and egg production, and their capacity to utilise feed efficiently compared to the local breeds. Farmers in the five regions of northern Ghana ranked improved local and local breeds as their most preferred breed of chicken for production and this preference could be attributed to the resilience and adaptable traits possessed by these breeds of chickens. Birhanu *et al.* (2021) revealed a strong Vietnamese consumer bias toward indigenous chicken breeds over crossbred or exotic varieties.

Trait preference of chicken farmers in the five regions of northern Ghana

Chicken farmers in the regions of northern Ghana preferred productive traits over physical traits of indigenous chicken breeds, which might be explained by cultural values, market, and



economic demands, and environmental factors. Bettridge *et al.* (2018) reported that indigenous village chicken possessed a high genetic diversity because of their breeding, management history, and rich biodiversity of the tropical regions. These results demonstrate that farmers prioritise maximising income, ensuring food security, and retaining resilience in their productive objectives of raising native chickens. Gunya *et al.* (2020) found that local chickens significantly impact most rural Africans' socioeconomic status and food security. The preference for chicken breeds with more productive traits by farmers in Northern Ghana indicates that farmers are mainly focused on the economic outcome and consumer preference as breeds with productive traits such as feed efficiency, high growth rate, and egg production significantly influence the profitability of chicken production. Desta (2021) reported that indigenous chicken production has many socio-cultural and economic importance and provides several ecosystem benefits. The climatic conditions within the Northern regions could influence the preference of chickens with productive traits over physical traits as these traits are more likely to adapt well and be suitable to these unfavourable climatic conditions. The less preference for indigenous chickens with physical traits over productive traits discovered in this study could also result from farmers' productive objectives as the demand for nutrition and income generation may be important, and chickens with physical traits may not directly result in nutrition and income production.

The outcome of the survey indicates that farmers in the five regions of northern Ghana prefer a mix of productive, environmental adaptability, and behavioural traits when selecting hens for breeding. In the Northern Region, farmers prefer hens with a larger body size, likely for meat production or sale. Across the Upper West, Upper East, North East, and Savannah regions, a high chick production rate is most valued, indicating a focus on expanding their flocks. Uniquely, farmers in the Upper West region pay close attention to feed requirements, suggesting a concern for input costs. Meanwhile, the North East region prioritizes scavenging



ability, highlighting a reliance on low-input, free-range systems. These regional differences highlight the diverse priorities and environmental influences shaping breeding practices among Ghanaian farmers. Gebremariam *et al.* (2017) reported that farmers consider productive, physical, behavioural, and environmental adaptive traits in indigenous chicken when selecting for breeding purposes. Practising this approach of breeding by farmers in northern Ghana, not only targets to improve productivity and profitability of chicken production but also ensures that their systems of production are sustainable, and resilient in adapting to challenging climatic conditions, and the market needs of consumers. Desta (2021) reported that the purpose of raising indigenous chickens is strongly linked with adaptation and production traits. Selection of hens with good productive traits like growth rate and egg production by farmers, directly contributes to the profitability of raising indigenous chickens, and this breeding strategy could help farmers maximise income returns, thereby balancing production efficiency with traits that would contribute significantly to the marketability of their chickens. The ranked data outcome reveals that farmers in the regions of northern Ghana prioritized body and growth rate as major traits when selecting hens and cocks for breeding. This trend could be a reflection of these traits to productivity and economic gains associated with hens and cocks breeding. Birhanu *et al.* (2023) documented that smallholder chicken farmers employ a multidimensional evaluation system when selecting breeding hens, prioritizing four critical phenotypic characteristics; body/feather colour, growth rate, egg size and comb shape. The survey's outcome reveals that farmers in the regions of northern Ghana significantly preferred productive and physical traits over environmental adaptability and behavioural traits and this might be explained by the cultural and economic demands of indigenous chickens by consumers. Okeno *et al.* (2011) reported that, farmers in Kenya preferred economically important and environmentally adaptive traits of indigenous chickens when selecting for breeding purposes. This finding suggests the essence of future consideration when selecting cocks for breeding to improve



overall flock sustainability, resilience, and adaptability. The preference for productive and physical traits when selecting cocks for breeding may be directly connected to profitability, and cocks that possess these traits may be aligned with farmers' breeding or productive objectives of maximising income and yield. Birhanu *et al.* (2023) reported that farmers prefer productive traits like large body size, growth rate, and physical traits such as body/feather colour when selecting cocks for breeding. This trend may significantly influence breeding decisions as farmers are more likely to lean toward traits that are market-demanding by consumers. Yakubu *et al.* (2020) and Sørensen (2010)) highlighted that both consumers and farmers who raise chickens for their own sustenance have a strong preference for indigenous village chickens. This preference is largely driven by the desirable qualities of their meat and eggs, particularly their superior flavour, and the diverse physical characteristics that these local breeds exhibit. The least significant preference for environmental adaptability and behavioural traits by farmers across these regions could be associated to their inadequate knowledge of the relevance of these traits. This may therefore influence their breeding objectives when selecting cocks for breeding. Birhanu *et al.* (2023) found that when smallholder farmers raise local chicken breeds, behavioural traits like brooding and mothering/rearing ability are considered the most crucial.

The survey findings reveal significant regional variations in breeding preference irrespective of selecting hens and cocks in Northern Ghana and this could be due to cultural preference, economic demands, environmental conditions, resources, and information availability. Mujiyambere *et al.* (2022) reported that indigenous chickens show significant differences in reproductive ability which is associated with high genetic diversity, high gene-environment interactions, and wide environmental variation. Farmers in the five Northern regions significantly preferred breeding hens and cocks with a blend of productive, physical, behavioural, and environmental adaptability traits. Chebo and Nigussie (2016) reported that

farmers' preferences for breeding chickens differ between cocks and hens. For cocks, farmers prioritize traits like marketability and certain physical (aggression) traits. When selecting hens, their main concerns are laying performance and motherhood abilities. The less significant preference for some traits across the regions could be associated with poor market infrastructure, low awareness of breeding benefits, and traditional knowledge. Edea *et al.* (2018) highlighted that understanding the genetic diversity and population structure of farm animals is crucial. This knowledge allows for the creation of effective strategies to improve production, ensure conservation, and facilitate better management of these valuable genetic resources. This outcome could result in a situation where farmers prefer breeding hens and cocks with higher immediate survival and more resilience over a wide range of productive and desirable traits. Farmers across the five regions of northern Ghana ranked producing a lot of eggs and chicken with large body size as the most preferred traits irrespective of when selecting hens and cocks for breeding respectively. This preference shows that egg production and physical traits are a top priority of farmers indicating the importance of these traits in breeding. Birhanu *et al.* (2023) observed that smallholder farmers primarily select hens based on their egg productivity, a characteristic often low in local chicken breeds due to their limited genetic potential.

Breeding ratio

Sex ratio analysis revealed significant deviations from both equal proportions (1:1) and a standard breeding ratio (1:10) across all five regions. These regional variations suggest the influence of traditional practices, ecological conservation efforts, and specific breeding preferences. Ali *et al.* (2013) found that the ratio of males to females significantly impacts the reproductive success of quails. Specifically, a 1 male to 1 female (1M:1F) sex ratio resulted in the highest fertility (79%) and hatchability (78%). In contrast, a 1 male to 4 females (1M:4F) sex ratio led to the lowest rates, with fertility at 70% and hatchability at 62%. This suggests



that having a more balanced sex ratio, or even an abundance of males, can improve reproductive outcomes in quail breeding. The preference toward other sex ratios by farmers in the regions of northern Ghana could strongly increase inbreeding. This practice can therefore reduce the genetic diversity of their flock. Mahoro *et al.* (2017) highlighted the frequent occurrence of consanguineous mating due to a lack of a proper mating plan. This unplanned breeding inevitably leads to inbreeding, a practice that subsequently deteriorates genetic vigour. This finding could cause a more homogenized gene pool thereby affecting some productive characteristics and environmental characteristics. Haghighi *et al.* (2016) found an interesting trade-off in quail breeding where increasing the sex ratio led to lower average egg production. However, on the positive side, this higher sex ratio improved hatchability. The researchers suggest this improved hatchability might be due to more frequent sexual interactions between the males and females.

Flock structure

Chick population is the highest within the flock,s followed by hens, indicating a good base of breeding stock. Pullets and cockerels follow, representing the intermediate growth stages, with pullets outnumbering cockerels. The cock population is the smallest, which is typical for poultry farming as fewer males are needed for breeding purposes compared to females. This distribution points to a farming strategy focused on replenishing the flock and maximizing egg production, while also maintaining a balanced approach to raising young birds. This aligns with the flock structure documented by Birhanu *et al.* (2023).

Distributions of qualitative traits in local chickens in the five regions of northern Ghana

The results showed significant regional variations in qualitative traits among local chickens in Northern Ghana. Frizzle feathering is more common in North East and Northern regions, while Naked Neck chickens are notably prevalent in Savannah and Upper West. Plumage patterns were highly diversified, with "Barred" being dominant in Upper East and North East, contrasting



with Plain in Northern region. Also, Red plumage is common in Upper East and North East, but White is more frequent in Northern region. Skin colour is most chickens had White, even though Upper West shows a higher proportion of yellow skin. The Comb types exhibit strong regional significant differences, with Rose combs dominating in North East and Upper East, and Single combs in Northern and Savannah regions. These unique distributions show the genetic diversity of local chicken populations, likely shaped by regional breeding practices or environmental adaptations, highlighting the need for tailored conservation efforts. This finding is consistent with Birteeb and Boakye (2020) who also observed normal feather morphology in indigenous chickens raised under an extensive system in Ghana's Tolon district.. The low occurrence of frizzle, silky, and other feather morphology across the five regions of northern Ghana may be associated with cultural preference, market demand, and local breeding practices. Dahloum *et al.* (2016) reported that when major genes have a low frequency of dominant alleles, it suggests that the animals carrying these alleles are at risk. Essentially, it means this carrier animals are in danger of extinction and are currently considered endangered. Normal feather distribution is highly dominant across the five regions of northern Ghana as compared to feathered shanks and naked necks. This outcome suggests that normal feather distribution may be influenced by standard phenotypic preference and selection pressures. Bhadauria *et al.* (2014) proposed that introducing major genes like frizzle (F), naked neck (NA), delayed feathering, and dwarfism could be a key strategy to boost productivity in chickens raised in hot climates. These genes are thought to improve a bird's ability to cope with heat, thus enhancing their overall performance. The high occurrence of naked neck feather distribution in the Savannah region could be attributed to their lower feed requirement and ability to dissipate heat effectively. Njenga (2005) and Magothe *et al.* (2012) reported that indigenous chickens possessing specific genotypes, such as the naked neck and frizzle genes, exhibit enhanced productivity and adaptability in tropical environments. These genetic traits



are linked to improved feed conversion, superior body weight, higher egg production, a faster growth rate, and better disease tolerance. Galal (2008) and Alvarez *et al.* (2003) both reported that the frizzle and naked neck genes enhance immune competence in chickens raised in high-temperature environment.

Plain plumage patterns recorded the highest frequencies across the five Northern regions of Ghana showing a commonality among plain feathered indigenous chickens in Northern Ghana. The significant variations in the plumage patterns distribution of indigenous chickens across the five Northern regions could be attributed to environmental adaptations, selection pressures, genetic drift, and market demands. Desta and Wakeyo (2023) highlighted that genetic drift, largely a consequence of the small size of family chicken flocks, is a significant evolutionary force affecting the genetic structures of indigenous village chickens. Red, white, and black plumage colours were dominant across the five regions of northern Ghana. The changes in plumage colour could be liken to genetic factors, selection pressures, and breeding practices. Khobondo *et al.* (2014) and Otecko *et al.* (2019) observed that indigenous chickens are characterized by their distinctive plumage pigmentation. While their coloration varies widely, the majority display extensive and mottled patterns, often incorporating black, brown, or red colours. White skin colour was predominant across the five regions of northern Ghana and this could be attributed to genetic variation and polymorphism. Desta *et al.* (2013), and Desta and Wakeyo (2012) highlighted that natural selection has been the primary force in shaping the genetic structure of indigenous chickens. This process has enabled these chickens to accumulate high levels of genetic polymorphism (genetic variation) and to adaptively radiate. The low frequency of blue skin colour suggests that it may be a rare genetic trait. Black, white, and yellow shank colours were the most occurring shank colours of indigenous chickens in the five regions of northern Ghana, suggesting that potential advantages or preferences influence these traits. The low frequency of green and blue colour shanks suggest that these traits may



be rare or specialised variants. Ngeno *et al.* (2014) and Khobondo *et al.* (2014) reported that indigenous chickens exhibit a diverse range of shank and skin pigmentation, including black, green, white, and brown colours. The outcome of the survey indicates that the red earlobe colour is the most predominant trait among the population of local chickens in the regions of northern Ghana, as compared to other earlobe colours, suggesting that the red earlobe colour could be a strongly heritable trait. Red earlobe colour as a major earlobe colour has been reported in indigenous chicken breeds in Ethiopia by Aklilu *et al.* (2013). Ngeno *et al.* (2014) found that the majority of indigenous chickens have red eye lobes, with a small area of white and mottled red within a small population.

In the five regions of northern Ghana, Single and Rose comb types are the most commonly observed in chickens. Walnut, cushion, strawberry, and v. shape were the less occurred comb types in this study and this trend could be influenced by genetic factors, selection pressures, environmental influences, and demographic, and behavioural factors. Desta (2021) highlighted that if there is high genetic variation within indigenous chicken populations, even a moderately stringent selection intensity can lead to rapid genetic gain. The majority of indigenous chickens largely possess single comb type, with some exceptional comb types such as rose, cushion, buttercup pea, crest, strawberry, walnut, and duplex also existing (Otecko *et al.*, 2019; Ngeno *et al.*, 2014). The results of the current study showed that large, medium, and small comb sizes are the common comb sizes among the populations of local chickens in the regions of northern Ghana, with small comb sizes being predominant. The variation of comb size across these regions may be due to age, maturity and population composition of the birds, as comb size increases as the birds grow. Oleforuh-Okoleh *et al.* (2017) observed variations in some morphological traits in indigenous chickens at four and eight weeks old. Birteeb *et al.* (2016) also reported some variations at all ages in all traits measured in indigenous chicken.



Associations among some qualitative traits in local chickens in the five regions of northern Ghana

The strong association between sex and skin colour could be explained by genetic factors which can cause some traits to be sexually dimorphic. Birteeb and Boakye (2020) found a notable link between a chicken's sex and the colour of its comb, eyes, shanks, and earlobes in the Tolon district of Ghana. They suggested that the genes and carotenoid pigments that control these traits might be expressed differently between male and female indigenous chickens. Selective breeding practices could have also contributed to this strong association between sex and skin colour as farmers may prefer some skin colours for females and males thereby establishing a clear link between skin colour and sex. Moderate associations were found between feather distribution and plumage pattern, plumage pattern and plumage colour, and skin colour and shank colour. Numerous weak, yet statistically significant, associations were also identified. Plumage colour in indigenous chickens also showed a weak association with a wide array of other traits. These include skin colour, shank colour, earlobe colour, comb type and size, skeletal variations, the presence of wattles, and beak types. The study identified weak connections between a chicken's sex and its shank colour, earlobe colour, and comb size. Similarly, feather morphology was only slightly linked to plumage and skin colour, and feather distribution showed weak ties to plumage colour, skin colour, and comb type. Further weak associations included plumage pattern with beak types; skin colour with comb type, comb size, and beak types; shank colour with comb type and comb size; and earlobe colour with comb type, comb size, and the presence of wattles. Lastly, comb type had weak links to skeletal variants, wattles, and beak types, and skeletal variants were weakly associated with wattles. These associations highlight complex developmental relationships among the observable characteristics of these local chicken populations. The highly significant difference of sex on shank length and wing span could have been influenced by sexual dimorphism as males and



females show distinct physical traits. Dana *et al.* (2010) found that most morphological traits of indigenous chickens differ between males and females.

Impact of qualitative traits on quantitative traits in local chickens in northern Ghana, a GLM analysis

Region was the most important factor that significantly impacted almost all quantitative traits, including live BW, WIS, HL, BL, CC, SL, WL, and TC. This showed the important effect of geographical location on chicken morphology. Feather morphology significantly affected BL and CC. Comb size was also influential, significantly impacting live BW, WIS, CC, WL, and TC. Sex showed a highly significant effect ($p < 0.001653.457^{**}$) on SL and a significant effect ($p < 0.0125.469^{*}$) on WIS, confirming sexual dimorphism in these particular traits. Skeletal variants showed a strong link with NL. Additionally, characteristics like feather patterns, skin colour, shank colour, earlobe colour, comb shape, the presence of wattles, and beak morphology typically had little to no significant impact on the majority of the quantitative traits measured. These findings collectively suggest that region and other specific physical characteristics are key determinants of local chicken morphology in Northern Ghana. Animals can develop multiple variations in their morphology, physiology, and behaviour in response to environmental changes. These adaptations arise through gene expression regulation and phenotypic plasticity, allowing them to adjust their traits for survival (Mansjoer *et al.*, 2007; Riva *et al.*, 2004; Noor, 2002; Karna *et al.*, 2001). Birteeb *et al.* (2024) found that geographical location significantly impacted various morphological traits in chickens. Specifically, the researchers observed variations in body length, shank length, chest circumference, comb length, neck length, thigh circumference, head width, wing length, head length and wattle length. Feather morphology recorded a significant association with qualitative traits such as comb size and body length of indigenous chickens in this study. Comb size had a significant influence or association on qualitative traits such as BW, WIS, CC, and WAL and this could



be due to pleiotropic effects indicating comb size may be influenced by the same genes that control other traits. Nematbakhsh *et al.* (2021) reported that wing span and chest circumference values can be used in predicting slow and fast-growing traits in indigenous chicken breeds. Skeletal variations had a notable influence on qualitative traits, such as neck length (NL). Kebede *et al.* (2019) reported that indigenous chicken trait variations could be attributed to genotype differences, environmental factors, location, feed availability, and traditional husbandry practices.

Plumage colour significantly influenced the WIS and BL of indigenous chickens in the five regions of northern Ghana. The impact of plumage colour on qualitative traits such as WIS and BL suggests that plumage colour could be a heritable trait. The positive correlation of morphometric traits such as BL, WIS, and CC with BW in local chickens suggest that an increase in these morphometric traits could increase the BW of the bird. A study conducted by Birteeb *et al.* (2024) on indigenous chickens in the Tolon district of Ghana's Northern Region revealed a low correlation coefficient between body weight and individual linear body measurements.. Tabassum *et al.* (2014)) found significant correlations between body weight and various morphometric traits in indigenous chickens. This trend indicates that these morphometric traits may influence each other functionally and developmentally. According to Yakubu *et al.* (2009), when phenotypic correlations are positive, it often suggests that the traits are influenced by the same set of genes. This means that if you observe a change in one trait, you can likely predict a corresponding change in the other. The strong positive correlation of morphometric traits such as BL, WIS, and CC on BW could be attributed to genetics, environmental, physiological, and nutritional factors. Morphological traits are strongly shaped by environmental conditions, particularly climatic factors and nutritional resources (Jing *et al.*, 2010; Salako, 2006; Lanari *et al.*, 2003; Andersson, 2001).



Phenotypic correlations and path coefficients among morphological traits

The path coefficient and phenotypic correlation analysis showed that Chest Circumference (CC) was the most critical direct predictor of BW, with a path coefficient of 0.252, indicating its strong direct contribution to heavier chickens. Body Length (BL) (0.143), Wingspan (WIS) (0.140), Wattle Length (WL) (0.099), and Thigh Circumference (TC) (0.100) also showed positive direct effects. Their phenotypic correlations with BW (0.405*, 0.354*, 0.329*, and 0.341* respectively) supported their overall importance. The analysis revealed that certain linear body measurements, namely Beak Length (BEL) (-0.002), Head Length (HL) (0.001), Neck Length (NL) (0.012), and Shank Length (SHL) (-0.015), exhibited very little direct or indirect impact on Body Weight (BW). For local chicken breeding programs, focussing on chest circumference and body weight as primary selection criteria is very crucial. Characteristics like body length, wingspan, wattle length, and thigh circumference should also be looked at due to their combined direct and indirect contributions to overall body weight. Assefa and Melesse (2018) conducted a study that found body weight had the strongest correlation with body circumference, followed by wing span. Yakubu *et al.* (2015) employed path analysis to examine morphological characteristics in Nigerian ducks, demonstrating that this analytical approach provides valuable insights into economically significant traits. Egena *et al.* (2014) found that, linear body measurements had been used by researchers to characterise carcass composition, body conformation, predict live weight gain, evaluate breed performance and examine relationships and reproductive performance among morphometric traits in several animals.

Mean ($\pm$ SE) body weight and linear body measurements of indigenous chickens by region, plumage colour and comb size

Chickens from the Savannah region produced the highest mean body weight (1.28kg), body length (20.36cm), and chest circumference (26.48cm). The Northern region had chickens with



the least weight (0.94kg) but had the longest shank length (10.54cm), indicating distinct regional adaptations. The Upper West was unique with chickens that had the largest wingspan (17.63cm). Plumage colour also showed some varied influence (including blue plumage often associated with smaller birds), its impact was not as consistent as that of region or comb size. Chickens with larger combs consistently showed greater body weight and larger body dimensions. There was strong correlation between larger combs and body weight/larger body dimensions, implying that comb size could be an indicator for selecting larger, more robust birds for breeding programs. The smaller size of indigenous chickens in the Northern region as revealed in this study could be associated with local breed characteristics and limited genetic diversity. A study by Desta and Wakeyo (2023), highlighted that natural selection, a primary driver of evolution and genetic diversity, significantly influences the genetic makeup of outbred indigenous chickens. The significant variation in body weight and linear body measurements observed among indigenous chickens with different plumage colours and comb types in this study likely reflects underlying genetic factors and evolutionary adaptations. Tadele *et al.* (2018) found a significant and strong association between body weight and linear body measurements in indigenous chickens. The survey outcome indicated that, indigenous chickens with other plumage colours tend to have heavier and larger body dimensions for some traits showing a potential correlation between plumage colour and growth characteristics. The study found that indigenous chickens with larger comb types exhibited significantly greater wingspan (WIS), body weight (BW), other linear body measurements include body length, chest circumference, shank length. Research by Birteeb *et al.* (2016) in Ghana's Gomaa West district found that comb type significantly influenced the growth traits of indigenous chickens.

Husbandry practices of farmers in the five regions of northern Ghana

Most farmers (78%) housed their chickens, mainly in dedicated structures, with 20% using kitchens. Majority (74.67%) provided supplementary feed twice daily, primarily morning and



evening. However, feed processing is uncommon (63% do not process), and the commonest method of feeding is throwing feed on the ground (83%). Most farmers (89%) did not vaccinate their flocks, and over half (55%) have not recorded disease outbreaks. Almost all farmers (98%) provide drinking water for their flock. This highlights good housing and feeding practices. Birhanu *et al.* (2021) highlighted a strong connection between the quality and type of housing system and the productivity and production of smallholder chickens. The relationship between poultry housing systems and production types, as highlighted by Desvaux *et al.* (2008) is a critical aspect of modern chicken farming. Delabougliise *et al.* (2019) observed distinct housing practices among smallholder chicken producers. They reported that young chickens and broilers are primarily kept indoors, while layer breeder chickens are housed outdoors, either in a confined pen or allowed to roam unconfined. Majority of the farmers provided supplementary feed for their chicken showing an understanding of their nutritional needs to increase their productivity and optimal growth. Research shows an ascending path in usage of different inputs such as supplementary feed to improved production strategy, and disease treatments by local chicken producers to increase productivity reported by Hailemichael *et al.* (2017). Most farmers across the five regions of northern Ghana provided feed for all types of chicken indicating a comprehensive approach to nutrition. Birhanu *et al.* (2023) reported that about 99.15% of local chicken farmers in Vietnam provided additional feed to their birds throughout the year. Again, the data indicated that, majority of farmers fed their chickens in the morning and evening, which ensures a balanced nutritional intake of their chickens throughout the day, this study agrees with Birhanu *et al.* (2023) who stated that farmers offered supplementary feeds to their chicken flocks multiple times a day specifically in the morning, afternoon, and evening. More than half of the farmers did not record disease outbreaks within their flock, showing generally good health practices by the farmers. According to reports by Carrique-Mas *et al.* (2019) and Delabougliise *et al.* (2019) disease and



bird mortality continue to be significant hurdles for productivity and overall production, especially on farms that raise multiple species of poultry. Effectively managing and controlling the frequent, severe disease outbreaks within the smallholder poultry value chain requires more than just addressing environmental and biological factors (Fournié *et al.*, 2012). It also critically depends on improving the socio-economic behaviours of producers, consumers, and traders. Birhanu *et al.* (2023) reported that 93.1% of farmers do not process their feed and 15.23% of farmers throw the feed on the ground for their local chickens in Vietnam.

The high cost of feed and lack of money to buy feed are closely related, which shows an important financial challenge faced by the farmers. The lack of awareness about supplementary feed shows a need for more extension and education services on the importance of feed supplementation in poultry production. The high levels of supplementary feeding recorded in January, February, March, April, and May could be attributed to the unavailability of feed as these months coincide with the dry season (harmattan) which might have resulted in less availability of natural forage due to dry conditions, causing farmers to provide more supplementary feed to their flocks. The reduction in feed supplementation from April to October could be due to the availability of natural forage as these months correspond with the rainy season, which could result in a reduced need for feed supplementation as birds can have access to abundant natural forage for feeding. The gradual increase in feed supplementation from October to December could be associated with the festive season, where market demand for poultry products is high and this may cause farmers to provide more supplementary feed to their birds to ensure optimum growth and productivity.



CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

- ❖ The study found that farmers primarily raise chickens for meat and eggs, with a strong preference for traits that boost income, such as high egg production and large body size. While farmers Favour local, adaptable breeds, the common practice of keeping fewer males than recommended could lead to inbreeding.
- ❖ When it comes to the chickens physical traits, there is significant variety across the region. Certain traits, like the frizzle feather in the North East and the naked neck in the Savannah, appear to be adaptations to the local environment. The study also found that comb size and chest circumference are reliable indicators of a chickens overall size and weight, which could be useful for farmers looking to select better birds for breeding.

In terms of farming methods, most farmers use an extensive system, where chickens roam freely. While many provide housing and supplemental feed, practices like vaccination are rare, making the flocks vulnerable to disease. Feeding is most common during the dry season when food is scarce.

6.2 Recommendation

Based on these findings, the study offers several recommendations to improve and sustain indigenous chicken farming:

- ❖ Farmers should be educated on the importance of having the right ratio of cocks to hens to prevent inbreeding. Community breeding programs could also be started to help farmers breed for desirable traits like large body size while also preserving unique local traits.



- ❖ Regional efforts should be made to preserve unique chicken traits, such as the naked neck, through selective breeding or gene banks. Farmers could also be taught to use simple traits like comb size to select the best chickens for breeding.
- ❖ Veterinary services need to be improved to increase vaccination rates and disease control. Training for farmers on low-cost feeding techniques and better biosecurity measures could also help reduce chicken deaths and improve productivity.
- ❖ Creating better market connections for products like processed eggs and meat could help farmers earn more money and align their production with market demand.
- ❖ By working together, the government, NGOs, and local farmers can implement these changes to make indigenous chicken farming more productive and profitable while preserving the unique genetic resources of the region.



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APPENDIX A

Chicken Production

Purpose & Objectives for keeping poultry

D1 For what purpose and objective do you raise poultry?

Species	Household keeps species? (0=No, 1=Yes)	If household keeps species rank the top 3 most important objectives (1= most important)		
		Rank 1	Rank 2	Rank 3
Chicken				
a) Objectives	1= for meat consumption, 2 = for egg consumption, 3 = for meat sale, 4 = for egg sale, 5 = for chick sale, 6= for ceremonies / festivals, 7 = to give away, 8 = for cock fighting, Other (specify), 9 = live adult chicken sales, -77=Not applicable			

D2 Even if farmer does not keep all breed types ask: Rank in order your preference for different breed types of CHICKEN – [, , ,] (1=local, 2=improved local, 3=exotic,

4=improved exotic, 5=crossbred (local x exotic), -77 not applicable)

D3 For the most preferred type of CHICKEN why do you prefer this breed type? [, ,] (code a – enter all that apply)

a) Reason: 1=produces a lot of eggs, 2=produces better tasting eggs, 3=produces eggs with harder/thicker shell, 4=has a large body size & weight – for meat, 5=the meat tastes better,
6=produces chicks with high survival rate, 7=is feed efficient, 8=is beautiful / good physical appearance, 9=is good fighter, 10=has less illnesses, 11=lives a long time,
Other (specify)

Chicken Inventory

D1 How long has chicken been kept in the household (*in years*)? []

D2 Do you currently keep exotic / crossbred birds? [] (0=No, 1=Yes)

D3 If No, have you had exotic/improved birds in the past? [] (0=No, 1=Yes).

D Fill in the table below, number of chickens refers to those present in the flock at the time of the survey.

Chicken Breed Type (code a)	If exotic which breed? (Name)	Number of Cocks	Number of Hens	Number of Growers		No. of chicks	Total number of birds	Source of foundation stock (code b)
				Male	Female-Pullet			
a) Chicken breed type – 1=local, 2=improved local, 3=exotic, 4=improved exotic, 5=crossbred (local x exotic) (if code 3 or 4 specify breed(s) –only for this question!!)								
b) Source of foundation stock code (main)		1= Purchase, ,2=Inherited, 3= Custody, 4=Gift (family, schools, government, neighbour, or NGO) Other (specify)						

Chicken productivity

F1 Do you have chickens ~~that~~ lay eggs usually? [] (0 = No, 1 = Yes).

If yes, state the productivity of your birds (by breed type) in the following table – use recall in the past 3 months to help the household complete:

Chicken breed type (code)	Age of sexual Maturity (weeks)		Average No. of <u>eggs</u> per <u>clutch</u>	Average No. of <u>days</u> per <u>clutch</u>	Average No. of clutches per year	Average No. eggs per year	Do you use this breed for brooding? (0 = No, 1 = Yes)	If yes, state the chick productivity of your birds?			
	Hen	Cock						No. of times the hen <u>hatches</u> in a <u>year</u>	Average no. eggs set per brood	No. of chicks <u>hatched</u> per brood	No. chicks per brood <u>surviving</u> to <u>separation</u> <u>from hens</u>

-99 = Unknown; -77 = Not Applicable (e.g. if exotic breed producing eggs all year around enter -77 if all appropriate columns)

Breeding – Bird Selection Practices

F2 Do you select specific chickens for breeding purposes? []

(0 = No, 1 = Yes) F3 If yes, complete the table below:

Sex of chicken	Whether selects for breeding? (0=No, 1=Yes)	What characteristics do you use to select? (code a) (please in order of importance – 1 st trait = most important, 2 nd trait = 2 nd most important, enter up to 5 traits).				
		1 st trait	2 nd trait	3 rd trait	4 th trait	5 th trait
Hens						
Cocks						
a) Selection characteristics / traits						
1=Body size / weight, 2=Growth rate, 3=Feed requirements, 4=body/feather colour, 5=Leg length, 6=Comb shape/ type, 8=wing span, 9=homestead recognition, 10=chick production rate, 11=clutch length, 12=egg size/weight, 13=cold tolerance, 14=heat/drought tolerance, 15=temperament, 16=scavenging ability, 17=Brooding / Hatching ability, 18=egg productivity, 19 = Rearing / Mothering ability, Other (specify), -77=Not applicable						

Trait Preferences

F4 Irrespective of whether you select specific chickens for breeding please complete the table below:

Sex of chicken	What do you think are the qualities/attributes of a good chicken (cock & hen)? (code a) (in order of importance – 1 st trait = most important, 2 nd trait = 2 nd most important, enter up to 5 traits).				
	1 st trait	2 nd trait	3 rd trait	4 th trait	5 th trait
Hens					
Cocks					

a) Qualities / Attributes: 1=produces a lot of eggs, 2=produces better tasting eggs, 3=produces eggs with harder/thicker shell, 4=has a large body size & weight – for meat, 5=the meat tastes better, 6=produces chicks with high survival rate, 7=is feed efficient, 8=is beautiful / good physical appearance, 9=is good fighter, 10=has less illnesses, 11=lives a long time, Other (specify), -77=Not applicable

Chicken Management

Housing

G1 Chicken Breed Type (code)	G2 Housing system – Dry season (code b)		G3 Housing system – Wet season (code b)		G4 If specific housing, indicate			
	Day	Night	Day	Night	Construction cost	When built (year)	Average longevity of the house (in years)	Used for other breed/ species (code c)?

b) Housing system 0=Free range (no housing), 1= Chicken house (coop/hut) made from mud/iron sheet/wood/rocks/bricks, 2=Kept in home (e.g. kitchen), 3=Confined in individual cage, 4= Confined in basket (e.g. bamboo), Other (specify)

c) Used for other breed / species? 0=no, 1= for all POULTRY species kept by the household, 2= for all breeds of chicken only, 3=with other livestock species

G5 If the housing system is in baskets or cages, how frequently in a week do you clean or move the basket to another location? [] (Number of times)

G6 If you are supplied with a new breed of chicken, will you be willing to provide a separate housing structure for them? [] 0=No; 1=Yes

Feeding

G7 Do you give supplementary feed (i.e. any feed not obtained from scavenging) to your chickens at any time of the year? [

] (0=No, 1=Yes) G7b If yes, tick months when supplementary feed given (tick all

Jan	Feb	Mar	Apr	May	Jun
Jul	Aug	Sept	Oct	Nov	Dec

that apply):

G8 If no, why? (enter all that apply) [, , ,]

Codes: 1=Lack of awareness about supplementary feed, 2=Unavailable feed, 3=High cost of feed, 4=Time shortage, 5=Lack of money to buy feed, 6=Others (specify)

G9 If yes, complete the table below on supplementary feeding types and methods for your chickens. Enter 1 row per Chicken type x Feed type combination:

Feed type? (code b)	Chicken Type (code a)	What time do you provide the feed? (code g)	Any processing g before feeding? (code c)	Method of feeding (code d)	Is the feed: 0=From own farm, 1=Purchased, 2=Both?	If purchased...					If from own farm, estimated monthly cost?
						Number of months / years purchased	Average monthly cost during months when purchased (incl. process)	Marketing channel (code e)	How do you transport the feed? (code f)	Average monthly cost of transport (0 if Free)	
a) Chicken type		1=Cock, 2 = Hen, 3 = Grower – male, 4 = Grower – female (pullet), 5 = chicks, 6 = all chickens, Other (specify)									
b) Feed type		1=Grains, 2=Vegetables, 3=Root crops, 4=Legumes, 5=Oil seeds, 6=Commercial feed (e.g. wheat bran, oilseed by-products, mash), 7=Kitchen waste, Other (specify)									
c) Processing type		1=No processing, 2=Chopped, 3=Ground, Other (specify)									
d)Feeding method		1=Put into containers, 2=Thrown on ground for collective feeding, Other (specify)									
e) Marketing channel		1= Fellow farmer / individuals; 2=Traders; 3= Village market; 4=City market; Other (specify, e.g. NGO)									

f) Mode of transport	1= Walking (carrying feed), 2 = owned car/truck/motorcycle, 3 = hired car/truck/motorcycle, 4=seller brings the feed with his/her own transport, Other (specify)	
g) Feeding time	1=Morning only, 2=Afternoon only, 3=Evening only, 4=Morning &/or Afternoon, 5=Morning &/or Evening, 6=Afternoon &/or Evening, 7=Morning, Afternoon and/or Evening, 8 = Always available / ad libtum	

G10 If purchase, do you have difficulty with obtaining the feed during anytime of the year? [] 0=No; 1=Yes; -77=Not applicable

G12 If purchase feed, do you have issues / challenges with quality of feed you usually purchase? [] 0=No; 1=Yes; -77=Not applicable

G13 If you are supplied with a new breed of chicken, Will you be willing to give supplementary feed to them? 0=No; 1=Yes

G14 Do you provide your chickens with water in a container / trough? [] 0=No; 1=Yes

G21 If you provide feed and/or water in a container, state the following details on the type of feeder and drinker you are currently using?

Type (code a)	Source (code b)	Number
a) Type of asset	1=Feeder (for feed), 2=Drinker (for water)	
b) Source	1=Purchased 2=Homemade 3= Gift 4= Other, specify	

Health

G19 Did you carry out any vaccination or routine medication of chicken in the past 12 months?

Disease	Vaccination / Routine Medication in the past 12 months? (0=No; 1=Yes)	Vaccination / Routine Medication provider (code a)	Vaccination/ routine medication round in 12 months	Average number of chicken vaccinated/ medicated per round?	Total cost of vaccination / routine medication in the last 12 months (0 = None)
Newcastle Disease					
Infectious Bursal Disease (Gumboro)					
Coccidiosis					
Bird Flu					
Avian pox					
Other (specify) []					
Deworming					
Delousing					
Chicken Cholera					
White diarrhoea					
a) Vaccination /treatment provider	0 = Self, 1=Government extension, 2=Private provider(e.g. para-vet, shop, company), 3=Cooperative or farmer group, 4= Research / training institute, 5 = NGO/Project, 6 = Other farmer / neighbour, 7= Local healer, 8=Certified vet, Other (specify)				

G15 Have you experienced any chicken disease outbreaks in the last 12 months? [] 0=No; 1=Yes. If yes, how many? []

G16 If yes, complete the table below: 1 row per event - Detailed Chicken Disease Management Overview (in the last 12 months)

Event num.	Event Month	Number of chickens that got sick	How many of these died?	What breed type of birds were most severely affected (code)?	Symptoms (code a – select all that apply)	What disease? (code b)	What action did you take? (code c)	If treated, who provided the services (code d)	What was the total cost of this service (including cost of drugs)?*	If treatment including drugs how effective was it? (1=Poor, 2=Fair, 3=Good, -77=N/A)
1										
2										
3										
4										
a) Symptoms		1= Diarrhoea - bloody, 2=Diarrhoea – green/white, 3= Circling, 4= Coughing and sneezing, 5= Decreased egg production, 6= Dehydration, 7= Drowsiness and weakness, 8= Head edema, 9= Lack of appetite (anorexia), 10= Nasal discharges, 11= Respiratory problems, 12= Soft shells and deformed eggs, 13= Swelling of the joints, 14= Twisting head and neck, 15= Vent picking, 16= weight loss, 17= Spots, Other (specify)								
b) Disease		-99 = Don't know, 1= Avian influenza (bird flu), 2=Coccidiosis, 3=Fowl Cholera, 4=Infectious Bursal Disease (Gumboro), 5= Newcastle disease, 6=Infectious Bronchitis, 7=Pullorum (Salmonella), 8 = Fowl Pox, 9 = Parasitic diseases, Other (specify)								
c) Action taken		0 = Nothing, 1=Treated myself – with traditional medicine, 2 = Treated myself - modern medicine (antibiotics, anthelmintics, aspirin etc.), 3=Got an 'expert' in to treat them, 4=Killed them immediately – and consumed, 5=Killed them immediately – did not consume, 6=Sold the live chickens immediately, Other (specify, e.g. quarantine)								
d) Service Provider		0=Myself, 1=Certified Vet, 2=Para-vet, 3=Vet technician, 4=Community health worker, 5=Other Farmer / Neighbour, 6=Local healer, Other (specify)								

*Can include vaccination if performed for healthy birds at the same time

G17 If household had events in table above but no paid service provider then ask: **Do you have access to paid health services?** [] 0=No; 1=Yes

G18 **If NO**, if you had access to paid health services for chicken, would you pay for these services? [] 0=No; 1=Yes

G20 Which household member provided the answers for Section F & G? [] (1= household head, 2= spouse (if head is male), 3= other household male, 4=other household female, 5=joint (household head & spouse), 6=other specify) and was this person / people the most appropriate / knowledgeable? [] (0 = No, 1 = Yes)

APPENDIX B

CHARACTERIZATION OF CHICKENS

1.0 DISCRETE OR QUALITATIVE VARIABLES

DATE.....
REGION.....

Feather morphology	Feather distribution	Plumage pattern (the colour pattern of feathers, if necessary, on the specified location on the body of birds)	Plumage colour	Skin colour	Shank colour	Earlobe colour	Comb type	Comb size	Skeletal variants	Presence of wattles	Beak types
	1 = normal ☐	1 = plain ☐	1 = white ☐	1 = not pigmented (white) ☐	1 = white ☐	1 = not pigmented (white) ☐	1 = single ☐	1=small ☐	1=normal ☐	1=yes ☐	1=normal ☐
2 ☐	2 = naked neck	2 = barred (specify if ☐	2 = black ☐	2 = yellow ☐	2 = yellow	2= red	2 = pea	2=	2= Crested	2=no	2=parrot

	☐	sex linked or autosomal)			☐	☐	☐	Mediu m ☐	☐	☐	☐
3 = silky ☐	3 = feathered shanks & feet ☐	3 = laced ☐	3 = blue ☐	3 = blue- black ☐	3 = blue ☐	3 = white and red ☐	3 = rose ☐	3=large ☐	3=polyda ctyl ☐		3=scissor s ☐
4 = other (specify)	4 = muffs and Beard ☐	4 =mottled ☐	4 = red ☐	4 = other (specify)	4 = green ☐	4 = other (specify)	4 = walnut ☐		4=extra toes ☐		
	5 = crest ☐	5 = others (specify)	5 = wheaten ☐		5 = black ☐		5 = cushion ☐		5=creepe r ☐		
	6 = vulture hocks (= long stiff feathers protruding down and back from the hock joint) ☐		6 = other (specify)		6 = brown ☐		6 = strawbe rry ☐		6=dwarf ☐		

	7 = other (specify)				7 = other (specify)		7 = duplex ☐		7=rumpl es ☐		
							8 = V- shaped ☐		8=multip le spurs ☐		
							9 = double ☐		9= others (specify)		

2.0 QUANTITATIVE VARIABLES Body measurements

Animal I.D	sex	Body weight (kg)	Wing Span (cm)	Beak length (cm)	Head length (cm)	Neck length (cm)	Body length (cm)	Chest Circumference (cm)	Shank length (cm)	Wattle Length (cm)	Neck length (cm)
1.											
2.											
3.											
4.											
5.											
6.											
7.											
8.											
9											
10.											