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**COMPARATIVE STUDIES ON PERFORMANCE AND CARCASS TRAITS OF
NAKED NECK, NORMAL-FEATHERED, TETRA-H CHICKEN
GENOTYPES, AND THEIR CROSSBREDS IN SOUTHWEST ETHIOPIA**

PhD Dissertation

By

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Addis Ababa University, College of Veterinary Medicine and Agriculture

Department of Animal Production Studies

PhD program in Animal Production

December, 2023

Bishoftu, Ethiopia

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**A dissertation submitted to the College of Veterinary Medicine and Agriculture,
Addis Ababa University, in partial fulfilment of the requirements for the degree of
Doctor of Philosophy in Animal Production**

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I hereby certify that I have read the revised version of this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

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Dedication

I dedicate this dissertation to the memory of my beloved sister, Tesfanesh Tadele, and brother, Yinges Tadele. Additionally, I would like to pay tribute to my mother, Bizunesh Tiruneh, who unfortunately passed away before witnessing my achievements.

Statement of the author

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

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Biographical sketch

I, the author of this dissertation, was born in September 1985 in Bonga Town, Kaffa Zone of Southwest Ethiopia. I completed my primary and secondary education at Bonga Primary and Secondary School, respectively. Upon successfully passing the Ethiopian Higher Education Leaving Examination, I enrolled at Ambo University and obtained my Bachelor of Science (B.Sc.) degree in Animal Production and Health in July 2006. Following my graduation, I began working as a livestock and health expert at Southern Regional State Bonga, Poultry Production Center, where I served for four years. In November 2011, I engaged in the Ministry of Agriculture, Mizan ATVET College to Southern Nations, Nationalities, and Peoples' (SNNP) Regional State of the current Southwest Ethiopia. As an instructor, I dedicated five years to teaching and guiding students in the field of Animal Science and served as Head of the extension and continuing education (four years), delegated as academic Vice Dean, and participated in several extracurricular activities. In 2014/15, I pursued a Master of Science (M.Sc.) degree in Animal Production at Hawassa University, College of Agriculture, which I completed in July 2016. Following that, I joined Mizan-Tepi University as a lecturer in the Department of Animal Science in August 2016. Later, in October 2018, I transferred to Bonga University, where I continued my teaching career and engaged in various extracurricular activities. Notably, I served as the Director of the Research Directorate. After accumulating numerous years of valuable experience, I joined Addis Ababa University, College of Veterinary Medicine and Agriculture, in September 2019/20 AY to pursue a Ph.D. in Animal Production Studies. Throughout my academic journey, I have published 13 articles in reputable journals, three of which are from my dissertation work.

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Abbreviation

ADG	Average daily gain
AH	Albumen height
AW	Albumen weight
BKM	Back muscle
BRM	Breast muscle
BWC	Body weight change
C	Control/basal diet
C+1	Control diet plus 1g/kg <i>Phytolacca dodecandra</i> (Endod)
C+2	Control diet plus 2g/kg <i>Phytolacca dodecandra</i> (Endod)
DFI	Daily feed intake
DM	Dry matter
DR	Dominant Red Barred
DS	Dominant Sussex
DSM	Drumstick muscle
EDTA	Ethylenediaminetetraacetic acid
EL	Egg length
EW	Egg weight
EWD	Egg width
FBW	Final body weight
FCR	Feed conversion ratio.
GZM	Gizzard muscle
H×H	Horro × Horro
H×K	Horro × Koekoek
H×Ku	Horro × Kuroiler
Hb	Hemoglobin
HU	Haugh
IBW	Initial body weight
NaT	Naked-neck (male) * Tetra H (female)
NfT	Normal-feathered (male) * Tetra H (female)
ThT	Tetra H (male) * Tetra H (Female)

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Comparative studies on performance and carcass traits of naked neck, normal-feathered, tetra-h chicken genotypes, and their crossbreeds in southwest Ethiopia

Abstract

This study consisted of two independent experiments carried out in Southwest region, Ethiopia. In the first experiment the effect of genotype on fertility and hatchability, growth performance, and carcass traits were assessed from the naked-neck, normal-feathered, and Tetra H chicken genotypes. For this study, a total of 135 day-old chicks, with 45 chicks from each genotype, were divided into 9 replicates (15 chicks per replicate) in a completely randomized design. The chicks were fed the same commercial starter, grower, and layer ration for 40 weeks. Data collection for growth, fertility, hatchability, morphometric, and carcass traits took place during the first 18 weeks of age, while the reproductive and productive performances and egg quality traits were evaluated between weeks 20 and 40. Statistical analysis using SAS software and one-way analysis of variance were employed to analyze the data. In the second experiment, the effect of genotype and addition of phytolacca dodecandra (Endod) up to 2g/kg on growth performance, carcass traits, blood profiles, and breast meat quality were evaluated during 18 weeks of age. In this experiment, a total of 360 unsexed chicks were assigned into nine groups with 40 chicks in each group, and each group was replicated four times with 10 chicks in each replicate. The study employed a 3 × 3 factorial design, consisting of three genotypes and three diets, namely standard commercial ration/control (C), phytolacca dodecandra 1g/kg (C+1), and phytolacca dodecandra 2g/kg (C+2). The data were analyzed using the general linear model in R, a two-way analysis of variance (ANOVA) was conducted. The Tukey standard range test was used to compare means, with a significance level of ($P < 0.05$). The results showed that daily feed intake, daily weight gain, and final body weight of the Tetra H genotype were significantly higher ($P < 0.05$) than the naked-neck and normal-feathered. The feed conversion ratio of the Tetra H genotype (3.76) was significantly lower ($P < 0.05$) than the naked-neck (5.6) and normal-feathered (6.1) genotypes, indicating the Tetra H was better in feed conversion efficiency. The Tetra H genotype had significantly higher body length, chest width, keel bone length and carcass traits such as carcass weight, breast, drumstick, and thigh muscle than the naked-neck and normal-feathered genotypes.

*The reproductive and productive performance traits indicate that the Tetra H hen exhibited significantly superior body weight, feed consumption, hen-housed egg production, egg mass, and a lower (better) feed conversion ratio compared to the other genotypes. The egg quality traits indicated the Tetra H genotype demonstrated better characteristics except for yolk width and color. In the second experiment, the results showed that diet and genotype*diet interactions significantly influenced performance parameters, with the 1g/kg Endod supplementation demonstrating better results compared to the other. Genotype also affected dressing percentage and various carcass components, with the naked-neck * Tetra H cross showing higher values. Supplementation improved dressing percentage and breast muscle compared to the control. Blood parameters were significantly influenced by genotype, diet, and their interaction. It increased protein levels and reduced cholesterol and triglyceride levels in the blood. Incorporating 1g/kg of phytolacca dodecandra (Endod) into the diet improved protein content and reduced fat content in the breast muscles. Thus, these findings contribute to the advancement of more efficient breeding programs for these chicken genotypes by providing valuable insights into their performance and egg quality. The study concluded that the Tetra H genotype is ideal for meat production due to its superior growth performance, body size, carcass traits, and feed conversion efficiency. The indigenous genotypes exhibited better fertility, hatchability, and livability. Adding up to 2g/kg phytolacca dodecandra (Endod) to chicken feed can enhance performance, carcass traits, blood profiles, and breast meat protein levels. Further investigations are recommended to confirm cross-breeding and adaptation of those genotypes in various agroecologies. Assessing Endod effects on various chicken genotypes, optimum dosage, and duration, evaluating consumer health and economic efficiency, and exploring underlying mechanisms are recommended.*

Keywords; *Blood profiles; Body weight gain; Breast meat; Egg mass; Feed conversion ratio; Phytolacca dodecandra; Proximate compositions; Reproductive performances.*

1. CHAPTER ONE

1.1 INTRODUCTION

In many developing countries, the livestock sector in general and chicken production in particular plays a critical role in supporting the national economy by providing essential sources of nutrition, income, and employment opportunities (Khanal *et al.*, 2022). The growth and transformation of the sector provide huge opportunities for agricultural development, poverty reduction, and food security gains (FAO, 2018). The global population is expected to reach 8.5 billion in 2030 (UN, 2019). The demand for meat and eggs is predicted to increase in line with rising incomes, urbanization, and population growth. Poultry production could be one of the best agricultural options that could sustainability achieve food security and serve smallholder income sources within a short period (Wong *et al.*, 2017). This will likely lead to further expansion of the global poultry industry (Mottet & Tempio, 2017). It was predicted that 153.8 million tons of poultry meat will be produced globally in 2031, an increase of 16% over 2022 and accounting for roughly 47% of all meat produced globally (FAO, 2022). Consumer interest in poultry meat production has developed as a result of several significant and advantageous qualities of poultry meat, such as its accessibility, source of protein, suitability for processing, and lack of religious prohibitions on consumption (Michel *et al.*, 2011; Wessels *et al.*, 2021). Poultry is often preferred as a source of protein, especially in underdeveloped nations, due to its affordability, high-quality protein content, and minimal conflicts with religious beliefs (Farrell, 2013; Mottet & Tempio, 2017).

The total chicken population in Ethiopia is estimated at 57 million, with 78.85% being indigenous chickens raised primarily by smallholder rural farmers in a scavenging management system. The rest 12.02% and 9.11% of chickens are hybrid and exotic (CSA, 2021). Indigenous chickens, which are mostly kept by smallholder rural communities, are chosen for their adaptive characteristics either naturally or by farmers who keep them and are frequently poor in egg production, late maturation, and extended broodiness (Negassa *et al.*, 2014). A previous study showed that indigenous naked-neck chicken locally known as “*Angete Melata*” (Melesse *et al.*, 2010) has a good heat dissipation mechanism is well

adapted to harsh environments and poor nutrition, and is highly resistant to disease, and is superior to indigenous normal-feathered and exotic egg-type or exotic naked-neck counterparts in terms of growth rate, egg production, egg, and meat yield traits (Islam & Nishibori, 2009). The Tetra H chicken genotype is a dual-purpose rural hybrid chicken that originated in Hungary and is popular in Europe and neighboring countries. It is characterized by calm characteristics, straw and wheat-colored feathers with black tail feathers. Its heavy weight with good conformations makes the chicken ready for slaughter at 10-12 weeks of age with a body weight over 1.6 kg, while females start egg-laying at 21-22 weeks of age (Guide, 2013; Gerzilov *et al.*, 2018).

Growth is defined as the process by which farm animals increase in size or weight over time until they reach maturity (Lawrence *et al.*, 2012). Several conformation traits have also been shown to predict chicken body growth, market value, and body dimension traits are also used to predict the carcass weight of chicken (Attrouny *et al.*, 2021). Chicken morphometric traits like body and shank length have a significant impact on growth performance as they are correlated with the live weight of the chicken (Fayeye *et al.*, 2017).

Poultry meat is a highly nutritious food that contains essential amino acids as well as micronutrients such as minerals and vitamins. It contains less cholesterol than red meat and is considered a healthy, safe, and affordable source of animal protein for poor farmers (Shafiq *et al.*, 2022). Carcass traits such as carcass weight, thigh, drumstick, and breast were studied to provide useful information to consumers and to improve chicken husbandry in the future (Abioja *et al.*, 2020; Shafiq *et al.*, 2022). As a result, producers benefit from reliable evidence on carcass traits in predicting meat yield and assessing market return.

Indigenous chickens can be improved through selection and crossbreeding, leading to increased productivity and income for farmers in developing nations (Wayas *et al.*, 2015). African countries, like Ethiopia, utilize crossbreeding methods to enhance egg and meat production (Leroy *et al.*, 2016). In the last few decades, the Ethiopian government has imported over 20 different exotic chicken breeds to improve the indigenous breeds through crossbreeding, and this has proven advantageous for both small and large-scale farming practices (Chebo *et al.*, 2022). Breeds such as white leghorns, Rhode Island Reds, Fayomi, Bovans, Sasso, Koekoek, and Tetra H have been introduced (Tadele *et al.*, 2023).

Consequently, the development of selective breeding, such as the Horro chicken breed, and synthetic breed (DZ-White), has resulted in improved performance both on farms and research stations (Chebo *et al.*, 2022). Numerous studies have shown that crossbreeding improves the productive and reproductive performances of chicken genotypes (Padhi, 2016; Tadele *et al.*, 2023). Because of the ongoing population growth and desire for high-quality protein in developing nations, the chicken industry has received a lot of attention and is anticipated to satisfy the community's requirements in a relatively short period (Geleta *et al.*, 2013; Melesse, 2014). Many variables affect egg production, including poultry strain, nutrition, mortality, culling, health and management practices, age at first lay, peak lay, and lay persistency (Farooq *et al.*, 2002; Amin & Nawawi, 2013).

Egg quality traits, on the other hand, refer to various features of an egg that determine its suitability for human consumption (Sreenivas *et al.*, 2013; Kumar *et al.*, 2022). In developed nations, eggs are sold based on several parameters that determine the price of eggs (Berkhoff *et al.*, 2020). The egg quality parameters are of great importance for egg industries which determine the grading, price, hatchability, chick weight, and consumer preferences (Farooq *et al.*, 2002; Sreenivas *et al.*, 2013; Kumar *et al.*, 2022), and due to these, the poultry breeding industries are more focused on egg quality traits. Several studies carried out in Ethiopia and other parts of the world provided poultry breeders and researchers with enormous opportunities. As a result, (Guide, 2013; Padhi, 2016; Tadele *et al.*, 2023) evaluated the egg quality traits of indigenous chickens and observed the potential of these genotypes for future improvements. Similarly, Fereja *et al.* (2016) and Assefa *et al.* (2019) examined local and exotic chicken egg quality traits and discovered the presence of genetic variations among the chicken genotypes. Thus, evaluating egg quality is crucial for maintaining good egg production (Nolte *et al.*, 2021).

However, prevalent diseases and the lack of affordable antibiotics have posed a challenge in maintaining the performance of certain chicken breeds (Leroy *et al.*, 2016). In recent years the use of herbal medicine has increased in livestock production due to the side effects of modern drugs, the high input costs, toxic residues in food, and microbial resistance (Kuralkar & Kuralkar, 2021). Due to these reasons, many countries have banned the use of antibiotics in livestock production (Jessika & John, 2020). The antibacterial

effects of numerous medicinal plants have been demonstrated in many human laboratory experiments (Amanpour *et al.*, 2015). Herbal extracts have beneficial effects as they increase feed intake, improve digestibility, stimulate the immune system, and have anthelmintic properties (Mudalal *et al.*, 2021). Chicks given a diet with 5g/kg of herbal mixture powder had higher body weight and weight gain than other groups (Ashour *et al.*, 2020). This aligns with prior research by Ansari *et al.* (2012), which showed that chickens supplemented up to 2.5g/kg of *Azadirachta indica* leaf meal had higher PCV, RBC, and Hb levels. *Phytolacca dodecandra* is one of the most commonly used herbal plants in Ethiopian traditional medicine for the treatment of liver and other diseases (Malede *et al.*, 2020). The plant has been used as a viable treatment for various diseases, such as malaria, rabies, ascariasis, and skin disorders, in many parts of Africa (Desta & Abd, 2021). The local communities use the leaves of the *Phytolacca dodecandra* (Endod) plant to treat poultry diseases like diarrhea (Wodegebriel *et al.*, 2018).

A lack of emphasis on improving or conserving indigenous chicken populations in the remote Kaffa Zone poses challenges for future breeding and improvement strategies. Specifically, there is a lack of information on the performance traits of two genotypes, Naked-neck and normal-feathered chickens, which may have genetic originality. This absence of data also hinders the commercialization of the Tetra H chicken genotype under on-station conditions. Additionally, although the plant *Phytolacca dodecandra* is abundant in Ethiopia, its potential usage in animal feed, particularly poultry nutrition, remains unexplored. This study aims to address these issues by evaluating the performance and carcass traits of the naked neck, normal-feathered, and Tetra-H chicken genotypes, as well as their crossbreeds, in the Southwest region of Ethiopia. By utilizing locally available plants like *Phytolacca dodecandra*, the study aims to provide valuable information for future breeding and improvement strategies, benefiting rural communities and reducing reliance on synthetic antibiotics in livestock production.

1.2 OBJECTIVES

General objective

- To evaluate the performance and carcass traits of the naked neck, normal-feathered, and Tetra-H chicken genotypes, as well as their crossbreeds, in Kaffa Zone Southwest Ethiopia.

Specific objectives

- To investigate the effect of genotype on fertility, hatchability, reproductive and productive performance of the chicken genotypes.
- To investigate the effect of genotype on growth performance and morphometric traits of the chicken genotypes.
- To investigate the effects of genotype on carcass traits and egg quality traits of the chicken genotypes.
- To investigate the effect of *phytolacca dodecandra* (Endod) supplementation on growth performance, carcass traits, blood profiles, and breast meat quality of the naked-neck and normal-feathered crosses with the Tetra H chicken genotype.

2. CHAPTER TWO

2.1 LITERATURE REVIEW

2.1.1 Fertility and hatchability of indigenous, exotic, and crossbred chickens

Table 1 shows the fertility and hatchability of eggs from several chicken genotypes. The indigenous chicken demonstrated better fertility than the exotic and crossbred chicken under improved management conditions. The study reported by Wolde *et al.* (2021), stated the indigenous local chicken genotype had 17.7% and 21.3% higher fertility than the LSR cross and SRSR, respectively, however, the crossbred chicken had 8.23% and 16.3% higher fertility and hatchability percentage than the exotic genotype. Bekele *et al.* (2021) reported from Gambella indigenous chicken ecotypes they observed 83.6% of the average fertility of eggs collected from farmers. However, the study reported by Tunsisa & Reda (2023) resulted in 78.2% fertility of eggs from indigenous chickens under scavenging management conditions. However, among the different poultry genotypes, the Guinea fowl was found to perform the lowest in fertility and hatchability under an intensive management system (Zelege *et al.*, 2020).

The fertility and hatchability percentages observed from the Fayomi crossbred chicken is better than the exotic and RIR cross (Alewi *et al.*, 2013). Likewise, the hatchability percentage reported on a total egg basis from the crossbred chicken was higher than the exotic chicken genotype (Bekuma & Tadesse, 2022). Similarly, Abdurehman & Urge (2016), observed the fertility and hatchability percentages in the crossbred chicken were higher than the exotic chicken genotype. Hatchability from fertile eggs was higher in the naked neck cross with white leghorn (90.6%) than in the RIR (87%), Fayumi (84.6%), Desi (82.6%), and least (55%) in Aseel crosses (Ahmed *et al.*, 2012). Another study, reported from Nigeria by Amao (2017) found that the fertility and hatchability of RIR x NN chickens were better than the pure line and this agrees with the results reported by several scholars in Ethiopia (Lemlem & Tesfay, 2010; Tunsisa & Reda, 2023). Consistent with these, the crossbreeding between RIR and Fayoumi resulted in better hatchability, indicating that crossbreeding could improve chicken hatchability (Islam & Nishibori, 2010).

Table 1. Fertility and hatchability of Indigenous, exotic, and crossbred's chickens in Ethiopia

Genetic resources	Rearing system	Fertility (%)	H set egg (%)	H fertile egg basis (%)	References
Indigenous	Scavenging	78.2	63.1	84.1	Tunsisa & Reda (2023)
Exotic		-	64.53	-	Bekuma & Tadesse (2022)
Crossbred		-	73.1	-	
Fayoumi		-	67.9	-	
SRSR	Intensive	75.6	-	55.9	Wolde <i>et al.</i> (2022)
LSR		77.9	-	68.6	
LL		91.7	-	80.0	
AB	Scavenging	89.1	82.3	89.1	Getachew <i>et al.</i> (2021)
GKZ		85.5	76.8	85.5	
IT		81.4	68.6	81.4	
LA		78.2	67.3	78.2	
Guinea fowl	Intensive	56.7	-	56.9	Zelege <i>et al.</i> (2020)
Tilili		95.6	-	81	
Horro chicken		98.9	-	88.9	
Koekoek		92.2	-	86.7	
Indigenous	Scavenging	-	82.2	-	Edmew <i>et al.</i> (2018)
Exotic	Scavenging	66.7	51.1	76.9	Abdurehman and Urge (2016)
Cross		72.2	64.5	89.4	
Indigenous		74.5	67.8	91.5	
Local kei	Intensive	73.4	59	-	Melesse <i>et al.</i> (2013)
Fayoumi cross		85.8	73.7	-	
RIR cross		80.5	54.7	-	
Horro	Intensive	77	43.8	62.6	Wondmeneh <i>et al.</i> (2011)
Fayoumi		91.4	81.9	86.6	
Lohmann silver		85.6	68.8	77.7	
Koekoek		77.7	79.9	83	
Indigenous	Scavenging	-	78.6	-	Lemlem & Tesfay (2010)
RIR		-	39.3	-	
White Leghorn		-	76.1	-	

SRSR, Sasso-RIR; LL, normal-feathered local; LSR, Sasso-RIR cross with normal-feathered local; AB, Abobo; GKZ, Gambella Ketema Zuria; IT, Itang; LA, Lare; H, Hatchability

2.1.2 Growth performance of indigenous, exotic, and crossbreed chickens in Ethiopia

Table 2 shows the growth performance of indigenous normal-feathered, exotic, and crossbred chickens. The study conducted to compare the growth performance of exotic and their crossbred chicken indicated that the male NC chicken genotype had significantly higher body weight (2934.4 g) and better FCR (2.36) than the other genotypes at 16 weeks of age (Ibrahim *et al.*, 2019). In another study, the exotic KK chicken, on the other hand, was found to perform better than the other chicken ecotypes in terms of body weight, average daily gain, and mortality rate, while the Tilili ecotype was better in feed conversion ratio than the other chicken ecotypes (Zelege *et al.*, 2020). The body weight of KK (2021.6 g) was 57.2% higher than GF, 31.4% from Horro, and 29% from Tilili ecotypes. On the other hand, the performance variables like daily gain, feed conversion ratio, and mortality rate were better in the KK than in the other chicken ecotypes under intensive management (Zelege *et al.*, 2020).

The body weight of female naked neck chickens kept at normal temperature was 952 g and 1273 g at 20 and 65 weeks of age, respectively (Melesse *et al.*, 2011). These results are significantly lower than the values reported by Adomako *et al.* (2014), who reported 1895.8 g and 2086 g for the F1 and F2 naked neck chicken genotypes at 20 weeks of age, respectively. In another study, Alam *et al.* (2021) reported the body weight of a naked neck chicken was 1.35 kg at 20 weeks of age. However, Shafiq *et al.* (2022) observed the body weight of four naked-neck chicken phenotypes and reported higher (441.5 g) in the light brown phenotype, indicating the existence of genetic diversity among the phenotypes. In agreement with this, the study reported from India demonstrated, that the naked neck chicken had significantly higher body weights compared to normal-feathered chickens (1,191.09 g and 972.08 g) in winter and summer seasons (Rajkumar *et al.*, 2011). On the other hand, studies conducted to evaluate the performance of the naked neck and their crosses on body weight gain showed that the naked neck had a higher final body weight (1654.87 g) than the naked neck cross (1461 g) at 40 weeks of age (Saleem *et al.*, 2014). Consistent with this, numerous studies demonstrated that the naked-neck chicken genotype

had better growth, weight gain, feed intake, and feed efficiency than their normal feathered counterparts (Islam & Nishibori, 2009; Adomako *et al.*, 2014; Kitso *et al.*, 2018).

The study conducted to compare the performance of exotic layer breeds demonstrated that Novo Brown chicken performed better than the other chickens in terms of body weight, ADG, FCR, and reduced mortality rate at 20 weeks of age (Yigzaw & Abate, 2020). The results reported by Wolde *et al.* (2021), suggest that the body weight of local normal-feathered chicken at 18 weeks of age (1070 g) was 75.4% lower than the Sasso RIR and 28.9% lower than the local normal-feathered crossed with the Sasso RIR (1379 g) chickens.

The results reported from Hawassa University in Ethiopia using the indigenous naked neck and local white cross with Rhode Island Red and Fayoumi chicken breeds resulted in the Fayoumi cross with a naked neck having higher weight gain at 4 months of age than the Rhode Island Red Cross with local white and the pure line (Fassill *et al.*, 2010). Likewise, Negash *et al.* (2023) reported among the reciprocal crosses, Fayoumi and Sasso performed better than the remaining seven genotypes. On the other hand, Hussen *et al.* (2018) investigated the performance of Horro ecotype (H) and Dominant Red Barred D 922 (DRB) chicken crosses, they found that DRBxH crosses with Horro ecotype in dam line resulted in higher growth rates than the pure line. Similarly, Taye *et al.* (2022) studied the effect of crossbreeding on performance traits and concluded that the Horro x Kuroiler crossbred chicken was found to perform better than the other genotypes.

Table 2. The growth performance of indigenous, exotic, and crossbreed chickens in Ethiopia

Genetic resources	Age	BW	ADG	FCR	Mortality	References
Lohmann	20 week	1830 g	-	-	1.28	Bekele <i>et al.</i> (2023)
Guinea fowl		1286 g	9	6.9	6.7	
Tilili		1567.1 g	11	5.4	9.3	Getnet <i>et al.</i> (2022)
Horro local	20 week	1538.5 g	10.8	5.6	9.3	
Koekoek		2021.6 g	14.2	6	5.3	
Sasso RIR		1877 g	16.4	5.53	13.3	
Local * Sasso RIR	18 week	1379 g	11.3	6.95	15.1	Wolde <i>et al.</i> (2022)
Normal-feathered		1070 g	8.83	7.61	17.7	
Female hybrid						
DR		1764.5 g	77	3.76	-	
DS		1753.3 g	52.5	3.85	-	
KK	16 week	1626 g	85.6	4.08	-	Ibrahim & Goshu (2020)
LB		1692.5 g	73.3	3.77	-	
NB		1705 g	74.1	3.18	-	
NC		1576.7 g	88.9	3.54	-	
Novo Brown		1400 g	10.46	6.4	3.5	
Dominant Sussex	20 week	1300 g	9.93	7.16	5	Mebratu <i>et al.</i> (2020)
Lohmann Brown		1200 g	10.13	6..8	21	
DRB ^A *DRB		1645.4 g	-	4.21	14.5	
H ^A *H	20 week	1198.6 g	-	6.29	4.27	Woldegiorgiss & Abegaz (2018)
DRB ^A *H		1602.9 g	-	5.12	11.9	
H ^A *DRB		1490.4 g	-	5.45	2.5	
Local kei		929 g	-	-	-	
Fayoumi cross	24 week	1000 g	-	-	-	Melesse <i>et al.</i> (2013)
RIR cross		1148 g	-	-	-	
Female chicken						
Naked-neck	20 week	952 g	-	-	-	
Lohmann white	20 week	1353 g	-	-	-	
New Hampshire		1575g	-	-	-	Melesse <i>et al.</i> (2011)
Na F1 * LW		1169 g	-	-	-	
Na F1 * NH		1259 g	-	-	-	
Fayoumi female		1200 g	-	-	35.3	
Indigenous female	77 week	1400 g	-	-	52	Lemlem & Tesfay (2010)
RIR female		1900 g	-	-	16.3	
Leghorn female		1200 g	-	-	21.3	

DR = Dominant Red Barred; DS = Dominant Sussex; KK = Koekoek; LB = Lohmann Brown; NB = Novo Brown; NC = Novo Color. RxK = Dominant Red Barred hens × Koekoek males; SxR = Dominant Sussex hens × Dominant Red Barred males; KxS = Koekoek hens × Dominant Sussex males; BW, Body weight; ADG, Average daily gain; FCR, Feed conversion ratio

Table 2. *Continued....*

Genetic resources	Age (week)	BW (g)	ADG (g)	FCR	Mort. (%)	References
H*H		1041.9	12.05	3.83	-	
H*K		1256.9	14.58	3.18	-	
K*H		1253.9	14.54	3.03	-	
K*K		1302.2	15.14	2.80	-	Taye <i>et al.</i> (2022b)
H*Ku	12 week	1665.8	19.38	3.21	-	
Ku*H		1461.9	17.63	2.82	-	
Ku*Ku		1652.9	19.23	2.38	-	
Horro		1416	14.4	5.46	4.48	
Koekoek	16 week	1734.4	19.3	5.05	8.89	
Kuroiler		2730.9	28.9	4.40	9.86	Biazen <i>et al.</i> (2021)
Sasso R		1845.4	21.5	4.90	2.30	
DR		1821.7	-	3.67	-	
R*K		2024.2	-	3.46	-	
DS		1567.2	-	4.28	-	
S*R		1351.7	-	4.17	-	Ibrahim <i>et al.</i> (2019)
KK	16 week	2057.8	-	3.40	-	
K*S		1959.2	-	3.59	-	
LB		1762.8	-	3.81	-	
NB		2418.9	-	2.91	-	
NC		2934.4	-	2.36	-	

DR = Dominant Red Barred; DS = Dominant Sussex; KK = Koekoek; LB = Lohmann Brown; NB = Novo Brown; NC = Novo Color. RxK = Dominant Red Barred hens × Koekoek males; SxR = Dominant Sussex hens × Dominant Red Barred males; KxS = Koekoek hens × Dominant Sussex males; H×H: Horro × Horro, H×K: Horro × Koekoek, K×H: Koekoek × Horro, K×K: Koekoek × Koekoek, H×Ku: Horro × Kuroiler, Ku×H: Kuroiler × Horro, Ku × K: Kuroiler × Kuroiler; BW, Body weight; ADG, Average daily gain; FCR, Feed conversion ratio

2.1.3 Reproductive and productive performances of indigenous, exotic, and crossbreed chickens in Ethiopia

The Bovans Brown chicken breeds are one of the suitable genetic resources available in Ethiopia and can produce higher eggs when reared under urban and peri-urban as well as under scavenging management systems compared with the other chicken genotypes (Table 3). The Bovans Brown can lay around 240 eggs/hen/year under improved management conditions (Aderaw *et al.*, 2021). If the Bovans Brown chicken is maintained under scavenging management conditions the egg production performance could be reduced to 117 eggs/hen/year (Assefa *et al.*, 2019). The Sasso chicken breed was found to be better under farmers' management conditions and can produce around 181 eggs/hen/year (Bekuma & Tadesse, 2022). However, the local chicken genotypes are known to produce

few eggs (40.5-54.6 eggs/hen/year) compared with those of exotic and hybrid chickens available in Ethiopia (Assefa *et al.*, 2019; Edmew *et al.*, 2018; Lemlem & Tesfay, 2010; Melesse, Alewi, *et al.*, 2013).

The annual egg production of Koekoek chickens in Ethiopia was 187 eggs per hen/per year (Tadesse *et al.*, 2013). However, under farmer conditions, egg production was reduced to 138 eggs per hen per year (Assefa *et al.*, 2019). The egg production of exotic Kuroiler, Sasso, and Sasso R was found to be low (100-112.8 eggs/hen/year), which were reported from Achefero Woreda under farmer's management conditions (Kassa *et al.*, 2022). These variations could be due to genetic variability, availability of scavenging feed resources, and management of the households. In other studies, comparing the performance of Horro ecotype (H) and Dominant Red Barred D 922 (DRB) chicken crosses demonstrated that, the DRBxH crosses with the Horro ecotype in the dam line produced more eggs than the KK, LB, NB, NC, LD and HH chicken breeds. These crosses improved chicken egg production performance in 19 more eggs (Kedija *et al.*, 2018). The hen day egg production performance reported in Ethiopia of 86.7, 85.1 and 81.8% for Sasso, Kuroiler, and Sasso R, respectively was higher than those reported by Ibrahim and Goshu (2020), who reported 41.9-56.1 for hybrid chicken. The DR, NB, and NC hybrid chicken genotypes were able to attain the age at first egg earlier than the other chicken genotypes when maintained under intensive management systems (Ibrahim and Goshu, 2020). However, Melesse *et al.* (2013), reported delayed sexual maturity (154-183 days) of local Kei, Fayoumi, and RIR crossbreed chickens under intensive management systems.

Table 3. Reproductive and productive performance of indigenous, exotic, and crossbred chickens in Ethiopia

Genetic Resources	Rearing system	Laying Period	Sexual maturity (d)	Egg no	Hen day egg (%)	EggWeig ht (g)	Mortality rate (%)	References
Bovans brown			164.3	189.3	-	-	-	
Sasso	Scavenging	52 week	173.7	180.9	-	-	-	Bekuma & Tadesse (2022)
Crossbred			182.2	118.9	-	-	-	
Kuroiler female	Scavenging		-	111.8	85.1	43.8	11.6	
Sasso female	Achefere	20 week	-	112.2	86.7	42.5	10	Kassa <i>et al.</i> (2021)
Sasso R female	Woreda		-	100	81.8	44.9	14.1	
Bovans	Urban		149.1	240.1	-	-	7	
Bovans	Peri-urban	22 week	152.5	232.3	-	-	7.8	Litigebew <i>et al.</i> (2021)
Sasso T44	Urban		172.5	-	-	-	3.75	
Sasso T44	Peri-urban		168	-	-	-	3.92	
DR			119	-	45.7	57.8	-	
DS			128.3	-	41.9	58.3	-	
KK	Intensive	16- 48 week	124.6	-	45.9	50.9	-	Dawud <i>et al.</i> (2020)
LB			127.8	-	49.6	56.7	-	
NB			119	-	56.1	57.1	-	
NC			112	-	47.3	59.2	-	
Local			238	49.1	-	-	-	
Sasso	Scavenging	52 week	155	133	-	-	-	
Bovan brown			157	117	-	-	-	Assefa <i>et al.</i> (2019)
Koekoke			174	138	-	-	-	
Indigenous	Scavenging	52 week	193.5	54.6	-	43.9	-	Edmew <i>et al.</i> (2018)
Local kei			183	-	40.5	38.3	12.5	
Fayoumi cross	Intensive	52 week	154	-	114	40	6.25	Melesse <i>et al.</i> (2013)
RIR cross			161	-	99.8	44.2	18.8	

DR = Dominant Red Barred; DS = Dominant Sussex; KK = Koekoek; LB = Lohmann Brown; NB = Novo Brown; NC = Novo Color

Table 3. *Continued...*

Genetic Resources	Rearing system	Laying Period	Sexual maturity (d)	Egg no	Hen day egg (%)	EggWeight (g)	Mortality rate (%)	References
Lohmann	Intensive	29 week	141	-	58.6	60	1.28	Bekele <i>et al.</i> (2023)
H*H			156	43.3	30.9	-	-	
H*K			150.3	53.7	38.3	-	-	
K*H	Intensive	21-40	136.8	67.3	50.4	-	0.11	Taye <i>et al.</i> (2022a)
K*K		week	145.3	61.5	43.9	-	-	
H*Ku			135	75.5	53.9	-	0.06	
Ku*H			139.3	75	53.7	-	0.20	
Ku*Ku			141.8	68.4	48.9	-	-	
DR			140	150.6	58.7	58.6	-	
R*K			154	151.1	62.8	55.6	-	
DS			157.5	126.8	52.5	58.2	-	
S*R			156.3	131.9	55.7	58.4	-	
KK		16-60	143.5	139	55.3	51.7	-	Ibrahim <i>et al.</i> (2019)
K*S	Intensive	week	151.7	162.3	62.2	55	-	
LB			128.3	181.8	68	57.5	-	
NB			123.7	158.8	65.9	57.7	-	
NC			119	157	56.4	62.3	-	
LD			135.3	123	45	56.7	-	
Fayoumi			231	144	-	43	35.3	
Indigenous	Intensive	77 week	-	54.3	-	42.2	52	Lemlem & Tesfay (2010)
RIR			239	185	-	52.5	16.3	
White Leghorn			245	173	-	52.1	21.3	

DR = Dominant Red Barred; DS = Dominant Sussex; KK = Koekoek; LB = Lohmann Brown; NB = Novo Brown; NC = Novo Color. RxK = Dominant Red Barred hens × Koekoek males; SxR = Dominant Sussex hens × Dominant Red Barred males; KxS = Koekoek hens × Dominant Sussex males; H×H: Horro × Horro, H×K: Horro × Koekoek, K×H: Koekoek × Horro, K×K: Koekoek × Koekoek, H×Ku: Horro × Kuroiler, Ku×H: Kuroiler × Horro, Ku × K: Kuroiler × Kuroiler; d, days

2.1.4 Egg quality traits of indigenous, exotic, and crossbreed chickens in Ethiopia

Chicken eggs have long been recognized as an important source of nutrition for humans, as well as a nutritional reservoir for the developing embryo (Sun *et al.*, 2019). The egg industry provides a high priority on egg quality characteristics since egg conformation influences grading, price, hatchability, chick weight, and consumer choice (Kumar *et al.*, 2022). From the available chicken genetic resources in Ethiopia, the best egg quality trait in terms of HU was observed in Lohmann chicken (Table 3). The study found that the Lohmann chicken genotype had the highest (97.2%) HU, heaviest egg (60 g), longest (57 mm), and better internal egg quality traits compared to the other chicken genotypes (Bekele *et al.*, 2023). However, several authors reported comparable internal and external egg quality traits of chicken genotypes in Ethiopia (Markos *et al.*, 2017; Tunsisa & Reda, 2023).

The egg weight of different chicken genotypes reported in Ethiopia indicated the presence of significant variations among the genotypes (Table 3). The local chicken genotype was found to be 29.7%, 25.5%, and 17.1% lower egg weight than the Sasso, Bovans Brown, and Koekoke chicken, respectively (Assefa *et al.*, 2019). Likewise, Edmew *et al.* (2018) and Tunsisa & Reda (2023) reported under the scavenging management system the egg weight and egg length of indigenous chicken were found to be similar however, lower HU (61.2) observed from the Bench Maji indigenous chicken populations (Edmew *et al.*, 2018). The study conducted to compare the egg quality traits between the exotic and crossbred chicken in the Chelliya District of Western Shoa demonstrated that the exotic chicken outperformed the crossbred in terms of egg weight and HU, whereas no significant variation was observed in shell thickness (Fereja *et al.*, 2016).

Table 4. Egg quality traits of indigenous, exotic, and crossbred chickens in Ethiopia

Genetic resources	Rearing system	Egg wt	Egg length	Egg width	Shell tick	Yolk weight	Albumen weight	Yolk het	Albumen height	Haugh Unit	References
Lohman	Intensive	60	57	43.2	0.35	16.2	37.3	18.5	9.56	97.2	Bekele <i>et al.</i> (2023)
Indigenous	Scavenging	45.8	52.3	38.21	0.273	16.8	23.6	16.22	5.39	76.84	Tunsisa & Reda (2023)
Bovan brown		50.7	-	-	0.29	-	-	-	-	79.3	
Sasso		52.4	-	-	0.29	-	-	-	-	78.5	
Koekoكة	Scavenging	47.3	-	-	0.28	-	-	-	-	79.6	Assefa <i>et al.</i> (2019)
Local		40.4	-	-	0.28	-	-	-	-	79	
Exotic		52.8	55.5	42	0.33	-	-	17.5	6.3	80.1	
Local	Scavenging	42.9	52.8	39.2	0.31	-	-	15.7	5.80	77.1	Kebede <i>et al.</i> (2019)
Indigenous	Scavenging	43.9	52.1	37.8	0.33	15.1	23.1	14	3.4	61.2	Edmew <i>et al.</i> (2018)
Highland ecotype		43.7	56.4	40.1	-	16.5	22.2	17.2	5.66	79.1	
Midland ecotype	Scavenging	41.2	56.2	38.3	-	15.6	21	14.9	5.65	79	Markos <i>et al.</i> (2017)
Lowland ecotype		36.8	53.8	35.7	-	13.1	19.3	13.5	5.05	78.8	
Crossbred		54.5	-	-	0.29	-	-	-	5.42	74.5	
Exotic	Scavenging	57.9	-	-	0.27	-	-	-	6.94	82.6	Fereja <i>et al.</i> (2016)
Isa Brown	Intensive	64.8	-	-	0.34	16.7	37.2	17.8	6.2	85.3	
Isa Brown	Scavenging	58.9	-	-	0.31	16.1	33.2	17.4	6.3	77.6	
Bovans Brown	Intensive	63.5	-	-	0.35	15.4	35.9	18.6	9.5	87.5	Woldegiorgiss <i>et al.</i>
Bovans Brown	Scavenging	59.3	-	-	0.33	15.9	34.5	18.1	9.9	79.3	(2015)
Koekoكة	Intensive	47.8	-	-	0.29	14.5	26.1	17.6	5.5	78.4	
Koekoكة	Scavenging	47.5	-	-	0.29	15.9	25.1	17.8	5.5	77.3	

wt, weight ; tick, thickness;het, height;

2.1.5 Carcass Traits of Indigenous, exotic, and crossbred chickens in Ethiopia

The results reported from the exotic and local chicken genotypes under an intensive management system indicated that the exotic KK chicken genotype demonstrated a higher slaughter weight over the other chicken genotypes (Table 5). In this study, the KK chicken genotype had 87.1%, 36.94%, and 32.1% higher than the GF, Horro, and Tilili chicken genotypes, respectively (Zelege *et al.*, 2020). Another study conducted on exotic and their crossbred chicken in Ethiopia under an intensive management system demonstrated the NC chicken had a higher slaughter weight (2934.4 g) and the S*R, however, had the lowest slaughter weight (1351.7 g) compared with the other chicken genotypes (Ibrahim *et al.*, 2019). Similarly, Biazen *et al.* (2021) observed the exotic Kuroiler chicken had significantly higher slaughter body weight compared with the other chicken genotypes. Likewise, another study reported from exotic chicken indicated that the Novo brown chicken had a higher slaughter weight compared to the other chicken genotypes (Yigzaw & Abate, 2020). On the other hand, Alemneh *et al.* (2021) under scavenging management conditions the Sasso F1 crossbred chicken had 49.7% higher slaughter body weight compared to the local chicken genotypes in Masha Woreda. Similarly, Kebede *et al.* (2019) reported the exotic chicken genotype had 7.41% higher than the local chicken genotype under scavenging management systems. According to the study conducted by Biazen *et al.* (2021), the dressing percentages were found to be higher compared to the results reported by other scholars (as shown in Table 5). However, it was observed that the exotic Koekoke chicken genotype had a significantly lower dressing percentage compared to the other genotypes reported by Biazen *et al.* (2021).

Likewise, Yigzaw & Abate (2020), reported the exotic Novo Brown chicken had a significantly lower dressing percentage compared to the other. Ibrahim *et al.* (2019), on the other hand, reported NC had a higher dressing percentage compared to the other chicken genotypes. Indigenous chicken has good carcass characteristics, such as relatively high dressing percentages and higher proportions of valuable carcass components (Edmew *et al.*, 2018). Consequently, the dressing percentage reported at Masha Woreda indicated that the indigenous chicken had a 10.6% higher dressing percentage than the Sasso F1 crossbred chicken (Alemneh *et al.*, 2021). Under intensive management systems, the exotic chicken

genotypes have better-dressing percentages than the local chicken genotypes, whereas the local chicken genotype had better dressing percentages under scavenging management conditions.

Table 5. Carcass traits of chickens in Ethiopia

Genetic resources	Rearing system	Slaughtered age (week)	Slaughter weight	Dressing percentage	References
Guinea fowl			1308.3 g	73.8	
Tilili	Intensive	20 week	1853.9 g	74.8	Zelleke <i>et al.</i> (2022)
Horro chicken			1788 g	73.2	
Koekoek			2448.4 g	72.2	
Local (Masha woreda F1- cross (Masha))	Scavenging	52 week	1605 g	73.8	
			2403 g	66.7	
Horro	Intensive	16 week	1334.5 g	80.5	Biazen <i>et al.</i> (2021)
Koekoke			1689.3 g	79.1	
Kuroiler			2716.3 g	81.0	
Sasso R			2285.6 g	80.7	
Novo Brown	Intensive	20 week	1690 g	50.6	Yigzaw <i>et al.</i> (2020)
Dominant Sussex			1540 g	53.6	
Lohmann Brown			1543 g	53.5	
<i>DR</i>	Intensive	16 week	1821.7 g	67.0	Ibrahim <i>et al.</i> (2019)
<i>R*K</i>			2024.2 g	68.1	
<i>DS</i>			1567.2 g	67.6	
<i>S*R</i>			1351.7 g	64.0	
<i>KK</i>			2057.8 g	68.1	
<i>K*S</i>			1959.2 g	68.5	
<i>LB</i>			1762.8 g	67.3	
<i>NB</i>			2418.9 g	69.5	
<i>NC</i>			2934.4 g	70.2	
Exotic	Scavenging	52 week	1784 g	66.8	Kebede <i>et al.</i> (2019)
Local			1661 g	67.2	

DR = Dominant Red Barred; *DS* = Dominant Sussex; *KK* = Koekoek; *LB* = Lohmann Brown; *NB* = Novo Brown; *NC* = Novo Color; *LD* = Lohmann Dual. *RxK* = Dominant Red Barred hens × Koekoek males; *SxR* = Dominant Sussex hens × Dominant Red Barred males; *KxS* = Koekoek hens × Dominant Sussex males

2.1.6 Effects of Medicinal Plants on the Growth Performance of chickens

The contribution of poultry production towards reducing the global food shortage is significant. As a result, the world is now actively seeking natural alternatives to enhance the productivity and immunity of birds (Salem *et al.*, 2022). Due to these reasons, the potential benefits of incorporating certain herbs and plants into broiler chicken diets have been widely studied and documented. For example, thyme herb has been investigated as a dietary supplement for broiler chickens and has been shown to improve body weight gain, and nutrient utilization, and exhibit antimicrobial activity against gastrointestinal microbiota (ELnaggar & El-Tahawy, 2018). The study conducted to assess the impact of nettle extract (0.5–2%) on the growth performance, immune response, and serum biochemistry of broiler chickens showed that, supplementing the broilers' diet with 1% nettle extract increased body weight and reduced (improved) feed conversion ratio compared to the control group at 42 days of age (Safamehr *et al.*, 2012). Similarly, in another study addition of a dietary supplement containing a combination of medicinal plants (1% *oregano*, 0.5% *Ziziphora*, and 0.5% *Peppermint*) resulted in increased weight gain (Narimani-Rad *et al.*, 2011). The inclusion of *Moringa oleifera* leaf meal also resulted in a noticeable impact on factors like feed intake, live body weight, and feed conversion ratio, resulting in significant improvements when compared to the untreated group (Health, 2023).

Likewise, a study conducted by Kiyama *et al.* (2017) indicated that diets containing 24 and 48 mg of lavender extract improved the final body weight of broiler chickens at 39 days of age. Additionally, garlic, known for its bioactive compounds such as *allicin*, *ajoene*, and *diallyl* sulfide, has been found to have positive effects on chicken growth, feed efficiency, and immune response (Ampode, 2019). Accordingly, ginger supplementation was found to result in a greater increase in overall body weight compared to the control group, and when ginger powder was utilized as a supplement, broiler chickens exhibited decreased total feed consumption (Vlaicu *et al.*, 2022). Basil leaf powder on the other hand, when included in chicken diets, has also demonstrated beneficial effects such as improved body weight gain, nutrient absorption, and enhanced immune system due to its antibacterial activities (Sheoran *et al.*, 2017). Similarly, Turmeric, containing the compound curcumin,

exhibits antimicrobial, anti-inflammatory, and antioxidant properties, contributing to improved feed conversion ratio, weight gain, and immune response in chickens (Ahmad *et al.*, 2020). At five weeks of age, the chicks that were given a basal diet supplemented with 5 g of herbal mixture powder/kg had significantly higher values of live body weight and body weight gain compared to the other groups (Ashour *et al.*, 2020).

2.1.7 Effects of medicinal plant supplementation on Carcass traits of chickens

Several studies have highlighted the positive effects of incorporating medicinal plants in the carcass traits of broiler chickens. For instance, a study by Criste *et al.* (2017) showed that including 2% dry oregano and 2% dog rose powder in the diet resulted in significantly higher liver weight and notably larger spleen in the supplemented group compared to the control. Furthermore, Ahmadian *et al.* (2020) found that chickens fed thyme experienced a 41% reduction in abdominal fat, while those fed sumacs saw an even greater reduction of 62%. Herbal plants were also found to positively affect carcass quality by enhancing amino acid absorption, nutrient utilization, and protein metabolism, as outlined by Hernández *et al.* (2010). Similarly, Hristakieva *et al.* (2023) reported that a 2% inclusion of rosemary in the chicken diet led to increased thigh and wing muscle compared to other groups. A study by Mansoub (2011) further confirmed the positive impact of herbal plants on carcass quality, specifically their role in amino acid absorption, nutrient utilization, and protein metabolism, leading to increased breast yield and carcass weight.

2.1.8 Effects of medicinal plant supplementation on blood profiles of chickens

According to a study conducted by Safamehr *et al.* (2012), broiler chickens that were fed a diet containing 1% nettle resulted in a significant decrease in their serum triglyceride and cholesterol concentrations. Similarly, Biswas & Wakita (2001) conducted a study that showed incorporating Japanese green tea powder as a dietary supplement remarkably decreased liver cholesterol, liver fat, and blood serum cholesterol levels. Another study found that the inclusion of composite leaf meal (*Telfairia occidentalis*, *Vernonia Amygdalina*, *Piper quinenses*, and *Ipomea batata*) had a significant effect on triglyceride levels, with an observed decrease as the inclusion of leaf meal increased. This trend was consistent with glucose levels as well, as reported by Onunkwo *et al.* (2022).

2.1.9 Effects of medicinal plant supplementation on breast meat quality of chickens

Zhang *et al.* (2018) investigated the effects of medicinal plant supplementation specifically on breast meat quality. Supplementation of ginger in a broiler diet reduced the fat content in meat (Rivas *et al.*, 2020). Their findings showed improvements in attributes like pH, color, water-holding capacity, and overall sensory characteristics. Furthermore, the study investigating the addition of *Aloe Vera* and *Clove* powder supplements found that it positively influenced breast yield and carcass weight. Importantly, the inclusion of these supplements did not show any detrimental effects on liver health and blood biochemistry (Arif *et al.*, 2022).

CHAPTER THREE

3. METHODOLOGY

3.1 Description of the study area

The research was conducted in Kaffa Zone Bonga town, on a poultry shade located between 6°20' to 8°0' North latitude and 35°1'40' to 37°20' East longitude in Southwest Region, Ethiopia (Figure 1). Kaffa Zone is divided into twelve districts and four administrative towns and situated within an altitude ranging from 500-3000 m.a.s.l. The average annual temperature ranges from 10.1 °C to 27.5 °C. The annual rainfall varies from 1001-2200 mm (Tadele *et al.*, 2018).

All procedures were approved by the College of Veterinary Medicine and Agriculture, Addis Ababa University Ethical Review committee with certificate Ref. No: VM/ERC/02/01/14/2022 (Appendix II).

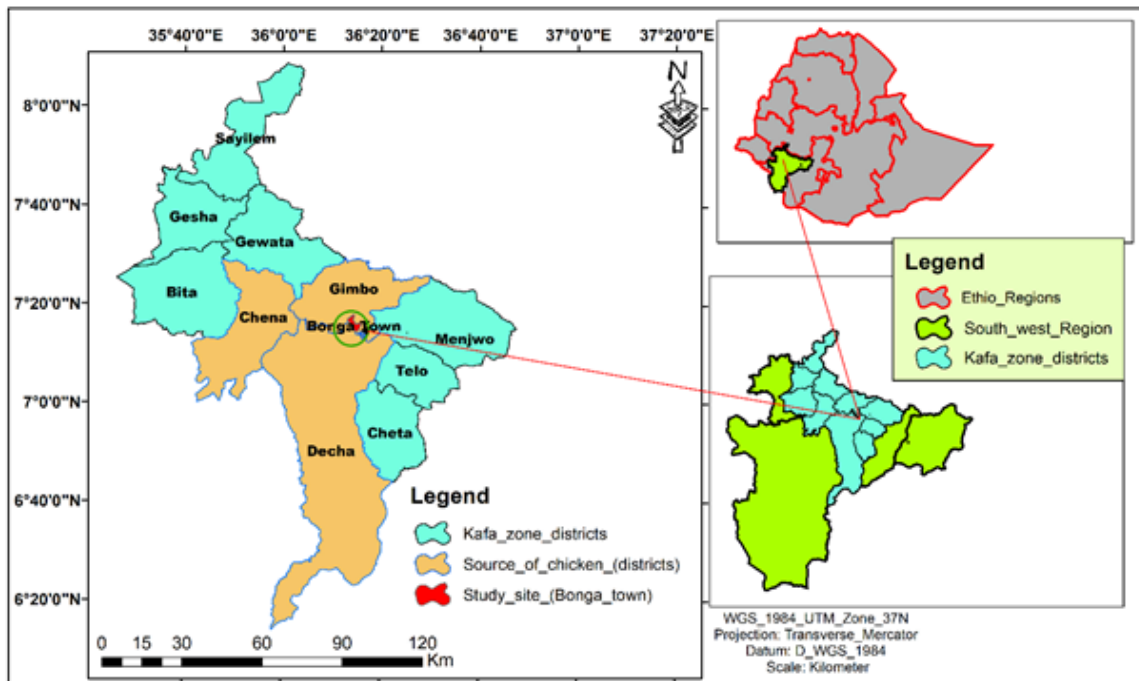


Figure 1. Map of the study area

3.2 Sampling methods

3.2.1 *Breeding strategy to produce experimental chicks*

Based on a previous indigenous chicken population study (Tadele *et al.*, 2018) and in consultations with Zonal and District livestock experts and referring to the FAO (2012) guideline for chicken population selection and characterization, mature (about 10-11 months old), indigenous (normal-feathered and naked neck) chicken were acquired through recalling method of the farmers from selected rural Kebeles of Decha, Chena and Gimbo districts which have been kept under semi-scavenging management conditions. The adult (10 months old) Tetra H chicken genotype was purchased from Bonga small-scale poultry producers, which have also been maintained under semi-scavenging management conditions. Then a total of 153 adult chickens; normal-feathered (n = 51; 12 males and 39 females), naked neck (n = 51; 12 males and 39 females), and Tetra H (n = 51; 12 males and 39 females) were randomly distributed to the three treatment groups to produce a pure lines chicken genotypes. Each treatment group was replicated three times in a completely randomized design (CRD), each making up 13 hens and 4 cocks per a replicate.

The three chicken genotypes were then vaccinated with New castle disease and dewormed against parasites and bacterial diseases. They were provided commercial layer feed and managed under a deep litter housing system for three months and egg collection was started thereafter. The collected eggs were chosen for their uniform size, good shape, and clean shell, and were then stored in a cool room for 7 days and a total of 360 eggs were collected (120 eggs from each chicken genotype) for hatching. Before being set, the hatching eggs were fumigated with potassium permanganate and formalin. Both the setter and Hatcher incubators were washed and fumigated with potassium permanganate and formalin. The setter and hatcher were set to standard relative humidity, temperature, and egg turning to Victoria Incubator of Italy. Each genotype's eggs were placed in the same incubator. Candling was carried out on day 18th to identify and remove infertile eggs, and the rest of the eggs were transferred to the hatcher, which was opened on day 21. The number of hatched chicks was counted separately, and the percentages of fertility and hatchability were computed.

In the second experiment, the base populations were 41 weeks, 108 Tetra H (*dam line*) and 18 cock (sire line; 6 from each genotype, namely; Tetra H, Naked-neck & Normal-feathered), where the same batch of 36 Tetra H hens of average weight managed under intensive management were added to the existing experiment (Tadele *et al.*, 2023a) at 41 weeks of age. They were assigned in a CRD, each treatment group was replicated three times with 12 hens and 2 cocks per replicate and were kept in the ratio of 1:6. They were provided a commercial layer feed (as shown in Table 8) and managed under a deep litter system. Egg collection was started after four weeks of eggs laid by the flock to get well-fertilized eggs. Eggs were selected based on uniform size, shape, and cleanliness and stored in a cool room for 10 days. Then a total of 560 eggs (200 eggs from Tetra H (male) * Tetra H (female); 232 from Naked-neck (male) * Tetra H (female) and 128 from Normal-feathered (male) * Tetra H (female) were collected for incubation. The incubation process followed industry standards (Victoria Incubator of Italy) as indicated above and was conducted at Bonga Poultry Production Center.

Genotypes

The genotypes used in experiment II were the Naked-neck * Tetra H, Normal-feathered * Tetra H, and Tetra H * Tetra H. Table 6 Shows the parents used for crossbreeding to obtain the chicks used for the study.

Table 6. Experimental parents design

Matting design	Abbreviations
Naked-neck (male) * Tetra H (female): Nam*THf	NaT
Normal-feathered (male) * Tetra H (female): NFm*THf	NfT
Tetra H (male) *Tetra H (female): THm*THf	ThT

Collection and preparation of Phytolacca dodecandra (Endod) leaves

Fresh and disease-free *Phytolacca dodecandra (Endod)* leaves were acquired from a nearby village. The leaves were carefully washed with clean drinking water before being laid out to dry on sheets for a week. Upon drying, the stems were removed and the leaves

were crushed by hand and kept as stock for later grinding. Subsequently, all the dried leaves were ground into a fine granular powder using a coffee blender mill (Figure 2).



Figure 2. Preparation of *Phytolacca dodecandra* (Endod) leaf powder

3.3 Experimental Design and Treatments

In the first experiment, immediately after hatching day-old chicks were kept in separate pens designed for the experiment. A total of 135 chicks, were used, with each treatment consisting of 45 chicks (11 females and 4 males in each replicate). The chicks were weighed together using a digital sensitive balance. Each treatment group was replicated three times and arranged in a completely randomized design (CRD). Prior to transferring of chicks to experimental pens, the pens, drinkers and feeders were cleaned, disinfected with formalin and aerated/or well dried. The chicks were reared in a deep litter housing system whose floor was covered with wood shavings at about 5 cm depth. Sufficient management conditions like floor space, light, temperature, ventilation and relative humidity were provided to each of the treatment groups. The chicks were vaccinated against Marek's, Newcastle, Gumboro and fowl typhoid diseases as per the recommended vaccination schedule. The vaccines were purchased from National Veterinary Institute (NVI) Debrezeit and application of the vaccine was as per the NVI prescription. During

the experimental period, chicks were fed *ad libitum* and provided with clean and fresh water. Feed was offered daily in two halves; first, half in the morning while the second half was offered in the afternoon. Feed refusal was measured and recorded while in the event of total usage of feed, an adjustment was made in the feed to allow for about 10% refusal subsequently and provided the same standard commercial ration (as presented in Table 9).

In the second experiment a total of 360 day-old unsexed chicks, with 120 chicks for each genotype, were randomly divided into nine groups, with 40 chicks in each group. Each group was then replicated four times, with each replicate consisting of 10 chicks. This arrangement was based on a 3×3 factorial design, comprising three genotypes (NaT, NfT, and ThT) and three levels of diets: control (basal diet), (c+1) with basal diet plus 1g/kg *Phytolacca dodecandra* (Endod) supplementation, and (c+2) with basal diet plus 2g/kg *Phytolacca dodecandra* (Endod) supplementation (as indicated in Table 8) and all procedures were followed as described above.

3.4 Data collection

3.4.1 Fertility and hatchability percentage

Fertile egg incubation and hatching

Prior to setting the eggs, the incubator was subjected to a 20-minute fumigation process using a potassium permanganate and formaldehyde solution, without the presence of eggs. During the fumigation, it was estimated that for every 1 cubic meter of incubator space (excluding eggs), 4.5 grams of potassium permanganate and 3 grams of formaline were used. Once the eggs were placed inside, the same amount of space required 1.5 grams of potassium permanganate and 1 gram of formaline for fumigation purposes. To maintain optimal conditions, the temperature in the setter was regulated to range between 99.5 and 100 °F (37.6 to 37.7 °C). In the hatchery unit, the temperature was maintained 1 °C lower than that of the setter. Furthermore, the relative humidity levels were carefully controlled. For the first 18 days in the setter, the relative humidity was set between 50-60%, which was then adjusted to 70-75% in the hatchery unit. To ensure uniform development, the eggs were arranged in trays with the small ends facing downward. The trays were periodically tilted at a 45° angle, causing the eggs to rotate 45° in opposite directions from the

perpendicular position, resulting in a total rotation of 90°. This rotation process was automated and occurred every two hours using a turner within the incubator. At the 18th day of incubation, the eggs were assessed for fertility through a method called candling. A bright light source was placed beneath the eggs while observing from above. Fertile eggs appeared relatively opaque due to the developing embryo, whereas non-fertile eggs appeared clear. A total of 360 eggs (120 eggs from each genotype) and 560 eggs in the first and second experiment, respectively were incubated. The fertility and hatchability percentages were computed following the equation provided by Adeleke *et al.* (2012) and Wolde *et al.* (2021).

$$\text{➤ Fertility (\%)} = \frac{\text{Total number of fertile eggs}}{\text{Total egg set}} * 100$$

$$\text{➤ Hatchability on a fertile egg basis (\%)} = \frac{\text{Number of chicks hatched}}{\text{Number of fertile egg}} * 100$$

$$\text{➤ Hatchability on a total egg set basis (\%)} = \frac{\text{Number of chicks hatched}}{\text{Total egg set}} * 100$$

3.4.2 Growth performance parameters

3.4.2.1 Body weight gain

Immediately after the arrival of the chicks, they were weighed in a group using a sensitive balance (initial weight) and then randomly assigned to the respective pens. Then all experimental birds were individually weighed weekly during the experimental period. The body weight gain was computed using the formula provided by Nobo *et al.* (2012).

$$\text{Body weight gain (g/b)} = \frac{\text{Final body weight (g)} - \text{Initial body weight (g)}}{\text{Experimental days}}$$

3.4.2.2 Feed intake

Feed intake was computed by the difference between feed offered and feed refusal. The measured amount of feed was offered throughout the experimental period and feed refusal was collected the next morning at 08:00 am from each pen. The feed offered and refusal was recorded from each pen. Then, the feed intake was computed following the formula given by Nobo et al. (2012).

$$\text{Feed intake (g/b)} = \frac{\text{Feed offered (g)} - \text{Feed refused (g)}}{\text{Experimental days}}$$

3.4.2.3 The feed conversion ratio (FCR) was computed by dividing feed intake by body weight gain following the formula (Yigzaw *et al.*, 2020).

$$\text{Feed conversion ratio (FCR)} = \frac{\text{Feed intake (g)}}{\text{Body weight gain (g)}}$$

$$\text{Mortality rate (\%)} = \frac{\text{Number of dead bird}}{\text{Total number of birds housed}} * 100$$

3.4.3 Morphometric traits

Linear body measurement traits such as chest width (the circumference of the breast region), body length (the distance from the tip of the beak to cauda/tail, without feathers), and shank length (length of the shank from the top of the hock joint to the bottom of the footpad) and shank circumference (measured around the midway of the shank), keel bone length (obtained from sternum to bottom of the keel), were taken following FAO (2012) guidelines.

3.4.4 Carcass yield measurements

At the end of the experimental period (18 weeks), four chickens (two males and two females) per replicate were randomly selected. A total of 36 chickens, 12 chickens per treatment and 72 chickens (8 chickens per group; 4 males and 4 females) from experiments I and II, respectively, were humanly slaughtered after overnight fasting. After proper bleeding, chickens were placed in a scaling tank. The dressed weight was taken after the legs, head, and feather were removed. The main cutout weight/values of the carcass, such as breast, drumstick, and thigh were recorded. The wings were removed by a cut through

the shoulder joint at the proximal end of the humerus. The thigh and drumstick portions were obtained by cutting through the joint between the femur and ilium bone of the pelvic girdle. The drumstick was separated from the thigh by a cut through the joint formed by the femur, fibula, and tibia. The visceral organs such as the heart, liver, and gizzard were also recorded in the given formulas (Wolde *et al.*, 2021; Mengesha *et al.*, 2022) and their values were presented in grams. In experiment II, the carcasses were weighed, and carcass yield was calculated as % of BW at slaughter. The carcass cut-up parts, including breast, thigh, drumstick, wings, back, and internal organs (heart, liver, and gizzard), were removed, weighed, and their relative weights were presented as % of BW at slaughter following Tudorache *et al.* (2022).

3.4.5 Reproductive and productive performance and egg quality traits

Data on performance traits were obtained from a total of 168 hens, with 48 hens from each (Naked-neck & Normal-feathered) and, 72 from Tetra H chicken genotypes. These hens were rearranged and distributed into four replications, where the same batch of 99 pullets of average weight added to the existing experiment (Tadele *et al.*, 2023a) at 19 weeks in a ratio of 1:6. They were then kept for a duration of 20-40 weeks under similar management conditions. The performance traits assessed included body weight, age at first egg, egg production, and egg quality from each chicken genotypes. Data on egg production were collected throughout the laying period and were calculated as a percent of hen-housed egg production (%HHEP). Weighing egg samples from each genotypic group yielded the mean egg weight. The eggs were weighed beginning at 22 weeks of age and every week thereafter.

The feed conversion ratio was calculated as $\left(\frac{\text{Feed intake(g)}}{\text{Egg mass (g/d)}}\right)$ and the percent of HHEP was calculated as following Islam *et al.* (2022) and while, the egg mass per hen per day was computed as laying percentage multiplied by average daily egg weight (Clark *et al.*, 2019).

$$\text{HHEP (\%)} = \frac{\text{Total egg produced (g)}}{\text{Number of birds housed initially} \times \text{days in egg production}} * 100$$

3.4.6 Egg quality measurements

Following FAO (2012) standards, 240 fresh eggs were collected from the three chicken genotypes (80 eggs from each genotype) for the evaluation of external and internal egg quality characteristics. The eggs were then individually weighed with a sensitive balance (Fig. 7a). The width and length of the egg were then measured with a digital caliper (Fig. 7b). After measuring the external egg quality, each egg was cautiously opened on a flat dish to determine the most important egg quality characteristics. The inner shell membrane was removed from three typical regions (top, middle, and bottom), and the shell thickness (in mm) was measured using a digital caliper (Fig. 7d). A sensitive balance was used to measure shell weight and albumen/or yolk in gram (Fig. 7a & 8a). Albumen and yolk height (mm) were determined using a tripod micrometer and yolk width in mm was measured using a digital caliper (Fig. 8c) and a yolk color fan with 1-15 calibrated color fans was used to determine yolk color (Fig. 8b).

The egg shape index (%) was computed by dividing egg width by egg length x 100. The egg shape index (SI) was determined based on the equation described by Anderson *et al.* (2004). The egg shape index was also classified as sharp egg where (SI < 72), standard (SI = 72-76) and/or round egg (SI > 76), Duman *et al.* (2016) and was computed following the formula given by Markos *et al.* (2017). The shell ratio was calculated as shell weight divided by egg weight x 100, following the equation given by Vekić *et al.* (2022). The Yolk index (%) was computed by dividing yolk height by yolk width x 100, according to the formula described by (Kul and Seker, 2004). Haugh (HU) unit was calculated by fitting the average albumen height and egg weight into the following equation; $HU = 100 \log (AH + 7.57 - 1.7 EW^{0.37})$ provided by Vekić *et al.* (2022); where AH is the albumen height in mm and EW is the weight of the egg in g.

3.4.7 Chemical analysis of *Phytolacca dodecandra* and breast meat

The dry matter (DM), crude protein, crude fat, crude fiber, ash, contents of *Phytolacca dodecandra* (Endod) (Table 7) and breast meat samples (Table 25) were analyzed. The bioactive compounds of *Phytolacca dodecandra* (Endod) were also examined at Jimma University (JU) College of Veterinary Medicine Nutrition Lab (Table 7). The ME (Kcal/kg DM) content of the experimental rations was estimated indirectly using the equation; $ME\ Kcal = (35 * fat + 85 * carbohydrate + 35 * Protien)$, as stated by (Lodhi *et al.*, 1976). The percentage of carbohydrates was calculated using the equation; $\%Carbohydrate = (\%moisture + \%fat + \%protien + \% Ash)$, according to Igbabul *et al.* (2014).

Table 7. Proximate compositions and bioactive constituents of *Phytolacca dodecandra*

Proximate	Percent
Dry Matter %	90.2
Crude Protein %	23.5
Crude Fat %	2.43
Crude Fiber %	8.29
Ash %	6.8
ME Kcal/kg	2818.9
Bioactive constituents (Mg/ml)	
Saponin	0.0939
Tannin	0.0837
Alkaloid	0.0837
Flavonoid	0.0838

Table 8. Compositions of nutrients in experimental diets and phytolacca dodecandra (Endod)

Ingredients	Starter (0-8 weeks)			Grower (9-18 weeks)		
	C	C+1	C+2	C	C+1	C+2
	Compositions (%)					
Maize	40.6	40.6	40.6	45.93	45.93	45.93
Wheat middling	26.83	26.83	26.83	36.22	36.22	36.22
Noug cake	21.47	21.47	21.47	7.25	7.25	7.25
Meat and bone meal	9	9	9	8.5	8.5	8.5
Limestone	1	1	1	1	1	1
Salt	0.5	0.5	0.5	0.5	0.5	0.5
Premix vitamin	0.5	0.5	0.5	0.5	0.5	0.5
Lysine	0.05	0.05	0.05	0.05	0.05	0.05
Methionine	0.05	0.05	0.05	0.05	0.05	0.05
Total	100	100	100	100	100	100
<i>Phytolacca dodecandra</i>	0	0.1	0.2	0	0.1	0.2
	Calculated Nutrients					
Crude Protein (%)	19.04	19.06	19.08	16.25	16.27	16.29
ME in (Kcal/kg)	2873.2	2875.9	2878.7	2749.8	2749.9	2750.1

C, Control diet; C+1, control diet plus 1g/kg Phytolacca dodecandra (Endod); C+2, control diet plus 2g/kg Phytolacca dodecandra (Endod) supplementations; ME, Metabolizable energy. The rations were prepared at Bonga Poultry Production Center.

3.4.8 Blood sample collection

At 18 weeks, following a 12-hour (h) fasting period, blood samples were collected from the wing vein using 23Gx3/4'-gauge needles and 5 ml syringes from 72 chickens (8 chickens per group; 4 males and 4 females) that were specifically selected based on their weights, closely matching the average weight of the respective groups. For hematological and serum studies blood was collected using 21-gauge sterile disposable needles and 5 ml syringes from the wing vein. During the collection process, the specimens were gathered in distinct tubes to analyze different parameters. For hematology analysis, a tube containing an anticoagulant called ethylenediaminetetraacetic acid (EDTA) was used. On the other hand, a separate serum tube was employed to study the blood serum parameters. Following necessary precautionary measures, the serum was subjected to centrifugation for ten minutes at 2000 rpm at room temperature in the laboratory of Bonga Gebretsadik Shawo General Hospital. The separated serum was then sent to Jimma University Teaching Hospital for analysis following appropriate precautions.

3.4.8.1 Hematological parameters

The packed cell volume (PCV) was measured by a microhaematocrit capillary tube using a hematocrit reader. Erythrocyte concentration (RBC) and hemoglobin (Hb) were measured using an automated cell counter, while leucocyte concentration (WBC) was manually counted using a WBC counter within 24 hours after the collection of blood at Bonga Gebretsadik Shawo General Hospital Laboratory. The mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH) and mean corpuscular hemoglobin concentration (MCHC) were calculated (Jain, 1986). The formula used was MCV in femtoliters (fL) = $10 \times \text{PCV (\%)} / \text{RBC counts (millions}/\mu\text{l})$. MCH in pg/cell = $\text{hemoglobin (g/ 100 ml)} / \text{RBC counts (millions}/\mu\text{l})$. MCHC in g/dl = $\text{hemoglobin (g/ 100 ml)} \times 100 / \text{PCV (\%)}$.

3.4.8.2 Serum biochemical parameters

The total protein (TP), albumin (Alb), total cholesterol (TC), triglycerides (TG), glucose (Glu), and calcium (Ca) were measured using an automated chemistry analyzer at Jimma University Teaching Hospital using a Blood Chemistry analyzer. The amount of globulin was determined by subtracting the total protein from albumin (Zhou *et al.*, 2021).

3.4.9 Proximate compositions of the breast meat

For proximate analysis, a total of 72 breast muscles were skinned and frozen at -20 °C awaiting further analysis, and sent to JU Animal Nutrition Laboratory. Individual samples were thawed for 24 h, and minced through a 5 mm plate meat-grinding machine. Chemical composition analysis of minced meat samples was performed on a wet basis by proximate analysis to determine the DM, ash, crude protein, fat, and fiber contents. The dry matter of fresh samples was analyzed by the oven method set at 105 °C for 12 h. Ash was determined after subjecting the samples to a furnace set at 500°C. Protein was analyzed by the Kjeldahl method and Fat contents were analyzed by the Soxhlet method.

3.5 Statistical analysis

The data analysis was carried out using the general linear model (GLM) procedure in SAS software (SAS, 9.0). To investigate variations in the response variables among the three chicken genotypes (model 1), we employed a one-way ANOVA. Similarly, for examining the effects of genotype and *Endod* supplementations, we utilized the R general linear model and conducted a two-way ANOVA (model 4). When the F-test declared significant differences at a 5%, significance level, we performed the Tukey HSD test to determine differences between treatment means. Graphs were analyzed using Graph Pad Prism and SPSS 20. Before conducting the analysis, we examined the normality of the data using the Shapiro test.

Model 1. $Y_{ij} = \mu + G_i + e_{ij}$; Where: Y_{ij} = represents the j observation in the i^{th} genotype level; μ = overall mean; G_i = genotype effect; and e_{ij} = random error.

Model 2: $Y_j = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + e_{ij}$

Where, Y_j = Response variable or predicted mean body weight of the chicken genotype, β_0 = the intercept $X_1 + X_2 + X_3 + X_4$ and X_5 are the explanatory variables for body length, chest width, keel bone length; shank length and circumference, respectively, and $\beta_1 + \beta_2 + \beta_3 + \beta_4$ and β_5 are the regression coefficient of the variables $X_1 + X_2 + X_3 + X_4$ and X_5 ; e_{ij} = the residual error.

Model 3.

$Y_{ijk} = \mu + G_i + D_j + (G * D)_{ij} + e_{ijk}$

Where Y_{ijk} = represents dependent variables; μ = overall mean; G_i = genotype effect (NaT, NfT & ThT); D_j = effect of diet (c, control/basal diet, c+1, basal diet + 1g/kg *Phytolacca dodecandra* (Endod), and c+2 basal diet + 2g/kg *Phytolacca dodecandra* (Endod)); $(G * D)_{ij}$ = interaction between genotype and diet; and e_{ijk} = random error.

Pearson's correlation employed to calculate the phenotypic association between two traits was based on the equation provided by Isaac (2020).

$$r = \frac{\sum xy}{(\sum x^2 \sum y^2)^{0.5}} \quad \text{Where } r = \text{correlation coefficient, } \sum xy, \sum x^2 \sum y^2 = \text{sum of variables}$$

Table 9. Chemical composition of commercial dual-purpose chicken feed used in the study

Nutrient compositions	Starter feed (0-8	Grower feed (9-18	Layer \geq 19 weeks
	weeks)	weeks)	
ME in (Kcal/kg)	2907.9	2933.6	2856
Crude protein %	19.4	18.4	17.3
Crude fiber %	3.52	3.9	7
Crude fat %	4.74	5.7	5
Moisture %	12.2	10.9	10
Ca %	0.63	0.99	3.5
P %	0.7	0.81	1.85

The compositions were provided by Bonga PPC; ME = Metabolizable Energy

CHAPTER FOUR

4. RESULTS

4.1 Experiment I

4.1.1 Fertility and hatchability of the three chicken genotypes

The fertility and hatchability percentages of eggs collected from the three chicken genotypes are presented in Table 10. The results showed that genotypes significantly affected ($P < 0.05$) the fertility and hatchability of eggs and a lower value was observed in Tetra H than in the naked-neck and normal-feathered chicken genotypes.

Table 10. Fertility and hatchability percentages of eggs from the three chicken genotypes

Traits	Treatment groups			SEM	<i>p</i> -value
	Naked-neck	Normal-feathered	Tetra H		
Number of eggs set	120	120	120	2.205	1.00
Number of fertile eggs	107 ^a	104 ^a	84 ^b	3.667	0.001
Number of hatched eggs	96 ^a	92 ^a	68 ^b	4.419	0.001
Fertility (%) of set eggs	89.2 ^a	86.7 ^a	70 ^b	3.056	0.001
Hatchability (%) of set eggs	80 ^a	76.7 ^a	56.7 ^b	3.683	0.001
Hatchability (%) of fertile eggs	89.7 ^a	88.5 ^a	80.9 ^b	1.553	0.012

^{a,b} Means across a row with different superscript letters are significantly different ($P < 0.05$), SEM = Standard error of the mean.

4.1.2 Growth performance of the three chicken genotypes

Results of initial body weight, final body weight, body weight change, average daily gain, daily feed intake, and feed conversion ratio values are presented in Table 11. The results demonstrated that the Tetra H chicken genotype had significantly higher ($P < 0.05$) body weight change, final body weight, daily weight gain, and lower (better) feed conversion ratio values during the starter phase (0-8 weeks). However, there was no significant difference ($P > 0.05$) in daily feed intake among the three chicken genotypes during the starter phase of rearing (0-8 weeks). Chicken in the normal-feathered genotype showed

significantly lower ($P < 0.05$) weight gain than chicken in the Tetra H genotype during the growing phase (9-18 weeks), whereas the weight gain of naked neck chicken was comparable with the Tetra H chicken. However, the Tetra H chicken genotype had significantly higher ($p < 0.05$) feed intake and body weight than the other genotypes. The body weight of Tetra H was 60.9% and 70.1% higher than the Naked-neck and normal-feathered genotypes, respectively. During the growing and entire experimental period, the naked-neck chicken had significantly lower ($P < 0.05$) feed intake than the other genotypes. Even though the normal-feathered and naked-neck chickens performed comparably during the growth phase, the naked-neck genotype was better in terms of feed conversion ratio than the normal-feathered.

The naked-neck chicken genotype consumed less feed during the entire experimental period as compared with the other chicken genotypes. As shown in Table 11, the Tetra H chicken genotype had higher ($P < 0.05$) daily feed intake and final body weight than the two chicken genotypes (Figure 3). During the entire experimental period, there was a significant variation ($P < 0.05$) in feed conversion ratio, which was lower (better) for Tetra H (3.76), intermediate for naked-neck (5.6) and high (poor) for the normal-feathered (6.1) chicken, respectively. The mortality percentage was significantly lower ($P < 0.05$) in the naked-neck chicken genotype throughout the entire experimental period (0-18 weeks) compared with the two chicken genotypes.

Table 11. Body Weight, Daily Gain, Feed Intake & Conversion in Chicken Genotypes

Traits	Treatment groups			SEM	<i>p</i> -value
	Naked-neck	Normal-feathered	Tetra H		
Starter Phase (0-8 weeks)					
IBW (g/bird)	31.3 ^b	32.5 ^b	40.5 ^a	1.48	0.001
DFI (g/bird)	31.5	31.8	32.1	0.12	0.115
FBW (g/bird)	320.3 ^b	392.2 ^b	742.8 ^a	66.1	0.001
BWC (g/bird)	288.9 ^b	359.7 ^b	702.3 ^a	64.7	0.001
ADG (g/day)	5.2 ^b	6.4 ^b	12.5 ^a	1.15	0.001
FCR (feed: gain)	6.1 ^a	4.9 ^b	2.6 ^c	0.53	0.001
Mortality %	6.7 ^b	11.1 ^{ab}	15.6 ^a	1.57	0.037
Grower Phase (9-18 weeks)					
DFI (g/bird)	65.0 ^c	68.2 ^b	71.5 ^a	0.96	0.001
FBW (g/bird)	1166.7 ^b	1103.5 ^b	1876.8 ^a	135.	0.005
BWC (g/bird)	846.4 ^{ab}	711.3 ^b	1134.1 ^a	79.0	0.005
ADG (g/day)	12.1 ^{ab}	10.2 ^b	16.2 ^a	1.12	0.005
FCR (feed: gain)	5.49 ^{ab}	6.71 ^a	4.55 ^b	0.35	0.007
Mortality %	2.38	2.38	2.56	1.22	0.998
Entire experiment (0-18 weeks)					
DFI (g/bird)	50.3 ^c	51.2 ^b	54.0 ^a	0.55	0.001
FBW (g/bird)	1166.7 ^b	1103.5 ^b	1876.8 ^a	135.	0.005
BWC (g/bird)	1135.3 ^b	1070.9 ^b	1836.4 ^a	134.	0.005
ADG (g/day)	9.01 ^b	8.50 ^b	14.6 ^a	0.38	0.005
FCR (feed: gain)	5.6 ^a	6.1 ^a	3.76 ^b	0.38	0.005
Mortality %	8.9 ^b	13.3 ^{ab}	15.6 ^a	1.74	0.009

^{a,b,c} Row means with different superscript letters are significantly different ($P < 0.05$), SEM = Standard error of the mean. IBW, initial body weight, FBW, final body weight, BWC, body weight change, ADG, Average daily gain, DFI, daily feed intake, FCR, Feed conversion ratio.

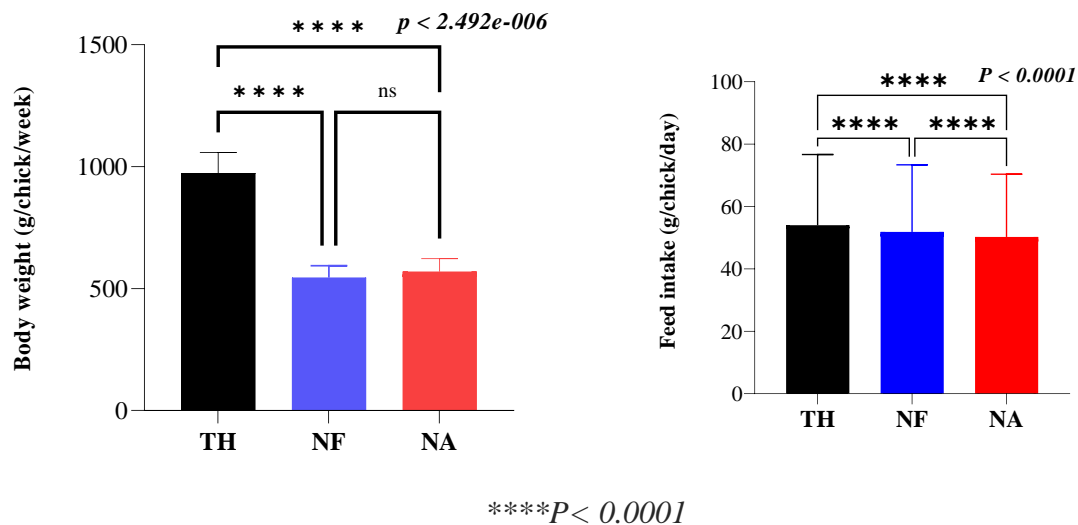


Figure 3. The average (body weight and daily feed intake) of TH, Tetra H, NF, Normal-feathered, NA, Naked-neck chicken genotypes (0-18 weeks).

4.1.3 Morphometric traits of the three chicken genotypes

The linear body measurement results presented in Table 12 showed that the Tetra H chicken genotype had significantly higher ($P < 0.05$) body length, width, and keel bone length than the other chicken genotypes. However, there were no significant differences ($P > 0.05$) in body length and width, keel bone length, and shank circumference between the naked-neck and normal-feathered chicken genotypes, and non-significant variations ($P > 0.05$) were also observed for shank length values among the three chicken genotypes. The results of hierarchical cluster analysis show that the Tetra H chicken was distinct from the naked-neck and normal-feathered chicken genotypes (Figure 4).

Table 12. Linear body measurement traits of F1 chicken genotypes

Morphometric traits	Treatment groups			SEM	p-value
	Naked-neck	Normal-feathered	Tetra H		
Body length (cm)	37.1 ^b	36.8 ^b	41.8 ^a	0.804	0.008
Chest width (cm)	24.9 ^b	23.6 ^b	28.8 ^a	0.841	0.018
Keel bone length (cm)	9.9 ^b	9.8 ^b	12.0 ^a	0.353	0.008
Shank length (cm)	8.2	8.0	9.0	0.285	0.325
Shank circumference (cm)	3.4 ^b	3.8 ^{ab}	4.4 ^a	0.179	0.035

^{a, b} Row means with different superscript letters are significantly different ($p < 0.05$; SEM, Standard error of the mean).

4.1.3.1 Body weight to shank length and keel bone length to chest width ratio

In the current study, the body weight to shank length ratio was significant ($P < 0.01$) and higher in the Tetra H compared to the other chicken genotypes (Table 13). The Tetra H was 55.6% higher than the normal-feathered and 50% from the naked-neck chicken genotype in body weight to shank length ratio. However, significant differences ($P > 0.05$) were not observed in the keel bone-to-chest width ratio among the chicken genotypes.

Table 13. Live body weight/shank length and Keel bone length/chest width ratios of the three chicken genotypes

Morphometric traits	Treatment groups			SEM	p-value
	Naked-neck	Normal-feathered	Tetra H		
Body weight/shank length (kg/cm)	0.138 ^b	0.133 ^b	0.207 ^a	0.011	0.003
Keel bone/chest width (cm/cm)	0.398	0.417	0.418	0.007	0.475

^{a b} Row means with different superscript letters are significantly different ($p < 0.05$), SEM Standard error of the mean.

4.1.3.2 Correlation between body weight and linear body measurements

In the current study, we found a strong and significant ($P < 0.05$) positive relationship between body weight and some linear body measurement traits among the chicken genotypes (Table 14). The naked-neck ($r = 0.832$) and normal-feathered ($r = 0.531$) and Tetra H ($r = 0.981$) chicken genotypes had a significant ($P < 0.05$) correlation between body weight and chest width. On the other hand, body weight was significantly ($P < 0.05$) correlated with body length in the normal-feathered ($r = 0.889$) and Tetra H ($r = 0.928$) chicken genotypes. The keel bone length, shank length, and circumference were significantly ($P < 0.01$) correlated with body weight in the normal-feathered and non-significant for the naked-neck and Tetra H chicken genotypes.

Table 14. Correlation of body weight with linear body measurement traits

Genotypes	Traits	BW	BL	CC	KBL	SHL	SHC
Naked-neck		1.00	0.742	0.832*	0.674	0.637	0.597
Normal-Feathered	BW	1.00	0.889*	0.531**	0.770**	0.992**	0.946**
Tetra H		1.00	0.928**	0.981**	0.788	0.807	0.647
Naked-neck			1.00	0.474	0.327	0.556	0.597
Normal-Feathered	BL		1.00	0.428	0.788	0.859	0.787
Tetra H			1.00	0.849**	0.469	0.652	0.358
Naked-neck				1.00	0.721	0.567	0.498
Normal-Feathered	CC			1.00	0.469	0.471	0.686
Tetra H				1.00	0.868*	0.833*	0.763
Naked-neck					1.00	0.860*	0.649
Normal-Feathered	KBL				1.00	0.728	0.767
Tetra H					1.00	0.900*	0.861*
Naked-neck						1.00	0.486
Normal-Feathered	SHL					1.00	0.945**
Tetra H						1.00	0.738
Naked-neck							1.00
Normal-Feathered	SHC						1.00
Tetra H							1.00

P < 0.01; *P* < 0.05; BW, Body weight; BL, Body length; CC, Chest width; KBL, Keel bone length, SHL, Shank length; SHC, Shank circumference

4.1.3.3 Stepwise multiple regression equation

Stepwise multiple regression analysis was employed to describe the quantitative relationship between the response variable (body weight) and linear body measurement traits. Table 15 shows predictive equations used to describe the body weight to linear body measurements of the three chicken genotypes. In this study, the best predictor for assessing the body weight of the naked-neck chicken was chest width and shank length in the normal-feathered. However, body length and chest width were the best for the prediction of the body weight of the Tetra H chicken. The coefficient of determination (R^2) in this study ranges from moderate (0.692) to highest (0.995) indicating these variables could accurately predict the body weight of a chicken. On the other hand, linear body measurement traits play a crucial role in evaluating and choosing genetically superior birds. Breeders can use various measurements to identify individuals with desirable body proportions, including a favorable skeletal structure, well-developed muscles, and overall body conformation. These traits are essential for enhancing important commercial characteristics such as growth rate, feed efficiency, and carcass quality.

Table 15. Stepwise multiple regression equations for the prediction of body weight of the three chicken genotypes

Treatment groups	R ²	Fitted stepwise multiple regression equation	P-value
Naked-neck	0.69	Y= -0.596+0.069(CC)	0.040
Normal-feathered	0.98	Y= -0.400+ 0.183(SHL)	0.001
Tetra H	0.99	Y= -4.519 + 0.072(BL) + 0.118(CC)	0.003

R², Coefficient of determination; Y, predicted body weight; CC, Chest width; SHL, Shank length; BL, Body length

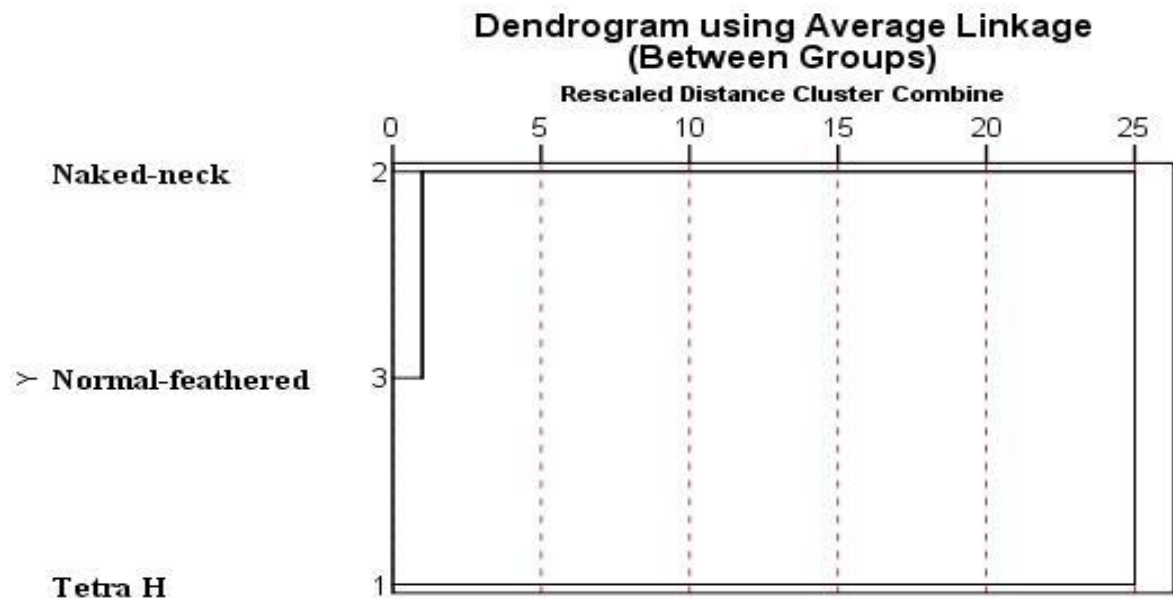


Figure 4. Hierarchical cluster analysis of the three chicken genotypes

4.1.4 Carcass components of chicken genotypes

In the current study, slaughter and dressed carcass weight, carcass components, and internal organs of the three chicken genotypes are presented in Table 16. The results demonstrated that the slaughter weight of Tetra H was significantly higher ($p < 0.05$) than the naked-neck and normal-feathered chicken genotypes. The Tetra H chicken, on the other hand, had a higher carcass weight ($p < 0.05$) than the two chicken genotypes. However, a significantly higher ($p < 0.05$) dressing percentage was recorded from the naked-neck than the Tetra H and normal-feathered genotypes. The most valuable chicken carcass components, such as carcass weight, breast, drumstick, and thigh muscle values, were

significantly higher ($p < 0.05$) in the Tetra H chicken compared with the other genotypes. The Tetra H chicken genotype had higher ($p < 0.05$) liver, heart, and gizzard weights than the indigenous normal-feathered and naked-neck chicken genotypes.

Table 16. Slaughter and carcass weights (g) along with proportions of carcass yield (g) of F1 chicken genotypes.

Carcass components	Treatment groups			SEM	<i>p</i> -value
	Naked-neck	Normal-feathered	Tetra H		
Slaughter weight (g)	1195 ^b	1156.7 ^b	1823.3 ^a	121	0.029
Carcass weight (g)	884.8 ^b	837.9 ^b	1308.5 ^a	85.1	0.035
Dressing percentage (%)	74.3 ^a	72.6 ^{ab}	71.8 ^b	0.471	0.003
Skin and feather (g)	188.9 ^b	194.4 ^b	298.1 ^a	20.6	0.040
Breast (g)	132.6 ^b	128.3 ^b	209.7 ^a	14.9	0.031
Thigh (g)	117.3 ^b	110.7 ^b	184.4 ^a	13.5	0.035
Drumstick (g)	104.9 ^b	104.7 ^b	172.1 ^a	12.9	0.037
Keel bone (g)	86.4	83.1	120.9	7.95	0.091
Back (g)	78.3 ^b	78.4 ^b	126.5 ^a	9.65	0.005
Wings (g)	40.0	38.4	47.0	2.74	0.417
Neck (g)	38.8	39.7	54.7	3.76	0.149
Gizzard (g)	53.5 ^b	53.8 ^b	70.4 ^a	3.05	0.024
Liver (g)	23.1 ^b	23.2 ^b	33.9 ^a	1.981	0.026
Heart (g)	5.13 ^b	5.37 ^{ab}	8.53 ^a	0.687	0.007

^{a,b} Row means with different superscript letters are significantly different ($P < 0.05$) SEM = Standard error of the mean.



Figure 5. Various carcass components of the three chicken genotypes

4.1.5 Reproductive and productive performance traits of female chicken genotypes

The Tetra H and naked-neck pullets started laying eggs earlier than the normal-feathered pullets, and there were significant differences in age at the first egg ($p < 0.05$) among the chicken genotypes (Table 17). During the experiment, the Tetra H chicken showed that its live body weight increased with age (Figure 6). In comparison to Tetra H and normal-feathered chicken genotypes, the naked-neck chickens had reduced average daily feed intake value by 1.37%. Tetra H hens significantly outperformed the normal-feathered and naked-neck chicken genotypes in terms of hen-housed egg production and feed consumption ($p < 0.05$) (Table 17). Tetra H chickens also exhibited significantly better performance ($p < 0.05$) in regards to both feed conversion ratio (FCR) and egg mass compared to the other genotypes.

Table 17. Reproductive and Productive traits of the three female chicken genotypes

Parameters	Treatment groups			<i>p-value</i>
	Normal-feathered	Naked-neck	Tetra H	
Body weight (g) at 20 weeks	991.7±24.6 ^b	1120±80.2 ^b	1412.7±66.8 ^a	0.007
Age at first egg (days)	161±2.48 ^a	152.3±3.04 ^b	150.2±2.25 ^b	0.006
Body weight at first egg (g)	1033.8±29.7 ^b	1168.2±36.2 ^b	1458.2±57.3 ^a	0.037
Average body weight (g) at 40 weeks	1285.2 ±19.8 ^b	1317± 17.1 ^b	1637.9±30.3 ^a	0.001
Total eggs/hen/20 weeks	51.0±1.158 ^b	54.8 ±1.277 ^b	95.4±1.247 ^a	0.001
Daily feed intake (g)	117.6±0.097 ^a	116.3±0.150 ^b	117.9±0.123 ^a	0.001
Feed conversion ratio(FI/EM)	5.28±0.108 ^a	4.79±0.117 ^a	2.18±0.052 ^b	0.001
HHEP%	36.4±0.827 ^b	39.1±0.912 ^b	68.2±0.891 ^a	0.001
EM (g/hen/day)	22.3±0.389 ^b	24.3±0.431 ^b	54.2±0.553 ^a	0.001

^{a,b} Row means with different superscript letters are significantly different ($p < 0.05$)

SE = Standard error; HHEP%, Percent of hen-housed egg production; EM, egg mass

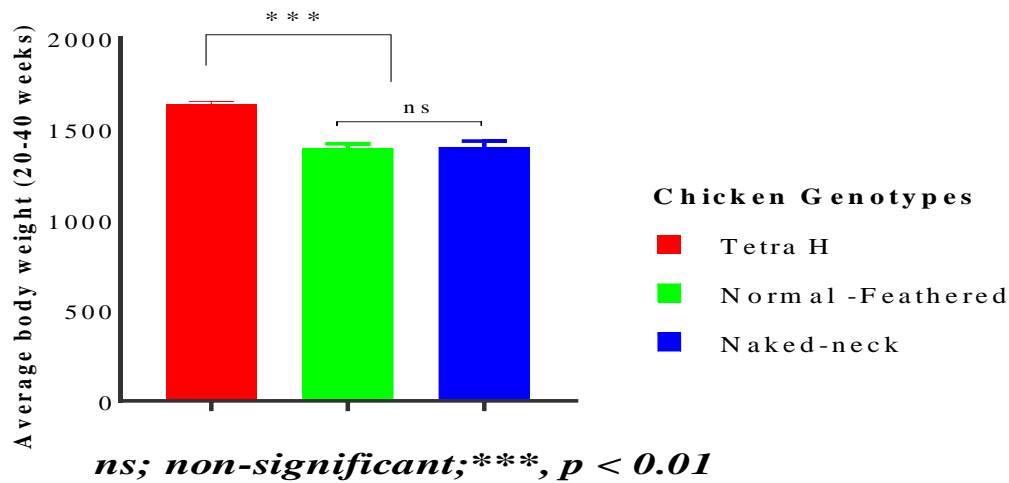


Figure 6. Average body weight of female chicken genotypes (20-40 weeks)

4.1.6 External and internal egg quality traits of chicken genotypes

4.1.6.1 External egg quality traits

The characteristics of external egg quality are shown in Table 18. In this finding, the Tetra H chicken had higher values for the majority of external egg quality traits, except for shell thickness, which did not differ significantly ($p > 0.05$) among the three chicken genotypes. The average egg weight, length, width, shell weight, and shape index all differed significantly ($p < 0.01$) among the genetic group of chickens. The average egg weight in the current study was 43.7 g, 44.3 g, and 56.8 g for the normal-feathered, naked-neck, and Tetra H chicken, respectively. The Tetra H chicken genotype recorded better than the other chicken genotypes in terms of egg length, which differed among chicken genetic groups.

Table 18. The mean \pm SE external egg parameters of eggs collected from chicken genotypes.

External egg quality traits	Treatment Groups			<i>p</i> -value
	Normal-feathered	Naked-neck	Tetra H	
Egg weight (g)	43.7 \pm 0.336 ^b	44.3 \pm 0.344 ^b	56.8 \pm 0.211 ^a	0.001
Egg length (mm)	52.3 \pm 0.273 ^b	52.6 \pm 0.216 ^b	56.2 \pm 0.353 ^a	0.001
Egg width (mm)	38.8 \pm 0.137 ^b	39.0 \pm 0.152 ^b	43.1 \pm 0.228 ^a	0.001
Egg shape index (%)	74.4 \pm 0.477 ^b	74.2 \pm 0.369 ^b	76.7 \pm 0.329 ^a	0.001
Shell weight (g)	5.33 \pm 0.049 ^b	5.52 \pm 0.053 ^b	6.02 \pm 0.084 ^a	0.001
Shell thickness (mm)	0.423 \pm 0.006	0.431 \pm 0.006	0.424 \pm 0.007	0.651
Shell ratio %	12.2 \pm 0.0907 ^a	12.4 \pm 0.079 ^a	10.6 \pm 0.152 ^b	0.001

^{a,b} Row means with different superscript letters are significantly different ($p < 0.05$)

SE = Standard error

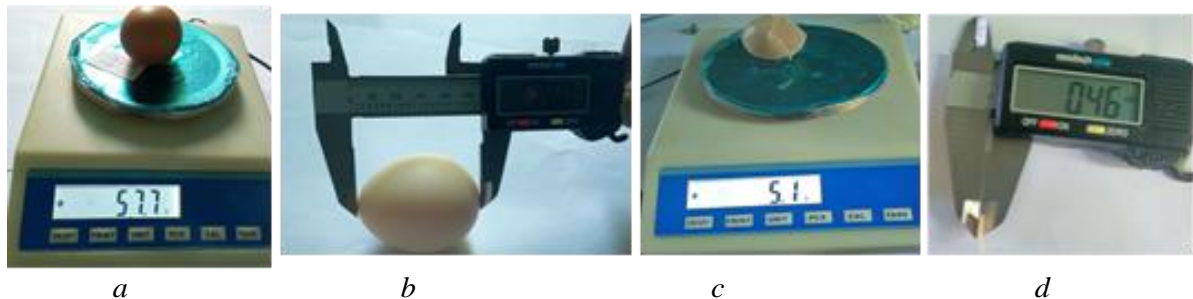


Figure 7. Photos of some external egg quality traits

4.1.6.2 Internal egg quality traits

The average albumen and yolk weight, albumen and yolk height, and Haugh unit varied considerably ($p < 0.01$) among the chickens in the genetic group, as shown in Table 19. The Tetra H chicken genotype had a substantially higher ($p < 0.01$) value for every trait evaluated aside from yolk width and color. The typical albumen weight in the current study was 22.9 g, 23.3 g, and 33.9 g for the normal-feathered, naked-neck, and Tetra H chicken respectively. Yolk weight for the Tetra H chicken genotype was considerably heavier ($p < 0.01$) than the chicken genotypes in the naked neck and normal feathers. However, there were no noticeable differences in the egg yolk width values among the genetic group of chickens ($p > 0.05$). The Haugh unit values in the current study showed significant differences ($p < 0.01$) among chicken genetic groups, with the Tetra H chicken genotype having a higher value.

Table 19. Internal traits of eggs collected from three chicken genotypes (Mean \pm SE)

Internal Egg traits	Treatment Groups			P-value
	Normal-feathered	Naked-neck	Tetra H	
Albumen weight (g)	22.9 \pm 0.254 ^b	23.3 \pm 0.251 ^b	33.9 \pm 0.104 ^a	0.001
Yolk weight (g)	15.4 \pm 0.084 ^b	15.5 \pm 0.077 ^b	16.8 \pm 0.208 ^a	0.001
Albumen height (mm)	5.42 \pm 0.084 ^b	5.27 \pm 0.096 ^b	8.55 \pm 0.165 ^a	0.001
Yolk height (mm)	15.0 \pm 0.128 ^b	15.1 \pm 0.089 ^b	16.1 \pm 0.075 ^a	0.001
Yolk width (mm)	38.7 \pm 0.113	38.7 \pm 0.126	38.4 \pm 0.144	0.070
Yolk index (%)	38.8 \pm 0.314 ^b	38.1 \pm 0.252 ^b	41.9 \pm 0.232 ^a	0.001
Haugh unit (%)	78.6 \pm 0.609 ^b	77.2 \pm 0.645 ^b	92.7 \pm 0.963 ^a	0.001
Yolk color (1-15)	10.1 \pm 0.050	10.2 \pm 0.097	10.3 \pm 0.039	0.131

^{a,b} Means across a row with different superscript letters are significantly different ($p < 0.05$)

SE = Standard error

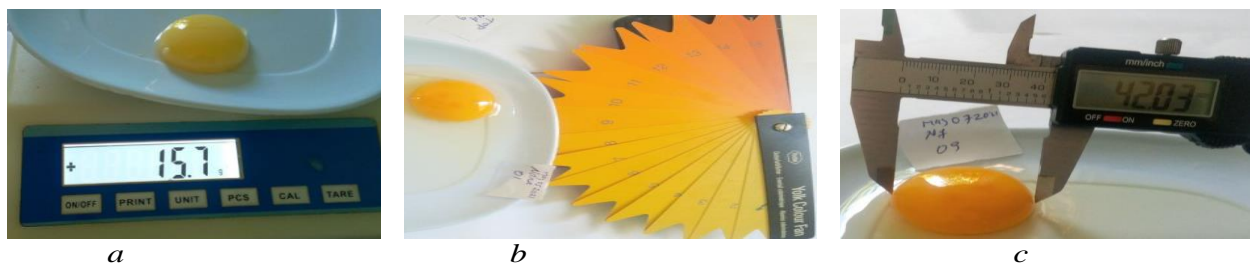


Figure 8. Photos of some internal egg quality traits

4.1.7 Phenotypic Correlation of External and internal egg traits

Except for shell thickness, the present study found that among chicken genotypes, egg weight, and external egg characteristics had a strong and significant ($p < 0.01$) positive association (Table 20). The association between egg weight and egg length was significant ($p < 0.01$) for the naked-neck ($r = 0.853$) and normal-feathered ($r = 0.827$) chicken genotypes but non-significant ($r = 0.119$) for the Tetra H chicken. The internal egg quality characteristics of albumen and yolk weight were considerably ($p < 0.01$) associated with egg weight among the genetic group of chickens. In the Tetra H genotype, egg length was significantly ($p < 0.01$) correlated with egg width, shell weight, albumen, and yolk height, and albumen and yolk weight in the naked-neck and normal-feathered chicken genotypes.

There were positive and significant ($p < 0.01$) associations between egg width and eggshell weight within the genetic group of chickens. However, there were no significant ($p > 0.05$) associations between egg width, albumen, or yolk height in the normal-feathered chicken genotype. Albumen weight and yolk weight were considerably linked for the three chicken genotypes ($p < 0.01$). In the normal-feathered and naked-necks, albumen weight was found to be significantly associated with yolk weight, but not in the Tetra H genotype. Yolk weight and yolk height were significantly ($p < 0.01$) associated with the naked-neck and normal-feathered genotypes but not in the Tetra H genotype. In the naked-neck and Tetra H genotypes, albumen height was found to be significantly associated with yolk height, but not in the normal-feathered genotype.

Table 20. Phenotypic correlation of external and internal egg quality traits of the three chicken genotypes

Genotypes	Traits	EW	EL	EWD	SW	ST	AW	YW	AH	YH
Normal-Feathered		1.00	0.511**	0.827**	0.615**	0.242	0.966**	0.715**	0.109	0.140
Naked-neck	EW	1.00	0.564**	0.853**	0.762**	0.136	0.971**	0.778**	0.645**	0.563**
Tetra H		1.00	0.114	0.119	0.079	0.119	0.414**	0.779**	-0.063	0.061
Normal-Feathered			1.00	0.227	0.167	0.005	0.762**	0.644**	0.077	0.218
Naked-neck	EL		1.00	0.23964	0.464**	0.059	0.535**	0.455**	0.577**	0.300*
Tetra H			1.00	0.726**	0.358**	-0.221	0.247	-0.152	0.383**	0.509**
Normal-Feathered				1.00	0.607**	0.297*	0.762**	0.644**	0.077	0.218
Naked-neck	EWD			1.00	0.700**	0.187	0.813**	0.678**	0.508**	0.536**
Tetra H				1.00	0.288*	0.080	0.157	-0.074	0.374**	0.482**
Normal-Feathered					1.00	0.446	0.495**	0.369*	-0.147	0.146
Naked-neck	SW				1.00	0.295*	0.651**	0.596**	0.571**	0.278*
Tetra H					1.00	-0.007	0.088	-0.368*	0.189	0.382**
Normal-Feathered						1.00	0.193	0.119	-0.148	0.235
Naked-neck	ST					1.00	0.105	0.06387	0.17758	-0.0147
Tetra H						1.00	-0.191	0.219	-0.067	0.056
Normal-Feathered							1.00	0.544**	0.175	0.017
Naked-neck	AW						1.00	0.634**	0.597**	0.601**
Tetra H							1.00	-0.114	-0.057	-0.004
Normal-Feathered								1.00	-0.007	0.424**
Naked-neck	YW							1.00	0.546**	0.361**
Tetra H								1.00	-0.112	-0.090
Normal-Feathered									1.00	-0.115
Naked-neck	AH								1.00	0.621**
Tetra H									1.00	0.547**
Normal-Feathered										1.00
Naked-neck	YH									1.00
Tetra H										1.00

EW, Egg weight; EL, Egg length; EWD, Egg width; SW, Shell weight; ST, Shell thickness; AW, Albumen weight; YW, Yolk weight; AH, Albumen height; YH, Yolk height; sig. ** $p < 0.01$; * $p < 0.05$.

4.7 Experiment II

4.7.1 Effect of Genotype and Diet on growth performance of Chickens

The effects of genotype and diet on the chicks' growth performance traits are shown in Table 21. The results indicated that diet and genotype by diet interactions had a significant ($P < 0.05$) effect on the performance traits during the grower and entire growth period, while genotype had no significant ($P > 0.05$) effects (Table 21). In this study, the diet had a significant effect on the performance measures; final body weight (FBW), body weight change (BWC), average daily gain (ADG), and feed conversion ratio (FCR) during the grower and entire phase ($P < 0.05$). The FBW, BWC, ADG, and FCR significantly differ ($P < 0.05$) among the supplemental diets during the grower and entire phase with C+1 having the highest values compared to the others. Supplementing the C+1 diet significantly improved ($P < 0.05$) chicks' performance; during the grower and entire growth phases, FBW, BWC, and ADG significantly ($P < 0.05$) increased while FCR was significantly ($P < 0.05$) reduced. On the other hand, genotype by diet interactions were found to have a significant ($P < 0.05$) effect on the performance parameters during the grower and the entire experimental period.

Table 21. Effect of genotype and diet on growth performance of chickens

Item	Starter phase (0-8 weeks)						Grower phase (9-18 weeks)						Entire experiment (0-18 weeks)			
	IBW	FI	FBW	BWC	ADG	FCR	FI	FBW	BWC	ADG	FCR	FI	FBW	BWC	ADG	FCR
Genotype																
NaT	36.8	32.1	669.5	632.8	11.3	2.863	71.8	1704.5	1034.9	14.8	4.92	54.3	1704.5	1034.93	13.2	4.12
NfT	36.7	32.1	653.9	617.1	11.0	2.925	71.9	1667.0	1013.1	14.5	4.99	54.3	1667.0	1013.13	12.9	4.20
ThT	36.8	32.2	670.5	633.7	11.3	2.862	71.9	1700.4	1029.9	14.7	4.89	54.2	1700.4	1029.93	13.1	4.11
SEM	0.025	0.019	14.7	14.7	0.262	0.068	0.321	17.4	9.15	0.131	0.041	0.009	17.4	20.8	0.138	0.042
Diet																
C	36.8	32.1	659.4	622.7	11.1	2.908	71.9	1642.7 ^b	983.4 ^b	14.0 ^b	5.13 ^a	54.3	1621.9 ^b	983.4 ^b	12.7 ^b	4.27 ^a
C+1	36.7	32.1	683.3	646.5	11.5	2.796	71.9	1767 ^a	1083.7 ^a	15.5 ^a	4.66 ^b	54.2	1729.3 ^a	1083.7 ^a	13.7 ^a	3.96 ^b
C+2	36.7	32.1	651.2	614.4	10.9	2.946	71.8	1662.1 ^b	1010.9 ^b	14.4 ^b	5.01 ^a	54.2	1651.7 ^b	1010.9 ^b	12.9 ^b	4.22 ^a
SEM	0.025	0.019	14.7	14.7	0.262	0.068	0.321	17.4	9.15	0.131	0.041	0.009	17.4	20.8	0.138	0.042
Genotype*Diet																
NaT C	36.8	32.3	682.6	645.7	11.5	2.82	71.9	1685.3 ^{bc}	1002.7 ^{cd}	14.3 ^{cd}	5.03 ^b	54.4	1685.3 ^{bc}	1002.8 ^{cd}	13.1 ^{bc}	4.15 ^{ab}
NaT C+1	36.7	32.3	669.8	633.1	11.3	2.88	71.9	1839.8 ^a	1169.9 ^a	16.7 ^a	4.31 ^d	54.3	1839.8 ^a	1169.9 ^a	14.3 ^a	3.81 ^c
NaT C+2	36.7	32.3	656.3	619.5	11.1	2.93	71.9	1588.4 ^c	932.1 ^d	13.3 ^d	5.40 ^a	54.3	1588.4 ^c	932.1 ^d	12.3 ^c	4.41 ^a
NfT C	36.7	32.1	649.4	612.7	10.9	2.94	71.9	1577.1 ^c	927.6 ^d	13.3 ^d	5.43 ^a	54.3	1577.1 ^c	927.6 ^d	12.2 ^c	4.44 ^a
NfT C+1	36.7	32	662.5	625.7	11.2	2.87	71.9	1686.7 ^{bc}	1024.2 ^{bc}	14.6 ^{bc}	4.91 ^{bc}	54.2	1686.7 ^{bc}	1024.2 ^{bc}	13.1 ^{bc}	4.14 ^{abc}
NfT C+2	36.7	32.1	649.7	612.9	10.9	2.97	71.9	1737.3 ^{ab}	1087.6 ^b	15.5 ^b	4.63 ^{cd}	54.2	1737.3 ^{ab}	1087.6 ^b	13.5 ^{ab}	4.021 ^{bc}
ThT C	36.7	32.2	646.3	609.5	10.9	2.97	71.9	1665.9 ^{bc}	1019.7 ^{bc}	14.6 ^{bc}	4.95 ^{bc}	54.3	1665.9 ^{bc}	1019.7 ^{bc}	12.9 ^{bc}	4.20 ^{ab}
ThT C+1	36.7	32.2	717.5	680.7	12.2	2.66	71.9	1774.6 ^{ab}	1057.1 ^{bc}	15.1 ^{bc}	4.77 ^{bc}	54.3	1774.6 ^{ab}	1057.1 ^{bc}	13.8 ^{ab}	3.94 ^{bc}
ThT C+2	36.8	32.2	647.6	610.8	10.9	2.95	71.9	1660.6 ^{bc}	1013.0 ^{bc}	14.5 ^{bc}	4.98 ^b	54.3	1660.6 ^{bc}	1013.0 ^{bc}	12.9 ^{bc}	4.21 ^{ab}
SEM	0.044	0.033	25.4	25.4	0.454	0.118	0.556	30.1	15.8	0.226	0.071	0.015	30.1	36.1	0.239	0.072
P-Value																
Genotype	0.936	0.950	0.672	0.672	0.672	0.790	0.999	0.264	0.229	0.229	0.238	0.062	0.114	0.229	0.114	0.177
Diet	0.749	0.995	0.292	0.291	0.291	0.285	0.999	0.001	0.001	0.001	0.001	0.074	0.003	0.001	0.033	0.004
Genotype*Diet	0.439	1.000	0.526	0.527	0.527	0.608	1.000	0.001	0.001	0.001	0.001	0.599	0.001	0.001	0.006	0.001

^{a-d}Means with different superscripts within a column differ ($p < 0.05$). Abbreviations: NaT, Naked-neck (male)xTetra H (female); NfT, Normal-feathered (male)x Tetra H (female); ThT, Tetra H (male)xTetra H (female); C = control diet; C+1, C plus Phytolacca dodecandra (Endod) supplementation with 1g/kg; C+2, C plus Phytolacca dodecandra (Endod) supplementation with 2g/kg; BWG = Body weight gain; FI = feed intake; FCR = feed conversion ratio; IBW, Initial body weight; FBW, Final body weight; ADG, Average daily gain; SEM = standard error of the mean.

4.7.2 Effect of genotype and diet on carcass traits of chickens

Table 22 shows the effect of genotype and diet on carcass characteristics of chicken slaughtered at 18 weeks of age. In the present study genotype and diet had a significant ($P < 0.05$) effect on the dressing percentage ($P < 0.05$). Genotype had a significant effect on breast yield, thigh, keel bone muscle, and gizzard ($P < 0.05$). The results of dressing percentage were significantly ($P < 0.05$) varied among the genetic group of chickens with lower values recorded in the NfT chicken genotype than the other. The values of thigh muscle in the current study denote lower values observed in the NfT than the other chicken genotypes. The keel bone muscle value in this study showed that the NaT and ThT chicken genotypes had significantly ($P < 0.05$) higher values than the NfT chicken. The values of gizzard in the current study demonstrated that the NfT chicken genotype had a significantly ($P < 0.05$) lower value than the other chicken genotypes. However, diet and genotype by diet interaction had no significant ($P > 0.05$) effects on the carcass components.

Table 22. Effect of genotype and *Phytolacca dodecandra* (*endod*) supplementation on carcass traits of chickens

Item	Parameters (%BW)										
	DRP	BRM	THM	DSM	KBM	BKM	WNM	NKM	GZM	LVM	HTM
Genotype											
NaT	71.6 ^a	14.7 ^a	11.7 ^a	9.7	7.68 ^a	7.3	2.69	3.24	2.463 ^{ab}	1.75	0.477
NfT	70.1 ^b	13.8 ^b	10.8 ^b	9.6	7.29 ^b	7.6	2.44	3.22	2.223 ^b	1.76	0.496
ThT	72.0 ^a	14.8 ^a	11.6 ^a	9.5	7.55 ^{ab}	7.5	2.46	3.23	2.474 ^a	1.80	0.483
SEM	0.119	0.155	0.087	0.127	0.065	0.079	0.047	0.026	0.041	0.032	0.008
Diet											
C	70.1 ^b	13.9 ^b	11.6	9.33	7.39	7.48	2.42	3.20	2.54	1.88	0.493
C+1	71.8 ^a	14.7 ^a	11.7	9.92	7.62	7.55	2.59	3.25	2.32	1.73	0.466
C+2	71.9 ^a	14.7 ^a	11.8	9.62	7.64	7.32	2.58	3.24	2.40	1.70	0.496
SEM	0.207	0.269	0.150	0.221	0.113	0.137	0.081	0.046	0.070	0.055	0.013
Genotype * Diet											
C	70.836	12.982	11.3	9.17	7.354	7.26	2.56	3.19	2.43	1.73	0.510
NaT C+1	70.922	13.646	11.6	10.2	7.575	7.62	2.83	3.23	2.46	1.84	0.455
C+2	70.349	14.361	11.9	9.84	7.956	7.15	2.68	3.28	2.66	1.69	0.465
C	69.963	12.246	11.8	9.49	7.402	7.69	2.22	3.25	2.67	2.06	0.509
NfT C+1	69.819	13.805	11.9	9.97	7.482	7.86	2.54	3.23	2.08	1.57	0.463
C+2	69.966	14.198	11.7	9.22	7.304	7.09	2.57	3.19	2.09	1.65	0.516
C	70.875	13.386	11.5	9.34	7.425	7.49	2.47	3.16	2.51	1.86	0.460
ThT C+1	70.916	13.253	11.5	9.58	7.814	7.18	2.42	3.29	2.42	1.79	0.482
C+2	70.561	13.492	11.5	9.81	7.666	7.71	2.49	3.24	2.45	1.77	0.506
SEM	0.358	0.466	0.260	0.382	0.195	0.237	0.140	0.079	0.122	0.095	0.023
p-value											
Genotype	0.0095	0.0173	0.0003	0.0376	0.0475	0.2630	0.0577	0.5238	0.0250	0.3235	0.6614
Diet	0.0071	0.003	0.7798	0.1775	0.3209	0.3098	0.2912	0.6625	0.1095	0.2546	0.3058
Genotype*Diet	0.8771	0.2809	0.6760	0.2711	0.3910	0.0516	0.6447	0.3151	0.0521	0.2547	0.3740

^a Means with different superscripts within a column differ ($p < 0.05$). Abbreviations: NaT, Naked-neck (male) * Tetra H (female); NfT, Normal-feathered (male) * Tetra H (female); ThT, Tetra H (male) * Tetra H (female); C = control diet; C+1, C plus *Phytolacca dodecandra* (Endod) supplementation with 1g/kg; C+2, C plus *Phytolacca dodecandra* (Endod) supplementation with 2g/kg; BW = Body weight; DRP = Dressing percentage; BRM, Breast muscle; THM, Thigh muscle; DSM, Drumstick muscle; KBM, Keel bone muscle; BKM, Back muscle; WNM, Wing muscle; NKM, neck muscle; GZM, Gizzard muscle; LVM, Liver muscle; HTM, Heart muscle; SEM, Standard error of the mean.

4.7.3 Effect of Genotype and Diet on Blood Profiles of Chickens

Table 23 presents the effect of genotype and diet on the chickens' serum biochemical profiles. The study found that genotype had a significant ($P < 0.01$) impact on TP, Alb, Glo, TC, TG, and Glu levels. The NaT genotype had higher TP and Alb levels compared to other genotypes, while the ThT genotype had higher TC and TG levels. The Glu level was higher in the NaT and NfT genotypes than in the ThT genotype. Ca levels were lower in the NfT genotype. Dietary treatments also had a significant ($P < 0.01$) impact on serum biochemical profiles. The C+1 and C+2 diets resulted in higher TP, Alb, and Glo levels than the C diet. Furthermore, supplementation of chicken with C+1 and C+2 significantly ($P < 0.01$) reduced TC, TG, and Glu levels, but did not affect Ca levels. The study also found that interactions between genotype and diet had a significant ($P < 0.01$) impact on the chickens' serum biochemical profiles.

Table 23. Effect of genotype and *Phytolacca dodecandra* (endod) supplementation on serum biochemical profiles of chickens

Item	Serum biochemical profiles						
	TP	Alb	Glo	TC	TG	Glu	Ca
Genotype							
NaT	3.420 ^a	0.824 ^a	2.596 ^a	133.0 ^b	52.2 ^b	297.8 ^a	10.3 ^a
NfT	2.962 ^b	0.664 ^b	2.298 ^b	137.3 ^{ab}	46.2 ^b	301.6 ^a	9.49 ^b
ThT	2.081 ^c	0.628 ^c	1.453 ^c	138.2 ^a	107.3 ^a	205.6 ^b	10.4 ^a
SEM	0.004	0.003	0.004	0.556	1.064	1.102	.049
Diet							
C	2.633 ^c	0.655 ^c	1.978 ^c	151.5 ^a	81.1 ^a	280.3 ^a	10.2
C+1	2.831 ^b	0.700 ^b	2.131 ^b	130.6 ^b	69.9 ^b	266.7 ^b	9.99
C+2	2.998 ^a	0.761 ^a	2.238 ^a	126.4 ^c	54.7 ^c	258.1 ^c	10.0
SEM	0.073	0.012	0.064	0.964	1.843	5.88	0.076
Genotype * Diet							
NaT C	3.22 ^b	0.720 ^c	2.498 ^b	171.3 ^a	64.0 ^b	307.3 ^a	10.2 ^{bc}
NaT C+1	3.08 ^c	0.838 ^b	2.243 ^{cd}	107.5 ^f	58.0 ^{bc}	268.7 ^b	10.4 ^b
NaT C+2	3.96 ^a	0.915 ^a	3.048 ^a	120.3 ^e	34.5 ^{de}	317.8 ^a	10.1 ^{bc}
NfT C	2.85 ^e	0.658 ^e	2.193 ^d	165.5 ^{cd}	69.3 ^b	318.3 ^a	9.23 ^{cd}
NfT C+1	3.12 ^c	0.675 ^{de}	2.440 ^b	135.0 ^{cd}	48.3 ^{cd}	303.4 ^a	9.53 ^{cd}
NfT C+2	2.92 ^d	0.660 ^e	2.260 ^c	147.5 ^{bc}	21.0 ^e	283.3 ^b	9.73 ^{bc}
ThT C	1.83 ^h	0.588 ^f	1.245 ^g	141.8 ^b	110.0 ^a	215.5 ^c	11.1 ^a
ThT C+1	2.29 ^f	0.587 ^f	1.710 ^e	133.0 ^{cd}	103.5 ^a	228.2 ^c	10.0 ^b
ThT C+2	2.11 ^g	0.708 ^{cd}	1.405 ^f	123.5 ^d	108.5 ^a	173.3 ^d	10.2 ^b
SEM	0.013	0.008	0.013	1.669	3.191	3.306	0.146
P-value							
Genotype	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Diet	0.001	0.001	0.001	0.001	0.001	0.001	0.221
Genotype*Diet	0.001	0.001	0.001	0.001	0.008	0.001	0.001

^{a-h} Means with different superscripts within a column differ ($p < 0.05$). Abbreviations: NaT, Naked-neck (male) * Tetra H (female); NfT, Normal-feathered (male) * Tetra H (female); ThT, Tetra H (male) * Tetra H (female); C = control diet; C+1, C plus *Phytolacca dodecandra* (Endod) supplementation with 1g/kg; C+2, C plus *Phytolacca dodecandra* (Endod) supplementation with 2g/kg; TP, Total protein; Alb, Albumin; Glo, Globulin; TC, Total cholesterol; TG, Triglycerides; Glu, Glucose; Ca, Calcium; SEM, Standard error of the mean.

Table 24 displays that only RBC, Hb, and PCV were notably impacted ($p < 0.05$) by the addition of *Phytolacca dodecandra* (Endod) in the diet, with higher values observed in C+1 and C+2 than the C. The other hematological parameters remained consistent among the genotypes and diets.

Table 24. Effect of genotype and *Phytolacca dodecandra* (endod) supplementation on hematology of chickens

Item	Hematology						
	WBC	Hb	RBC	PCV	MCV	MCH	MCHC
Genotype							
NaT	21.5	10.1	2.992	29.9	100.7	34.9	34.8
NfT	21.7	10.2	2.948	28.6	97.6	36.7	37.9
ThT	22.6	10.4	2.894	30.8	108.2	38.6	35.4
SEM	0.932	0.327	0.088	0.630	3.977	1.830	1.108
Diet							
C	21.2	9.4 ^b	2.77 ^b	28.2 ^b	102.9	37.8	36.8
C+1	23.1	10.5 ^{ab}	3.163 ^a	31.4 ^a	99.5	34.8	35.1
C+2	21.6	10.8 ^a	2.90 ^{ab}	29.8 ^{ab}	104.1	37.6	36.1
SEM	0.932	0.327	0.088	0.630	3.977	1.830	1.108
Genotype * Diet							
NaT C	19.4	9.45	2.760	28.6	104.6	37.1	35.5
NaT C+1	22.2	10.5	3.250	30	92.8	32.4	35.2
NaT C+2	23.0	10.4	2.967	31	104.5	35.2	33.7
NfT C	21.6	9.50	2.825	26.5	94.1	36.9	39.8
NfT C+1	21.4	10.4	3.125	31	99.5	35.7	35.8
NfT C+2	22.1	10.8	2.895	28.5	99.3	37.4	37.9
ThT C	22.4	9.5	2.730	29.4	109.9	39.4	35.2
ThT C+1	25.5	10.7	3.113	33.1	106.1	36.4	34.2
ThT C+2	19.8	11.1	2.840	30.1	108.5	40.1	36.9
SEM	1.614	0.566	0.153	1.091	6.888	3.169	1.918
P-value							
Genotype	0.688	0.7509	0.7349	0.065	0.1758	0.359	0.1344
Diet	0.345	0.0142	0.0133	0.005	0.6975	0.451	0.5357
Genotype*Diet	0.175	0.9874	0.9794	0.350	0.7800	0.982	0.6657

^{a-h} Means with different superscripts within a column differ ($p < 0.05$). Abbreviations: NaT, Naked-neck (male) * Tetra H (female); NfT, Normal-feathered (male) * Tetra H (female); ThT; Tetra H (male) * Tetra H (female); C = control diet; C+1, C plus *Phytolacca dodecandra* (Endod) supplementation with 1g/kg; C+2, C plus *Phytolacca dodecandra* (Endod) supplementation with 2g/kg; WBC, White blood cells; Hb, Hemoglobin; RBC, Red blood cells; PCV, Packed cell volume; MCV, Mean corpuscular volume; MCH, Mean corpuscular hemoglobin; MCHC, Mean corpuscular hemoglobin concentration; SEM, Standard error of the mean.

4.7.4 Effect of genotype and diet on proximate compositions of breast meat

In this study, it was observed that the levels of crude protein and fat in breast meat varied significantly ($p < 0.05$) among different chicken genotypes (as shown in Table 25). The exotic ThT genotype displayed comparatively lower values as compared to the other genotypes. Furthermore, administering *Phytolacca dodecandra* to chicken genotypes

resulted in increased crude protein and decreased fat contents of breast meat compared to the control group.

Table 25. Proximate compositions of breast meat of chicken genotypes

Item	Nutrient compositions					
	DM	CP	Cf	Fiber	Ash	
Genotype						
NaT	27.5	23.6 ^a	7.29	6.56	1.557	
NfT	27.4	23.1 ^b	7.27	6.42	1.560	
ThT	27.4	22.9 ^b	7.37	6.23	1.520	
SEM	0.107	0.069	0.064	0.209	0.021	
Diet						
C	27.6	22.8 ^c	7.48 ^a	6.42	1.541	
C+1	27.5	23.2 ^b	7.25 ^b	6.40	1.545	
C+2	27.2	23.7 ^a	7.21 ^b	6.38	1.552	
SEM	0.107	0.070	0.063	0.209	0.021	
Genotype * Diet						
NaT	C	27.7 ^{ab}	23.3 ^b	6.65 ^d	6.36	1.623
	C+1	27.1 ^b	24.2 ^a	7.49 ^{bc}	6.33	1.497
	C+2	27.5 ^{ab}	23.4 ^b	7.74 ^{ab}	6.98	1.553
NfT	C	27.5 ^{ab}	22.6 ^c	8.16 ^a	6.40	1.510
	C+1	28.0 ^a	22.6 ^c	6.99 ^{cd}	6.58	1.555
	C+2	26.9 ^b	24.2 ^a	6.66 ^d	6.28	1.615
ThT	C	27.5 ^{ab}	22.6 ^c	7.65 ^{ab}	6.49	1.490
	C+1	27.4 ^{ab}	22.9 ^{bc}	7.25 ^{bc}	6.31	1.583
	C+2	27.3 ^{ab}	23.4 ^b	7.23 ^{bc}	5.88	1.488
SEM	0.186	0.121	0.109	0.363	0.036	
P-value						
Genotype	0.939	0.001	0.491	0.548	0.330	
Diet	0.099	0.001	0.010	0.993	0.934	
Genotype*Diet	0.003	0.001	0.001	0.438	0.170	

^{a-c} Means with different superscripts within a column differ ($p < 0.05$). Abbreviations: NaT, Naked-neck (male) * Tetra H (female); NfT, Normal-feathered (male) * Tetra H (female); ThT, Tetra H (male) * Tetra H (female); C = control diet; C+1, C plus *Phytolacca dodecandra* (Endod) supplementation with 1g/kg; C+2, C plus *Phytolacca dodecandra* (Endod) supplementation with 2g/kg; DM, dry matter; CP, Crude protein; CF, crude fat; ME, Metabolizable energy

CHAPTER FIVE

5. DISCUSSION

Experiment I

5.1 Fertility and hatchability of the three chicken genotypes

Fertility and hatchability are the two major factors influencing the reproductive performance of chicken breeds (Gallus, 2021). In the current study significant differences in fertility and hatchability were observed between the chicken genotypes. Fertility was highest for naked-neck (89.2%) and normal-feathered (86.7%) and lowest for Tetra H (70%). The fertility percentage was 19.2% higher in the naked neck and 16.7% higher in the normal-feathered than in the Tetra H chicken genotype. The hatchability of indigenous naked-neck (80%) and normal-feathered (76.7%) chickens had significantly higher ($p < 0.05$) than the exotic Tetra H (56.7%) genotype, respectively. Hatchability of fertile eggs was 80.9% to 89.7% in the current study, which was consistent with those reported by Bamidele *et al.* (2020), who reported hatchability 80% except for the Fulani (72%) genotype.

The hatchability of set eggs in Tetra H (56.7%) was significantly lower than the other genotypes and was consistent with the values reported by Wolde *et al.* (2021), where hatchability of 55.9% for the exotic Sasso-RIR genotype. The variations in fertility and hatchability percentage between chicken genotypes in the current study could be attributed to a genetic factor, which agrees with the findings (Gallus, 2021; Mengesha *et al.*, 2022). Consistent with this the observed differences in fertility and hatchability percentages between genotypes in the current study agreed with the findings of Adeleke *et al.* (2012) and Bamidele *et al.* (2020) who observed that breed and strain influence fertility and hatchability percentages. Tetra H larger egg size, on the other hand, could have contributed to the observed differences in fertility and hatchability. This was consistent with the findings of several studies (Kingori *et al.*, 2010; Fathi *et al.*, 2022), which found variations on fertility and hatchability percentage. Molapo & Motselisi (2020) and Attrouny *et al.* (2021) reported that indigenous chickens had higher fertility and hatchability percentages than exotic and crossbred chickens, which is consistent with the findings of this study.

5.2 Growth performance of the three chicken genotypes

The present study showed significant variations in the final body weight and body weight gains during the starter phase (0-8 weeks) among the genetic group of chicken. The Tetra H chicken had high final body weight and body weight gain compared to the other genotypes. These findings are consistent with the findings of Zelleke *et al.* (2022), who found that the final body weight and body weight gain for exotic Potchefstroom Koekoek was significantly higher than for local chicken genotypes. The presence of significant genotype effects on body weight, weight gain, feed intake, and feed conversion ratio in the current study suggests the presence of genetic differences between genotypes for these traits, which are consistent with the findings of Wolde *et al.* (2021). In agreement with the current findings, Wondmeneh *et al.* (2015) and Zelleke *et al.* (2022) observed that the growth rate of local chickens was generally slower than that of commercial breeds, owing to their poor genetic makeup. The higher body weight and weight gain observed in the exotic Tetra H chicken genotype indicates the genetic superiority of Tetra H chicken in body weight and weight gain over the other genotypes, which was consistent with the observations of Wolde *et al.* (2021), who noted that the exotic genotype is superior in body weight and weight gain as compared with the local genotype. In the current study, feed intake recorded during the starter phase did not differ significantly ($p > 0.05$) between genetic groups; however, differences were observed during the grower phase and the entire experimental period.

The Tetra H chicken genotype had higher feed intake than the other genotypes, while the naked-neck chicken genotype had significantly lower ($p < 0.05$) feed intake. The lower feed intake observed in the naked-neck genotype was due to 20-40% less feather coverage in the naked-neck, which might reduce dietary requirements for feather development and save nutrients (Makled & Rahman, 2006). In general, the feed intake observed in Tetra H was in agreement with the previous studies of (Bamidele *et al.*, 2020) and (Wolde *et al.*, 2021) who reported feed intake was higher for the commercial chicken genotype than the indigenous chicken and this was due to the positive association of weight gain with feed intake and feed efficiency (Wolde *et al.*, 2021).

The body weight of the genotypes varied significantly, with higher values recorded in the Tetra H (1876.8 g) than in the naked neck (1166.7 g) and normal-feathered genotypes (1103.5 g). In this study, the Tetra H was 77.3% and 71% heavier than the normal-feathered and naked-neck chicken genotypes, respectively. The body weight observed in Tetra H was consistent with the recommendation of manufacturer Bábolna Tetra (Guide, 2013) at 18 weeks of age and, however, was lower than the reported values of several authors (Drobnyak *et al.*, 2019) in Hungary, who observed 3109 g, Almasi *et al.* (2012) 2558.5 g and Simiz *et al.*, (2013) 2150 g, respectively at 12 weeks of age. In terms of live weight, there were no significant differences ($p > 0.05$) between the naked-neck and normal-feathered chicken genotypes. The absence of a significant difference in body weight between the naked-neck and normal-feathered genotypes in this study was consistent with the findings of (Duah *et al.*, 2020), who found insignificant differences ($p > 0.05$) between the naked-neck and normal-feathered chicken genotypes at 19 weeks of age, but differed from the values reported by (Adomako *et al.*, 2014) and (Adedeji *et al.*, 2006) who reported a significant difference ($p < 0.05$) between the naked-neck and normal-feathered in body weight.

The body weight of naked-neck (1116.7 g) and normal-feathered (1103.5 g) chicken genotypes in the current study were higher than the values reported by Wolde *et al.* (2021) at a similar age, who reported 1070 g for the local chicken genotype. Similarly, the body weights of local chickens reported for the local Kei phenotype (924 g) (Alewi & Melesse, 2013) and the improved Horro (964 g) (Wondmeneh, 2015) at 20 weeks of age were lower than the values observed in the current study from the indigenous naked-neck and normal-feathered. Similarly, Hassen *et al.* (2006) reported that local Debre Ellias (1054 g) and Gassaye (1038 g) chickens had lower body weights at 22 weeks of age when compared to the naked-neck and normal-feathered at 18 weeks of age. However, Adomako *et al.* (2014) in Ghana, reported the body weight at 20 weeks of age was 1895.8 g for naked-neck and 1565.4 g for normal-feathered chicken, which were higher than the values observed in the current study.

In the present study, the FCR was significantly lower (better) for exotic Tetra H (3.76), followed by the naked-neck (5.6) and poor for the normal-feathered (6.1) chicken genotypes. The FCR observed in the Tetra H chicken genotype was consistent with the findings of Simiz *et al.* (2013), who reported FCR within the range of 3.47-3.74 at the age of 12 weeks. Consistent with this result, Zelleke *et al.* (2022) and Wolde *et al.* (2021), reported lower (better) FCR in the exotic genotype than in the indigenous chicken. However, higher (poor) FCR values were observed in the naked-neck and normal-feathered genotypes, which were consistent with those reported by Wolde *et al.* (2021) and Alam *et al.* (2021) for local chicken genotypes. The observed differences in FCR between genotypes could be related to the genetic differences among chicken genotypes, implying that the exotic Tetra H was more efficient in feed conversion than the other genotypes. Several authors (Alam *et al.*, 2021; Mengesha *et al.*, 2022; Tudorache *et al.*, 2022), reported genetic differences in FCR among chicken genotypes, and exotic lines were more efficient than local chicken genotypes. The selection of a chicken genotype for better FCR improves feed utilization, reduces feed intake, and increases growth rate (Aggrey *et al.*, 2010). In line with this, Khawaja *et al.* (2012) and Das *et al.* (2014) reported genetic that variations could lead to changes in FCR.

The mortality rate observed in the current study was significantly lower ($p < 0.05$) in naked-neck chickens than in the other genotypes. The mortality rate reported by Adomako *et al.* (Adomako *et al.*, 2014) was in the range of 7.89 – 9.1 % and Zelleke *et al.* [2] reported 9.3 % for Horro chicken are in good agreement with the current results observed in the naked-neck chicken genotype (8.9 %) and however, lower than the other chicken genotypes. Contrary to this, Wolde *et al.* (2021) reported slightly higher mortality rates of local and exotic Sasso chickens 17.7% and 13.3%, respectively. A higher mortality rate reported by Hassen *et al.* (2006) for indigenous chicken genotypes in the range of 18.9 % - 82.4 % was higher than in the current study. The mortality rate result observed in the current study during the starter phase (0-8 weeks) was due to a mild Coccidia outbreak and was consistent with Wolde *et al.* (2021), who reported coccidian outbreak resulted in the mortality of chicken. However, the naked-neck chicken genotype was better in survivability than the other chicken genotypes under intensive management conditions,

suggesting that the presence of the Na gene in the chicken might have increased their resistance against diseases (Adomako *et al.*, 2014).

5.3 Morphometric traits of the three chicken genotypes

Variations in morphometric traits could provide valuable information for the design of genetic improvement and selection programs for chickens, which rely primarily on variations within and between breeds or populations (Shafiq *et al.*, 2022). The linear body measurement traits observed in the current study demonstrated Tetra H chicken genotype had significantly higher body and keel bone length, chest width, and shank circumference than the other genotypes. On the other hand, the hierarchical cluster analysis indicated the genetic variability between studied chicken genotypes (Figure 3). The body length observed in Tetra H (41.8 cm) in the present study was significantly higher ($p < 0.05$) than the naked-neck (37.1 cm) and normal-feathered (36.8 cm) chicken genotypes. The higher body length observed in the Tetra H genotype agrees with (Fadare, 2014), who observed the presence of genetic diversity in the body length of exotic Giri-raja and Nigerian local chicken genotypes. In contrast to this study Ahmad *et al.* (2019), observed insignificant differences in body length among the exotic and local Horro chicken genotypes. In this study, body length was not significantly different between the naked-neck and normal-feathered chickens, which was consistent with the values reported by Udumma and Francis (2017).

The chest width values recorded in the current study showed a higher value for Tetra H than the indigenous naked-neck and normal-feathered chicken genotypes. The difference in chest width reported in the current study was in agreement with Adomako *et al.* (2014), who reported variations in chest width between the naked-neck and normal-feathered chicken genotypes. Likewise, Atansuyi *et al.* (2017) observed variations in chest width among the chicken genotypes at 8 weeks of age. Results on keel bone length in the current study were significantly varied among the chicken genotypes with higher values observed in the Tetra H genotype. In line with the present findings, Ahmad *et al.* (2019) reported variations in keel bone length between naked-neck and crossbred genotypes. Consistent with these, Shafiq *et al.* (2022) also observed significant differences in keel bone length among the chicken genotypes.

The current results demonstrated significant differences in shank circumferences among the chicken genotypes, with the higher value recorded from the Tetra H genotype. These findings correspond to those of Zelleke *et al.* (2022). Similar findings have also been reported by Oleforuh *et al.* (2017) who reported significant differences in shank circumference between the two chicken genotypes. In agreement with these findings Ahmad *et al.* (2019), reported significant differences in shank circumferences among male chicken genotypes at 21 weeks of age. The observed morphometric variation in the present study suggests these traits could vary due to genotype and agrees with the reports of Islam & Nishibori, (2009) and Adomako *et al.* (2014), who observed morphometric variations between naked-neck and normal-feathered genotypes in Ghana. This is also consistent with the findings of Ahmad *et al.* (2019), who also observed morphometric variation among naked-neck and two crossbreeds chickens in Pakistan.

The significant effect of genotype on the body weight to shank length ratio obtained in this study corresponds to the reports of Tadele *et al.* (2018) who observed a significant effect of the body weight to shank length ratio of female chickens. In this study, positive and significant ($p < 0.05$) correlations were observed between body weight and some linear body measurement traits among the genetic group of chicken and are in good agreement with the reports of Adeleke *et al.* (2012) and Egena *et al.* (2014). The observed positive correlations of body weight with linear body measurements indicate measuring one of these linear body measurement traits enables one to predict the live body weight of chickens (Tadele *et al.*, 2018; Mbara, 2020). The results of the present study and the findings of other scholars, therefore, suggest that selection for any of these linear body measurable traits will cause direct improvement in the body weight of chickens (F. I. & S. W., 2020). In the present study, the coefficient of determination (R^2) values ranged from medium (0.69) to high (0.99) indicating that the equations could be used to accurately predict the live body weight of chickens. The predictive equations provide a readily available tool in body weight estimation and this is particularly true in rural areas or areas where weighing scales are not available (Fayeye *et al.*, 2017). The use of hierarchical cluster analysis was effective in distinguishing the three chicken genotypes using the quantitative morphological traits. The formation of two groups of clusters seen in Figure 3 could correspond to correlations that exist among the genetic group of chicken. However, the

result indicated the Tetra H chicken was distinct from the other genotypes whereas, the naked-neck and normal-feathered chickens were strongly related to each other. This supports the existence of genetic variations among the genetic group of chicken and corresponds with the observations of Melesse *et al.* (2021), who reported genetic variability among chicken populations.

5.4 Carcass components of the three chicken genotypes

In the current study, significant variations were observed in terms of carcass traits with higher carcass yield observed in the Tetra H chicken genotype. The higher carcass yield observed in the Tetra H genotype could be attributed to the heavier slaughter weight of the Tetra H genotype. These results are in agreement with the findings of Biazen *et al.* (2021) who reported significant differences in slaughter weight of the four chicken phenotypes at 16 weeks of age. Likewise, Zelleke *et al.* (2022) also observed significant differences in the slaughter weight of poultry genotypes. The indigenous naked-neck and normal-feathered chicken genotypes have a higher dressing percentage than the Tetra H genotype. This finding was in agreement with the result reported by Kebede *et al.* (2019), who observed a higher dressing percentage from the local chicken genotype than the exotic birds. Alemneh *et al.* (2021) also observed higher dressing percentage values from the indigenous chicken genotypes than exotic crossbreed chicken. Similarly, Shafiq *et al.* (2022) observed a higher dressing percentage from the indigenous chicken genotype. The lower dressing percentage recorded from the Tetra H genotype could be due to the presence of higher non-edible offal. However, the variations in dressing percentage observed in the current study and the results of other findings indicate the existence of genetic variations which influence this trait (Choo *et al.*, 2014).

The most valuable carcass components of chicken such as carcass weight, breast, drumstick, thigh, and keel bone muscles are desired by the consumers and therefore, influenced by genotype (Kebede *et al.*, 2019). In the current study, these carcass components were significantly higher in the Tetra H genotype. These results are in agreement with the previous findings of various scholars, who reported exotic genotypes to have higher values of these traits than indigenous chickens (Kingori *et al.*, 2010; Bamidele *et al.*, 2020). The higher carcass component values observed in the Tetra H

genotype indicate the suitability of the genotype for meat production than the indigenous chicken genotypes, which is consistent with the observation of (Kebede *et al.*, 2019). Edible offal which includes gizzard, liver, and heart in the current study were significantly varied across genotypes. The higher liver, heart, and gizzard weight exhibited by the Tetra H genotype than the indigenous chicken genotypes was in agreement with the result reported by (Biazen *et al.*, 2021).

5.5 Reproductive and productive performances of the three chicken genotypes

The age of the first egg is an important economic trait in poultry production as it determines the productivity of the flock (Mohanta *et al.*, 2018). In the present study, significant differences were found in the genetic group of chickens for age at sexual maturity of female chickens, and the Tetra H (150 days) and naked-neck (153 days) laid eggs earlier than the normal-feathered chicken (161 days). The Tetra H chicken began laying eggs at 21-22 weeks, as recommended by the producer Babolna TETRA (Guide, 2013). However, the findings reported by (Gerzilov *et al.*, 2018) were 117 and 134 days age at the first egg in the first and second experiments in the Tetra H chicken genotype, respectively, which were even earlier than the producer Babolna TETRA Guide (2013) guidelines. The age of the first egg in the naked-neck and normal-feathered chicken genotypes reported by (Adomako *et al.*, 2010), was comparable with the naked-neck, however earlier than the reported values from the normal-feathered than the current study.

The Tetra H genotype's body weight (1412.7 g) at 20 weeks was 29.8% higher than the normal-feathered and 20.72% higher than the naked-neck, but 18.1% lower than the manufacturer's Babolna TETRA (1725 g) at the same age (Guide, 2013). Similarly, Almasi *et al.* (2012) reported a higher live body weight (2215 g) of Tetra H females at 12 weeks of age which was even higher than the manufacturer value by 22.12% (Guide, 2013). The observed variations in live weight may be due to environmental, nutritional, and other management factors; however, in the current study, the observed variations are due to genetic differences and agree with the reports of Tadele *et al.* (2023a). On the other hand, body weight is associated with egg production performance and age at sexual maturity, and thus, the Tetra H genotype laid earlier than the other chicken genotype due to their higher

body weight (Gerzilov *et al.*, 2018), and the naked-neck was also relatively higher in body weight and laid earlier than their normal-feathered counterparts. As shown in Table 17, genotype had a significant influence on average hen-housed egg production during the laying experimental period, with higher values recorded in the Tetra H chicken. These results are in agreement with the observations of Islam & Nishibori (2009) and Yonas *et al.* (2019) who reported the genotype affects hen-housed egg production. When compared to the other genotypes, the naked-neck chicken had the lowest feed consumption. These findings are consistent with earlier research, which found that the naked-neck genotype consumes less feed than other chicken genotypes (Tadele *et al.*, 2023a).

5.6. External and internal egg quality traits of the three chicken genotypes

5.6.1 External egg quality traits

The result of egg weight recorded from the Tetra H chicken genotype (56.8 g) in the present study was significantly heavier ($p < 0.05$) than the two chicken genotypes. These results are in agreement with the findings of Fereja *et al.* (2016) and Yonas *et al.* (2019) who reported heavier egg weight values from exotic chickens than the indigenous chicken genotype. Consistent with the present study, the result observed in Nigeria, the egg weight of exotic chicken was significantly higher (59.6 g) for the Dominant blue chicken than the indigenous normal-feathered (52.33 g) and Naked neck genotypes (52.70 g) (Issn, 2013) and the results were higher than the observed egg weight values from the current indigenous normal-feathered (43.7 g) and naked neck (44.3 g) chicken genotypes. The egg weight values reported by Markos *et al.* (2017) in the highlands of the Tigray region (43.7 g) and Edmew *et al.* (2018) in Bench Maji Zone, Southwest Ethiopia (43.9 g) were consistent with the result observed in the naked-neck and normal-feathered chicken genotypes of the present study.

However, various scholars in Ethiopia and other parts of the world also reported lower egg weights of indigenous chickens than in the present study. Accordingly, Melesse *et al.*, (2013) found lower egg weights of indigenous chickens in different agroecology (39.4 g, 40.2 g, and 39.3 g, from the lowland, midland, and highland) of Ethiopia. Assefa *et al.* (2019) also reported 41.1 g and 39.5 g from low and midland agroecology. Accordingly,

Hussain *et al.* (2013) in Pakistan reported 41.05 g of egg weight of indigenous chicken, and (Liswaniso *et al.*, 2020) reported 41.7 g and 40.59 g for Assel and Kadaknath chicken genotypes. The higher egg weight value recorded from the Tetra H chicken genotype in the current study might be associated with the heavier body size of the Tetra H chicken genotype. According to Alex (2001), report egg weight of a chicken was proportional to body weight, indicating the heavier body weight of a chicken would likely produce big-sized eggs as they can consume more feed. This was also a similar scenario to the report of Issn (2013) who reported that egg weight was higher for heavy chickens than for light chicken breeds. In agreement with this, Liswaniso *et al.* (2020) reported a positive relationship between chicken body weight and egg weight. As a result, the lower egg weight exhibited by the indigenous normal-feathered and naked-neck chicken genotypes in the current study was associated with the genotypes' lower body weight (Tadele *et al.*, 2023), and thus, the selection of chickens with heavier body weight would produce superior egg weight (Tongsiri *et al.*, 2019).

The Tetra H chicken's average egg length (56.2 mm) was substantially greater ($p < 0.05$) than the other two chicken genotypes. The differences in egg length found may be related to genetic composition (Issn, 2013). The current study's findings agreed with those of Yonas *et al.* (2019) from Hawassa and Yirgalem Town, who reported egg length values of 55.7 mm and 55.59 mm from Sasso and Bovan chicken, respectively. Consistent with this, Assefa *et al.* (2019) reported average egg length values of 54.8 mm, 55 mm, and 53.2 mm from Bovan, Sasso, and Koekoek chickens, respectively. In line with this, the result reported from Nigeria was consistent with the current study, which reported the exotic Dominant blue had a 58.8 mm higher egg length value than the indigenous normal-feathered (55.0 mm) and naked-neck (55.8 mm), chicken genotypes (Issn, 2013). In the current study, egg length observed from indigenous normal-feathered (52.3 mm) and naked-neck (52.6) mm chickens was comparable with the observations of Kumar *et al.* (2022), for Assel (51.6 mm) and Kadaknath (51.3 mm) native chickens. However, Yonas *et al.* (2019) reported comparatively higher egg length (54.6 mm) in India and Hussain *et al.* (2013) reported 55.5 mm of egg length from native chicken.

The egg width observed in the present study showed a significant difference ($p < 0.05$) among the genotypes, with a higher value (43.1 mm) recorded from the Tetra H chicken. Consistent with the current study, previous comparative studies from exotic chicken genotypes showed higher egg width values than the indigenous chicken genotype. Based on this Kebede *et al.* (2019) reported 42 mm from Exotic chicken in the Metekel Zone and Assefa *et al.* (2019) also reported the egg width value from exotic ranged from 39-41.2 mm in the low and mid-agro-ecologies of the Sidama Zone. Similarly, the results reported in Nigerian Dominant blue chicken exhibited higher (44.3 mm) than the indigenous normal-feathered (42.1 mm) and naked-neck (42.7 mm), chicken genotypes, respectively (Issn, 2013). However, the egg width reported by Kumar *et al.* (2022) from Aseel (38.5 mm) and Kadaknath (37.9 mm) native chicken, and Yonas *et al.* (2019) observed egg width values of 40.6 mm agreed with the values recorded from indigenous chicken genotypes.

The egg shape index in the current study varied significantly among the genetic group of chickens with higher values recorded from the Tetra H chicken genotype. The Tetra H chicken had a significantly higher egg shape index of 76.7 % and indigenous normal-feathered (74.4 %) and naked-neck (74.2 %). The result of the current study was consistent with the values reported by various scholars in Ethiopia and other parts of the world (Nkukwana, 2018; Vekić *et al.*, 2022). Similarly, the shape index reported from Aseel (74.75 %) and Kadaknath (74.02%) chicken breeds were consistent with the results recorded from indigenous normal-feathered and naked-neck chickens in the current study (Kumar *et al.*, 2022). However, a relatively higher shape index value than the indigenous chicken in the current study was reported by Haunshi *et al.* (2011) and Valavan *et al.* (2016), which were 76.39 % and 77.23 %, respectively. Similarly, Ahmad *et al.* (2013) also found 77.25 % to 83.87 % of the shape index from indigenous chicken. The egg shape index was a good indicator of the similarity of the egg size and the higher shape index indicates the uniformity of the eggs (Agarwal *et al.*, 2021). Thus, the shape index observed from the indigenous naked-neck and normal-feathered chicken genotypes falls within the standard egg size (72-76 %) and the Tetra H falls with a round egg size > 76 % (Duman *et al.*, 2016).

The average eggshell thickness values obtained from the current study (0.43 mm) were in agreement with the findings of Ojo & Ayorinde (2011) who reported 0.40 mm for Nigerian Dominant Black female chickens, and Rajaravindra *et al.* (2015) for homozygous and heterozygous naked-neck chicken genotypes. Consistently, the eggshell thickness reported in Nigerian indigenous normal-feathered and exotic dominant blue chicken reported by Issn (2013), 0.42 mm agrees with the present study. However, lower eggshell thickness values were reported in various studies (Abdurehman & Urge, 2016) observed a 0.29 mm in Eastern Hararghe Ethiopia, (Yonas *et al.*, 2019) in Yirgalem and Hawassa Ethiopia reported in the range of 0.19-0.32 mm, and (Van *et al.*, 2020) from Vietnam reported 0.22-0.23 mm for indigenous chicken and (Liswaniso *et al.*, 2020) from Zambia reported 0.34 mm and (Issn, 2013) observed 0.36 mm in Nigerian indigenous normal-feathered chicken. On the other hand, higher eggshell thickness values of 0.59 mm were reported for the Fulani chicken Ecotype and Dominant black chicken (0.50 mm) in Nigeria (Ojo & Ayorinde, 2011). According to Liswaniso *et al.* (2020), the eggshell thickness of 0.33 mm was supposed to be strong enough to resist minimal handling, and thus, the average eggshell thickness recorded in the present study (0.43 mm) was able to withstand handling during storage and transportation.

5.6.2 Internal egg quality traits

The egg yolk weight result of the present study differed considerably between genetic groups of chicken, with the highest weight observed from exotic Tetra H chicken. This was consistent with the findings of (Issn (2013), who found that exotic Dominant blue had substantially higher egg yolk weight than indigenous normal-feathered and naked-neck genotypes in Nigeria. The egg yolk weight of the indigenous normal-feathered and naked-neck chicken genotype found in this research was similar to several studies. Accordingly, (Edmew *et al.*, 2018) reported 15.1 g, and (Abdurehman & Urge, 2016) observed, 15.05 g was consistent with the results observed from indigenous normal-feathered (15.3 g) and naked-neck (15.6 g) chicken genotypes. Similarly, Markos *et al.* (2017) reported 16.5 g egg yolk weight in highland agro-ecologies of the Tigray region, Ethiopia, and Van *et al.* (2020) in Vietnam indigenous Ho chicken reported 16.76 g and these were in agreement with the current result observed from Tetra H chicken genotype and Liswaniso *et al.* (2020)

in Zambia also reported 16.92 g from indigenous chicken. However, higher egg yolk weight was reported in Nigerian indigenous normal-feathered (17.55 g), naked-neck (18.2 g), Dominant black (18.1 g), and Dominant blue (19.5 g) chicken genotypes (Issn, 2013) and 17.44 g from indigenous Dong Tao chicken in Vietnam (Van *et al.*, 2020) than the current study. A lower egg yolk weight of 13.75 g was reported from indigenous chicken in Pakistan (Hussain *et al.*, 2013).

The yolk height values observed from indigenous normal-feathered (15 mm) and naked-neck chickens (15.1 mm) were consistent with the values reported from Aseel native chicken (15.3 mm) in India (Kumar *et al.*, 2022). A higher egg yolk height of 18.22 mm was reported in India (Yonas *et al.*, 2019) than in the current study. However, lower yolk height values were reported in various studies (Issn, 2013) and from Kadaknath native chicken in India (Kumar *et al.*, 2022). In the present study albumen height observed from indigenous normal-feathered, naked neck and Tetra H was found to be 5.42 mm, 5.27 mm, and 8.55 mm, respectively. The albumen height values reported by Yonas *et al.* (2019) from Yirgalem and Hawassa towns in Ethiopian local and exotic chicken genotypes were consistent with the present study. However, the albumen height reported by Hussain *et al.* (2013) was 5.2 mm, and Kadaknath native chickens 5.52 mm (Kumar *et al.*, 2022) agreed with the reported values from indigenous normal-feathered and naked-neck chickens. The albumen weight in the present study was varied significantly among the genetic group of chicken and higher values recorded from exotic Tetra H chicken. The results reported from Nigeria indicated the albumen weight recorded from the Dominant black (33.8 g) was higher than the reported values of the naked-neck (30.05 g) chicken genotype (Issn, 2013). However, the results of albumen weight observed from indigenous normal-feathered and naked-neck chickens in the present study were in agreement with various studies reported from indigenous chickens (Issn, 2013; Vekić *et al.*, 2022).

The Haugh unit (HU) value was mainly influenced by albumen height and egg weight (Assefa *et al.*, 2019) and in the present study, a higher value was reported from exotic Tetra H (92.7). This result was in agreement with the reports of various studies (Islam & Dutta, 2010), which reported the exotic chicken genotype to have higher HU values than the local chicken genotypes. The HU value reported by Rath *et al.* (2015) in Indian White leghorn

chicken (92.0) was consistent with the value reported in Tetra H chicken. On the other hand, the HU values reported from the East Shewa Zone of Ethiopia from exotic chicken maintained in various management conditions showed significant differences with higher HU observed from intensively managed chicken (Woldegiorgiss *et al.*, 2015). Similarly, higher HU value was reported from intensively managed chicken breeds in Tanzania (Guni *et al.*, 2021). However, the Haugh unit values observed in the normal-feathered (78.6) and naked-neck (77.2) chicken genotypes in the current study were higher than the values reported by various scholars (Almasi *et al.*, 2012; Geleta *et al.*, 2013; Issn, 2013; Padhi, 2016). In addition, lower Haugh unit values were also reported by Yonas *et al.* (2019) who reported an HU value of 74.9 from Hawassa town and Hussain *et al.* (2013) from Indigenous chicken in Pakistan reported 71.4, and Kumar *et al.* (2022) studied 63.97 from Indian Kadaknath native chicken.

5.7 Phenotypic correlation of external and internal egg traits of the three chicken genotypes

In the present study, there were strong, positive, and significant correlations between egg weight and albumen and yolk weight were observed among the genetic group of chickens. Strong correlation coefficients found between egg weight and, albumen and yolk weight in the three chicken genotypes were consistent with the findings of Kgwatalala *et al.* (2016), who found strong, positive correlations between egg weight and albumen weight ($r = 0.892$ and $r = 0.907$) in the naked-neck and normal-feathered, respectively). Positive and significant ($p < 0.01$) correlations were also observed between egg weight and in most of the traits considered except shell thickness in the three chicken genotypes and non-significant correlations were recorded between egg weight and albumen and yolk height in the normal-feathered and Tetra H chicken genotypes. These results agree with the values reported by Bobbo *et al.* (2013) for the naked-neck genotype except for shell thickness which reported significant values. A significant positive correlation ($p < 0.01$) was found between egg weight and albumen and yolk weight in the three chicken genotypes compares favorably with the result reported by (Assefa *et al.*, 2019; Kebede *et al.*, 2019).

The positive and significant correlations observed between egg width and shell weight among the genetic group of chickens were in the same scenario as the observations of (Vekić *et al.*, 2022). However, non-significant correlations were recorded between egg width and yolk and albumen height for the normal-feathered chicken genotype and agreed with (Bobbo *et al.*, 2013). For the normal-feathered and naked-neck chicken genotypes, albumen weight was significantly ($p < 0.01$) correlated with yolk weight, which was consistent with the findings of (Rath *et al.*, 2015; Tongsiri *et al.*, 2019). Albumen and yolk weight were significantly ($p < 0.01$) correlated with albumen and yolk height in the naked-neck genotype, and albumen height was significantly ($p < 0.01$) correlated with yolk height in the naked-neck and Tetra H chicken genotypes and the results are in the same scenario with the observations of several scholars (Haunshi *et al.*, 2011; Rath *et al.*, 2015). Thus, selecting a chicken genotype for increased egg weight will eventually result in increased weight of the various egg components.

5.8 Experiment II

5.8.1 Effect of Genotype and Diet on growth performance of Chickens

The use of medicinal plants in animal feeds has gained much attention in recent years due to its potential to enhance growth performances (Hashemi & Davoodi, 2011). The active components present in *Phytolacca dodecandra*, also known as *Phytolacca dodecandra* (Endod) or Ethiopian soapberry, have various physiological and biochemical functions in the body (Iteku *et al.*, 2019). According to the present study presented in Table 7, the plant contains a range of bioactive compounds such as saponins, tannins, flavonoids, and alkaloids, which is in agreement with the results reported by Iteku *et al.* (2019). Our study indicates that both diet and genotype*diet interactions significantly affect the growth performance of chicks. Consequently, the C+1 diet demonstrated significant improvements in terms of final body weight (FBW), body weight change (BWC), average daily gain (ADG), and feed conversion ratio (FCR) compared to the C+2 and C diets throughout the grower phase and the entire experimental period.

In agreement with this, several authors indicated that supplementation of medicinal plants significantly improved the performance traits of chickens. One study found that including herbs such as oregano and thyme in the diet of broiler chickens improved their growth performance, including body weight gain and feed efficiency. These herbs have been shown to have antibacterial and antifungal properties, which can help prevent infections and improve gut health (Wareth *et al.*, 2012). Similarly, the use of herbal plants *Azadirachta indica* and *Moringa oliefera* leaf powder as feed additives has also been shown to improve growth performance in broiler chickens (Kanwal *et al.*, 2022). Likewise, a study (Gurbuz & Ismael, 2016) reported that peppermint supplementation at the rate of 1.5% significantly improved the growth performance traits of broiler chickens. The current study demonstrated that *Phytolacca dodecandra* (Endod) significantly improved the growth performance of chickens and this might be due to the presence of a bioactive component (*i.e.* saponin). In line with this, previous studies have shown that saponins can enhance the secretion of digestive enzymes and promote gut health, thereby improving the absorption of nutrients in poultry (Youssef *et al.*, 2021).

5.8.2 Effect of genotype and diet on carcass traits of chickens

In the present study, the dressing percentage, breast, thigh, and keel bone muscle, and gizzard were significantly influenced by genotype among the chicken genetic groups. The NfT genotype displayed lower values when compared to the other groups. Moreover, the diet was found to have a significant effect on the dressing percentage and breast muscle, with higher values observed in the supplemented group compared to the control. The results of this study agree with previous studies on the effect of medicinal plants on carcass yield, as reported by Kalantar *et al.* (2017), Ahmadian *et al.* (2020), and Kanwal *et al.* (2022). These studies found that supplementing the broiler chickens' diets with medicinal plants led to a significant increase in dressing percentages than the non-supplemented. Likewise, Rastad (2020) reported that broiler chickens that were fed diets containing 1% garlic powder and 0.9g/kg probiotics showed a significant increase in the weights of the carcass, heart, gizzard, spleen, abdominal fat, and liver. However, in contrast to the findings of Al-Massad *et al.* (2018), who observed significant changes in the weights of heart, liver, and gizzard in broiler chickens fed with 2.5, 5, and 7.5 kg/ton garlic powder, the present study did not detect any substantial variations in the organs among the supplementation of *Phytolacca dodecandra*.

5.8.3 Effect of Genotype and Diet on Blood Profiles of Chickens

5.8.3.1 Serum parameters

Several studies (Animashahun *et al.*, 2022; Asaniyan & Akinduro, 2020; Toghyani *et al.*, 2010) have shown that genotype, sex, nutrition, management, and stress are among the factors that can influence the blood biochemical parameters in chickens. Blood metabolites such as total cholesterol, concentrations of triglycerides, glucose, and proteins are important indicators that are directly linked to their health (Cox & García-Palmieri, 2011). The normal cholesterol range for chickens is reported to be between 87-192 mg/ml according to Meluzzi *et al.* (1992). Our study found that the blood cholesterol level in chicken genotypes ranged from 133-138.2 mg/dl, with the NaT and NfT genotypes showing lower values than the ThT genotype. Higher cholesterol levels may increase the risk of developing cardiovascular disease (Soliman, 2018). Our study suggests that crossing

indigenous normal-feathered and naked-neck chicken genotypes with exotic chicken genotypes may result in lower cholesterol levels, as demonstrated by the NaT and NfT genotypes having significantly lower levels compared to the ThT genotype.

In the present study, the ThT chicken genotype had significantly higher values of TC and TG compared to the other genotypes. Consistent with this study, the results reported by (State & Breeding, 2021) explained that the exotic Kuroiler chicken genotype had higher values of TC and TG compared to the indigenous normal feathered, naked neck and their crossbreds. Our results showed that total protein concentration varied among the genotypes with lower values observed in the exotic ThT than in the other chicken genotypes. Consistent with this, (Tudorache *et al.*, 2022) observed that the R genotype displayed the highest Alb value in comparison to other genotypes. Based on (Ladokun *et al.*, 2008) findings, an increase in the overall amount of proteins in the plasma indicates the essential role of globulin in enhancing the immune system.

The serum protein levels of birds are considered important indicators for the determination of their health status (Tóthová *et al.*, 2019). The current study results showed that the inclusion of *Phytolacca dodecandra* significantly increased the levels of TP, albumin, and globulin compared to the control group. In addition, TP, albumin, and globulin showed linear increases with increasing supplementation of *Phytolacca dodecandra*. The present study results are in the same scenario as the results of (Abdul Basit *et al.*, 2020), who noted higher serum TP, Alb, and Glo levels were observed with broilers fed *Persicaria odorata* Leaf Meal.

The incorporation of up to 2g/kg of *Phytolacca dodecandra* into the chicken feed resulted in a considerable enhancement in the plasma levels of total protein, albumin, and globulin as compared to the control group. In line with this, a study conducted by (Alagawany *et al.*, 2016) found that the inclusion of garlic supplements in the diet of chicken resulted in a significant improvement in TP, Alb, and lipid profile. Similarly, (Abdul Basit *et al.*, 2020) observed that supplementation of *Persicaria odorata* Leaf Meal linearly increased the serum levels of TP, Alb, and globulin. According to the findings of the current study, the reduction of blood cholesterol and triglyceride levels resulted from the addition of *Phytolacca dodecandra* in the diet of chicken genotypes, which is in line with the results

reported by (Al-Khalaifah *et al.*, 2022) who observed similar effects upon the inclusion of ginger powder in the diet of broiler chicken. Similarly, in agreement with our current study, the trends of serum total protein and globulin were reported by (Abudabos *et al.*, 2018) for broilers fed with anise and thyme essential oils. Moreover, the inclusion of dietary fermented garlic powder led to a significant increase in serum levels of total protein and albumin, while cholesterol and triglyceride concentrations were significantly reduced (Lim *et al.*, 2023). Similarly, (Kairalla *et al.*, 2022) reported a significant reduction in cholesterol and triglyceride levels when garlic powder was added to the diet of broiler chicken.

5.8.3.2 Hematology

Hematology blood tests can be used to evaluate physiological and pathological conditions in organisms, as stated by (Oloruntola *et al.*, 2016). In this particular study, hematological blood indicators fell within the normal range (Olfert *et al.*, 1993), indicating that chickens supplemented with *Phytolacca dodecandra* had sufficient nutrients and improved immune status. However, variations in hemoglobin (Hb), red blood cell (RBC), and packed cell volume (PCV) values were observed among dietary treatments, with higher values in chickens supplemented with *Phytolacca dodecandra* compared to the control group. These findings align with previous studies; (Toghyani *et al.*, 2010) reported that the inclusion of black seed resulted in a significant increase in Hb, RBC, and PCV counts, while (Ansari *et al.*, 2012) found that chickens supplemented with up to 2.5 g/kg of dried leaf meal from *Azadirachta indica* led to higher PCV, RBC, and Hb levels. According to (Abd El-Latif *et al.*, 2013), chickens fed a diet containing 200 mg/kg of rosemary exhibited improved PCV levels, and supplementing the chicken with both rosemary and garlic increased Hb concentrations compared to the control diet.

5.8.4 Effect of Genotype and Diet on proximate compositions of the breast meat

In the present study, variations were observed in the level of crude protein and dry matter in breast meat of chicken genotypes, with exotic ThT genotypes showing lower values compared to other genotypes. These findings agree with a prior study by Hailemariam *et al.* (2022) which found higher levels of crude protein in indigenous chicken compared to the other genotypes. Similarly, Petracci *et al.* (2013) reported that the crude protein content in high breast yield (HBY) and standard breast yield (SBY) hybrid chicken were 22.82 and 23.48, respectively, which were consistent with the present study. In our study, it was observed that the supplementation of *Phytolacca dodecandra* at c+2 and c+1 groups exhibited protein contents of 23.7% and 23.2%, respectively, which were higher than the control group's protein content of 22.8%. In line with this study, (Mahala & Kumari, 2023) reported, the inclusion of Ajwain seed powder in the diet of broiler chicken led to a significant increase in crude protein in the breast meat compared to the control group.

According to the research conducted by Puvāča *et al.* (2015), the inclusion of medicinal plants, such as black pepper, as a supplementary diet for broiler chickens had a remarkable effect on improving the protein levels in their breast meat. The study revealed that the addition of black pepper (24 g/100 g) to the diet of broilers increased protein content. The impact of supplementing fermented *Salicornia herbacea L.* (FSH2), a medicinal plant, on meat quality of chickens was examined by (Bostami *et al.*, 2017). According to the findings, FSH2 significantly improved the protein content (increased from 21.98% to 22.98%) and resulted in a reduction in fat content (decreased from 4.08% to 3.38%) of the breast meat of broiler chicken. Consistent to these findings, addition of garlic powder, black pepper powder, red pepper powder, and a combination of all three powders led to a significant rise in the crude protein levels in breast meat, while simultaneously decreasing the fat levels compared to control (Khurshed & Jumaa, 2022). Likewise, in a study by (Mahala & Kumari, 2023), chickens that were given dietary supplements comprising of the garlic bulb and husk exhibited a significant increase in protein content of thigh muscles while simultaneously showing a decline in fat content compared to chickens that were not given any supplements.

CHAPTER SIX

6. CONCLUSION AND RECOMMENDATION

CONCLUSION

In conclusion, the growth, feed conversion efficiency, body measurements, carcass traits, age at first egg, egg production, and egg quality were superior in the Tetra H genotype. On the other hand, the naked-neck and normal-feathered chickens showed better fertility, hatchability, and mortality rates. The study revealed that crossbreeding Tetra H females with the naked-neck male genotype led to significant improvements in most carcass traits and serum biochemical profiles. The addition of *Phytolacca dodecahedra* to the diet of the chicken genotypes had a remarkable impact on their growth, resulting in increased body weight gain and improved feed conversion efficiency at a supplementation rate of 1g/kg. Moreover, supplementing the diet at rates of both 1g/kg and 2g/kg significantly improved dressing percentage and breast meat traits. The blood serum biochemical profiles revealed that the exotic Tetra H had decreased levels of total protein but higher amounts of total cholesterol and triglycerides. However, supplementation of *Phytolacca dodecahedra* led to improvements in red blood cells, hemoglobin, and packed cell volume.

RECOMMENDATIONS

- The Tetra H chicken genotype is suitable for improved growth and egg production performances.
- By implementing improved management practices, such as proper nutrition, clean housing, and regular monitoring, the performance of the Tetra H chicken genotype could be maximized.
- To improve fertility, and hatchability, and reduce mortality rate, it is recommended to use the naked-neck and normal-feathered chicken genotypes for crossbreeding programs.
 - The naked neck cocks are well-suited with Tetra H hens for improved carcass traits, higher protein content, and reduced levels of cholesterol and triglycerides.
 - It is necessary to study their adaptive performances in various agro ecological settings.
- It is recommended to conserve and improve the naked-neck and normal-feathered chicken genotypes for future breeding programs.
- Conduct molecular-level studies to validate the existing genetic variations among the indigenous naked-neck and normal-feathered chicken genotypes.
- For improved growth performance traits, it is advised to include *phytolacca dodecandra* in chicken feed at a rate of 1g/kg.
- Explore mechanisms of action: It is necessary to investigate the underlying mechanisms through which *Phytolacca dodecandra* supplementation influences growth performance, carcass traits, blood profiles, and breast protein contents in chickens.
- Investigate the optimal dosage and duration of phytolacca dodecandra supplementation to achieve desired outcomes in growth performance, carcass traits, blood profiles, and breast meat quality.
- Evaluate the impact of phytolacca dodecandra supplementation on chicken meat to ensure its safety and nutritional composition for consumers.
- Assess economic viability and cost-benefit of phytolacca dodecandra supplementation in commercial chicken production to determine its feasibility.

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APPENDIX

Appendix I. List of publications, accepted and submitted manuscripts

Published

1. Abiyu Tadele, Gebreyohannes Berhane, Wondmeneh Esatu and Teketay Wassie, 2023. Effect of genotype on hatchability, growth, morphometric and carcass traits of Chicken. *Journal of Agriculture and Food Research*, 11:1-9. <https://doi.org/10.1016/j.jafr.2023.100531>.
2. Journal of Animal Health and Production

OPEN ACCESS
Research Article

Journal of Animal Health and Production

Check for updates

The Effect of Genotype on Performance and Egg Quality Traits of the Naked-Neck, Normal-Feathered, and Exotic Tetra H Chickens

ABIYU TADELE^{1,2}, GEBREYOHANNES BERHANE², WONDMEHEH ESATU³

¹Bonga University, College of Agriculture and Natural resources, P.O. Box 334, Bonga, Ethiopia; ²Addis Ababa University, College of Veterinary Medicine and Agriculture, P.O. Box 34, Bishoftu, Ethiopia; ³International Livestock Research Institute (ILRI), P. O. Box: 5689, Addis Ababa, Ethiopia.

Abstract | Studies on the performance and egg quality traits of chicken are essential for consumers and chicken husbandry, helping them to anticipate yield, market, and exploitation of the genotypes in future breeding plans. The main ecotypes in Southwest Ethiopia are the indigenous naked-neck and normal-feathered chicken genotypes, and the exotic Tetra H, a dual-purpose genotype that was imported from Hungary. Data were collected from 144 hens of the three genotypes kept under intensive management for 20 weeks. The Tetra H genotype had significantly greater ($p < 0.05$) body weight, feed consumption, hen-housed egg production, egg mass, and a lower (better) feed conversion ratio than the other genotypes. Similarly, the naked-neck chicken genotype outperformed the normal-feathered chicken in terms of age at first egg, body weight, egg number per bird, hen-housed egg output, and egg mass. Furthermore, Tetra H had a 29.8% higher body weight at the first egg and a 20.72% higher body weight at the first egg than the normal-feathered and naked-neck genotypes, respectively. For the assessment of egg quality traits, 240 fresh eggs from the three genotypes were sampled. The findings revealed that, except for yolk breadth and color, the Tetra H genotype had considerably better ($p < 0.05$) egg quality characteristics than the other genotypes. Internal and external egg quality characteristics were found to have positive and significant associations among the genetic group of chickens, demonstrating that choosing birds with bigger eggs increases the proportion of edible eggs. As a result, our findings will help to develop more effective breeding programs for these three chicken genotypes by providing valuable insights into the genetic basis of chicken performance and egg quality.

Keywords | Age at first egg, Body weight, Correlation coefficients; Egg mass, Egg quality traits

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*Correspondence | Abiyu Tadele, Bonga University, College of Agriculture and Natural resources, P.O. Box 334, Bonga, Ethiopia; Email: abiyu.tadele@yahoo.com
Citation | Tadele A, Berhane G, Esatu W (2023). The effect of genotype on performance and egg quality traits of the naked-neck, normal-feathered, and exotic tetra h chickens. *J. Anim. Health Prod.* 11(2): 222-233.
DOI | <https://doi.org/10.17582/journal.jahp/2023/11.2.222.233>
ISSN | 2308-2801

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Submitted to journal of Heliyon and under review (HELIYON-D-23-25530)

1. Effects of genotype and *Phytolacca dodecandra* (Endod) supplementation on growth performance, carcass traits, blood profiles and breast meat quality of chickens.



Analyze manuscript references

Effects of genotype and *Phytolacca dodecandra* (Endod) supplementation on growth performance, carcass traits, blood profiles and breast meat quality of chickens

Alene, Abiyu, Mersha, Gebreyohannes, Woldegiorgis, Wondmeneh, Anley, Teketay

Appendix II. Ethical certificate

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ADDIS ABABA UNIVERSITY
College of Veterinary Medicine
and Agriculture
Bishoftu

Animal Research Ethical Review Committee

Ethical clearance certificate

Certificate Ref. No: VM/ERC/02/01/14/2022

Name of Applicant: **Abiyu Tadele (MVSc in Animal Production, PhD fellow)**

Address: Department of Clinical Studies, College of Veterinary Medicine and Agriculture, Addis Ababa University

Title of the project: Comparative study on performance and carcass quality traits of indigenous naked neck ("Angete melata"), normal-feathered and their F1 crosses with TETRA-H hybrid chicken breed under intensive management system in southwest Ethiopia

Date of application: **January, 2022**
Nature of the project: **Non-invasive**
Target animal species: **Chicken**
Number of animals involved: **270**
Study area: **Kaffa Zone, Ethiopia**

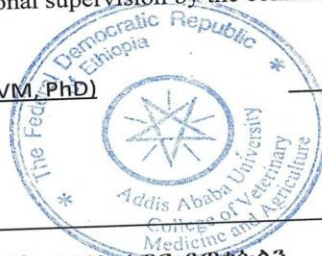
Minutes No. and date of review: **VM/ERC/01/14/022, 22/02/2022**

The above indicated research project is acceptable from ethical perspective, relevance, originality and technical competence points of view. Hence the project is ethically sound to be executed provided that:

1. All procedures and conditions stipulated in the proposal are respected, minor comments are corrected and any deviation or changes be reported to the committee
2. The project activities be open for occasional supervision by the committee when deemed necessary

Professor Getachew Terefe (DVM, PhD)
Chairman


Signature



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Appendix III. Chicken feeding according to their age

Age(weeks)	Age(days)	Type of feed	Feed intake(g/day)	Remark
1	0→ 7	<p style="text-align: center;">↑ ↑ Chicken Feeds ↓ ↓</p>	11	
2	8→ 14		17	
3	15→ 21		25	
4	22→ 28		32	
5	29→ 35		37	
6	36→ 42		42	
7	43→ 49		46	
8	50→ 56		50	
9	57→ 63	<p style="text-align: center;">↑ ↑ Grower Feeds ↓ ↓</p>	58	
10	64→ 70		61	
11	71→ 77		64	
12	78→ 84		67	
13	85→ 91		70	
14	92→ 98		73	
15	99→ 105		76	
16	106→ 112	80		
17	113→ 119	<p style="text-align: center;">Layers Feeds</p> <p style="text-align: center;">↓↓</p> <p style="text-align: center;">Layers Feeds</p>	84	
18	120→ 126		87	
19	127→ 133		97	
20	134→ 140		103	
21	141→ 147		109	
22	148→ 154		112	
23	155→ 161		114	
24	162→ 168		116	
25	169→ 175		117	
26	176→ 182		118	
27	183→ 189		119	
28	190→ 196		120	
29	197→ 203	120		
30	204→ 210	120		
31	211→ 217	120		
32	218→ 224	120		
33	225→ 231	120		
34	232→ 238	120		
35	239→ 245	120		
36	246→ 252	120		
37	253→ 259	119		
38	260→ 266	118		
39	267→ 273	117		

*Appendix IV. Tetra H, Tetra H*Naked-neck and Tetra * Normal-feathered crossbred chicken genotypes*



Appendix V. Hatching process and chicken in the brooder house



Appendix VI. Mating process to produce crossbred chicken in experiment II



Appendix VII. Blood and serum samples for lab analysis



Appendix VIII. Carcass components of chicken



Appendix IX: Statistical analysis results

The GLM Procedure

Class Level Information

Class	Levels	Values
Genotypes	3	Naked Normal Tetra
Diets	3	C C+1 C+2

The GLM Procedure

Dependent Variable: AVBody_wt18wk AVBody wt18wk

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	225523.4664	28190.4333	7.79	<.0001
Error	27	97677.5794	3617.6881		
Corrected Total	35	323201.0458			

R-Square	Coeff Var	Root MSE	AVBody_wt18wk Mean
0.697781	3.557689	60.14722	1690.626

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Diets	2	107259.2497	53629.6248	14.82	<.0001
Genotypes	2	10140.5948	5070.2974	1.40	0.2636
Genotypes*Diets	4	108123.6220	27030.9055	7.47	0.0003

The GLM Procedure

Dependent Variable: ADG ADG

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	14.21204483	1.77650560	7.80	<.0001
Error	27	6.14971141	0.22776709		
Corrected Total	35	20.36175624			

R-Square	Coeff Var	Root MSE	ADG Mean
0.697977	3.635905	0.477250	13.12602

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Diets	2	6.75985238	3.37992619	14.84	<.0001
Genotypes	2	0.63834094	0.31917047	1.40	0.2636
Genotypes*Diets	4	6.81385152	1.70346288	7.48	0.0003

The GLM Procedure

Dependent Variable: AvDFI AvDFI

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	0.08086472	0.01010809	11.03	<.0001
Error	27	0.02474914	0.00091663		
Corrected Total	35	0.10561386			

R-Square	Coeff Var	Root MSE	AvDFI Mean
0.765664	0.055762	0.030276	54.29526

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Diets	2	0.00527665	0.00263833	2.88	0.0736
Genotypes	2	0.07302585	0.03651293	39.83	<.0001
Genotypes*Diets	4	0.00256222	0.00064055	0.70	0.5995

The GLM Procedure

Dependent Variable: FCR FCR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	1.36876384	0.17109548	8.17	<.0001
Error	27	0.56566797	0.02095067		
Corrected Total	35	1.93443181			

R-Square	Coeff Var	Root MSE	FCR Mean
0.707579	3.488067	0.144743	4.149675

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Diets	2	0.63975585	0.31987792	15.27	<.0001
Genotypes	2	0.04987235	0.02493618	1.19	0.3196
Genotypes*Diets	4	0.67913564	0.16978391	8.10	0.0002

The GLM Procedure

Class Level Information

Class	Levels	Values
Genotypes	3	Naked Normal Tetra
Diets	3	C C+1 C+2

The GLM Procedure

Dependent Variable: Drcorred_ Drcorred
 values. However only 72 observations can be used in this analysis.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	99.7201628	12.4650203	2.83	0.0095
Error	63	277.5790980	4.4060174		
Corrected Total	71	377.2992608			

R-Square	Coeff Var	Root MSE	Drcorred_ Mean
0.264300	2.945600	2.099052	71.26057

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Diets	2	47.24699607	23.62349804	5.36	0.0071
Genotypes	2	47.19264248	23.59632124	5.36	0.0071
Genotypes*Diets	4	5.28052423	1.32013106	0.30	0.8771

The GLM Procedure

Dependent Variable: _THCorr HCorr

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	12.85636576	1.60704572	2.70	0.0127
Error	63	37.48767871	0.59504252		
Corrected Total	71	50.34404447			

R-Square	Coeff Var	Root MSE	_THCorr Mean
0.255370	6.772537	0.771390	11.38997

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Diets	2	0.29715404	0.14857702	0.25	0.7798
Genotypes	2	11.17128936	5.58564468	9.39	0.0003
Genotypes*Diets	4	1.38792236	0.34698059	0.58	0.6760

The GLM Procedure

Dependent Variable: _THM HM

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	12.66393273	1.58299159	2.66	0.0138
Error	63	37.44273304	0.59432910		
Corrected Total	71	50.10666578			

R-Square Coeff Var Root MSE _THM Mean
0.252739 6.756537 0.770927 11.41010

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Diets	2	0.13630220	0.06815110	0.11	0.8918
Genotypes	2	11.13622545	5.56811273	9.37	0.0003
Genotypes*Diets	4	1.39140508	0.34785127	0.59	0.6744

The GLM Procedure

Dependent Variable: _DSM 184648920SM

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	14.80737268	1.85092159	2.09	0.0504
Error	63	55.90121259	0.88732083		
Corrected Total	71	70.70858527			

R-Square Coeff Var Root MSE _DSM Mean
0.209414 9.756871 0.941977 9.654500

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Diets	2	3.98642023	1.99321011	2.25	0.1142
Genotypes	2	6.13624089	3.06812045	3.46	0.0376
Genotypes*Diets	4	4.68471156	1.17117789	1.32	0.2723

The GLM Procedure

Dependent Variable: KLBM KLBM

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	1670.25000	208.78125	1.13	0.3529
Error	63	11589.62500	183.96230		
Corrected Total	71	13259.87500			

R-Square	Coeff Var	Root MSE	KLBM Mean
0.125963	10.60666	13.56327	127.8750

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Diets	2	116.583333	58.291667	0.32	0.7296
Genotypes	2	1000.750000	500.375000	2.72	0.0736
Genotypes*Diets	4	552.916667	138.229167	0.75	0.5608

The GLM Procedure

Dependent Variable: BK_ BK

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	8.43307686	1.05413461	1.89	0.0777
Error	63	35.18257709	0.55845360		
Corrected Total	71	43.61565396			

R-Square	Coeff Var	Root MSE	BK_ Mean
0.193350	10.08581	0.747298	7.409395

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Diets	2	1.33333821	0.66666910	1.19	0.3098
Genotypes	2	1.52371730	0.76185865	1.36	0.2630
Genotypes*Diets	4	5.57602136	1.39400534	2.50	0.0516

The GLM Procedure

Dependent Variable: Win_ Win

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	1.86040163	0.23255020	1.37	0.2250
Error	63	10.65705823	0.16915965		
Corrected Total	71	12.51745987			

R-Square Coeff Var Root MSE Win_ Mean
 0.148625 16.34097 0.411290 2.516927

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Diets	2	0.42571515	0.21285758	1.26	0.2912
Genotypes	2	1.01018930	0.50509465	2.99	0.0577
Genotypes*Diets	4	0.42449718	0.10612430	0.63	0.6447

The GLM Procedure

Dependent Variable: NK_ NK

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	0.44439947	0.05554993	0.87	0.5445
Error	63	4.01169863	0.06367776		
Corrected Total	71	4.45609810			

R-Square Coeff Var Root MSE NK_ Mean
 0.099728 7.887812 0.252345 3.199170

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Diets	2	0.05278070	0.02639035	0.41	0.6625
Genotypes	2	0.08321418	0.04160709	0.65	0.5238
Genotypes*Diets	4	0.30840459	0.07710115	1.21	0.3151

The GLM Procedure

Dependent Variable: Giz_ Giz

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	2.83665068	0.35458133	2.87	0.0087
Error	63	7.78323305	0.12354338		
Corrected Total	71	10.61988373			

R-Square	Coeff Var	Root MSE	Giz_ Mean
0.267108	14.72598	0.351487	2.386852

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Diets	2	0.56624822	0.28312411	2.29	0.1095
Genotypes	2	0.96735105	0.48367553	3.92	0.0250
Genotypes*Diets	4	1.30305141	0.32576285	2.64	0.0421

The GLM Procedure

Dependent Variable: LI_ LI

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	0.77122525	0.09640316	1.32	0.2495
Error	63	4.59603526	0.07295294		
Corrected Total	71	5.36726051			

R-Square	Coeff Var	Root MSE	LI_ Mean
0.143691	15.56418	0.270098	1.735383

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Diets	2	0.20400159	0.10200079	1.40	0.2546
Genotypes	2	0.16763351	0.08381675	1.15	0.3235
Genotypes*Diets	4	0.39959016	0.09989754	1.37	0.2547

The GLM Procedure

Dependent Variable: Hr_ Hr

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	0.04084155	0.00510519	0.95	0.4859
Error	63	0.34001942	0.00539713		
Corrected Total	71	0.38086097			

R-Square Coeff Var Root MSE Hr_ Mean
 0.107235 15.45286 0.073465 0.475415

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Diets	2	0.01303242	0.00651621	1.21	0.3058
Genotypes	2	0.00449215	0.00224607	0.42	0.6614
Genotypes*Diets	4	0.02331699	0.00582925	1.08	0.3740

The GLM Procedure

Class Level Information

Class	Levels	Values
Genotype	3	Naked Normal Tetra
Diet	3	C C+1 C+2

Number of observations 72

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The GLM Procedure

Dependent Variable: TP TP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	27.02040000	3.37755000	2615.68	<.0001
Error	63	0.08135000	0.00129127		
Corrected Total	71	27.10175000			

R-Square	Coeff Var	Root MSE	TP Mean
0.996998	1.273888	0.035934	2.820833

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Diet	2	1.60230000	0.80115000	620.44	<.0001
Genotype	2	22.23443333	11.11721667	8609.52	<.0001
Genotype*Diet	4	3.18366667	0.79591667	616.38	<.0001

The GLM Procedure

Dependent Variable: Alb Alb

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	0.75744444	0.09468056	196.54	<.0001
Error	63	0.03035000	0.00048175		
Corrected Total	71	0.78779444			

R-Square	Coeff Var	Root MSE	Alb Mean
0.961475	3.112067	0.021949	0.705278

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Diet	2	0.13541111	0.06770556	140.54	<.0001
Genotype	2	0.52497778	0.26248889	544.87	<.0001
Genotype*Diet	4	0.09705556	0.02426389	50.37	<.0001

The GLM Procedure

Dependent Variable: Glo Glo

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	20.71837778	2.58979722	1956.32	<.0001
Error	63	0.08340000	0.00132381		
Corrected Total	71	20.80177778			

R-Square	Coeff Var	Root MSE	Glo Mean
0.995991	1.719841	0.036384	2.115556

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Diet	2	0.81441111	0.40720556	307.60	<.0001
Genotype	2	16.85541111	8.42770556	6366.25	<.0001
Genotype*Diet	4	3.04855556	0.76213889	575.72	<.0001

The GLM Procedure

Dependent Variable: Glu Glu

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	171281.0000	21410.1250	244.86	<.0001
Error	63	5508.5000	87.4365		
Corrected Total	71	176789.5000			

R-Square	Coeff Var	Root MSE	Glu Mean
0.968841	3.447281	9.350749	271.2500

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Diet	2	6541.0000	3270.5000	37.40	<.0001
Genotype	2	141921.0000	70960.5000	811.57	<.0001
Genotype*Diet	4	22819.0000	5704.7500	65.24	<.0001

The GLM Procedure

Dependent Variable: Ca Ca

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	18.83911111	2.35488889	13.84	<.0001
Error	63	10.71935000	0.17014841		
Corrected Total	71	29.55846111			

R-Square	Coeff Var	Root MSE	Ca Mean
0.637351	4.099737	0.412491	10.06139

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Diet	2	0.52521111	0.26260556	1.54	0.2216
Genotype	2	11.98901111	5.99450556	35.23	<.0001
Genotype*Diet	4	6.32488889	1.58122222	9.29	<.0001

The GLM Procedure

Dependent Variable: TC TC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	19722.00000	2465.25000	110.62	<.0001
Error	63	1404.00000	22.28571		
Corrected Total	71	21126.00000			

R-Square	Coeff Var	Root MSE	TC Mean
0.933542	3.466909	4.720775	136.1667

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Diet	2	8672.33333	4336.16667	194.57	<.0001
Genotype	2	369.33333	184.66667	8.29	0.0006
Genotype*Diet	4	10680.33333	2670.08333	119.81	<.0001

The GLM Procedure

Class Level Information

Class	Levels	Values
Genotypes	3	Naked Normal Tetra
Diets	3	C C+1 C+2

The GLM Procedure

Dependent Variable: IBW IBW

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	0.00951667	0.00237917	0.31	0.8682
Error	31	0.23690208	0.00764200		
Corrected Total	35	0.24641875			

R-Square	Coeff Var	Root MSE	IBW Mean
0.038620	0.237887	0.087419	36.74792

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Genotypes	2	0.00102917	0.00051458	0.07	0.9350
Diets	2	0.00848750	0.00424375	0.56	0.5795

The GLM Procedure

Dependent Variable: AVBody_wt18wk AVBody wt18wk

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	117399.8444	29349.9611	4.42	0.0061
Error	31	205801.2014	6638.7484		
Corrected Total	35	323201.0458			

R-Square	Coeff Var	Root MSE	AVBody_wt18wk Mean
0.363241	4.819428	81.47852	1690.626

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Genotypes	2	10140.5948	5070.2974	0.76	0.4745
Diets	2	107259.2497	53629.6248	8.08	0.0015

The GLM Procedure

Dependent Variable: ADG ADG

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	7.39819331	1.84954833	4.42	0.0061
Error	31	12.96356293	0.41817945		
Corrected Total	35	20.36175624			

R-Square	Coeff Var	Root MSE	ADG Mean
0.363338	4.926612	0.646668	13.12602

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Genotypes	2	0.63834094	0.31917047	0.76	0.4747
Diets	2	6.75985238	3.37992619	8.08	0.0015

The GLM Procedure

Dependent Variable: AvDFI AvDFI

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	0.07830250	0.01957563	22.22	<.0001
Error	31	0.02731136	0.00088101		
Corrected Total	35	0.10561386			

R-Square	Coeff Var	Root MSE	AvDFI Mean
0.741404	0.054667	0.029682	54.29526

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Genotypes	2	0.07302585	0.03651293	41.44	<.0001
Diets	2	0.00527665	0.00263833	2.99	0.0647

The GLM Procedure

Dependent Variable: FCR FCR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	0.68962820	0.17240705	4.29	0.0070
Error	31	1.24480361	0.04015496		
Corrected Total	35	1.93443181			