EVALUATION OF FEEDING STRATEGIES FOR SASSO AND KUROILER CHICKENS UNDER SEMI-SCAVENGING SYSTEM OF PRODUCTION IN TANZANIA

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EXTENDED ABSTRACT

Smallholder chicken farmers produce more than 60% of chicken meat and eggs in Tanzania. As the poultry industry grows, it is increasingly becoming important to focus on strategies to increase meat and egg production while considering quality and safety in order to produce and retain the ever-expanding markets. The study was conducted to evaluate the effect of breed, diet and level of feed supplementation on growth performance, egg production, feed conversion ratio, survivability, meat and egg quality of Sasso and Kuroiler chickens. The study was conducted in three separate growing phases, that is the starter phase (0–6 weeks of age), grower phase (6–20 weeks of age) and layer phase (21–40 weeks of age). One thousand sixty (1060) day-old Sasso and Kuroiler chicks were raised until 6 weeks under intensive management system with three dietary treatments. At the age of 6 weeks, a total of 960 birds (480 Sasso and 480 Kuroiler) were randomly selected from each treatment diet and assigned to four feed supplementation levels viz. 25%, 50%, 75% and 100% with two replicates having 20 birds each. Beginning week 7, all experimental birds were allowed to semi-scavenge from 6:00 am in the morning to 6:00 pm in the evening with free access to open grass area with a space allowance of 1 bird/4 m^2. Grower rations and layer rations based on the three categories, which is commercial, medium-cost and low-cost formulation were fed from 7^{th} to the 20^{th} week of age and 21^{st} to the 40^{th} week of age respectively. At the age of 20 weeks, five male chickens were randomly selected from each treatment combination and sacrificed for detailed carcass and meat quality assessments. Concurrently, four hundred and eighty female chickens aged twenty weeks were randomly assigned to 24 treatment combinations in a 2x3x4 factorial experiment with two replicate each. The treatments were breeds (Sasso and Kuroiler), diets (D1 - commercial, D2 – medium-cost and D3 - low-cost), and levels of supplementation (100%, 75%, 50% and 25%).

In phase I, birds given commercial diet (D1) excelled ($p < 0.05$) in live weight, total live weight gains and feed conversion ratio followed by medium-cost (D2) and low-cost (D3) diets respectively. In phase II, during the 7th to 20th weeks of the growing phase, breed, diet and levels of supplementation had a significant influence ($p < 0.05$) on the live weight and weight gain at 20 weeks of age. Sasso (2776.25g) chickens were heavier than Kuroiler (2509.54g) chickens on weight at 20 weeks of age. The average weight of birds in D1 (2642.89g) and D2 (2521.75g) was better than D3 (2102.58g). The higher average body weight was attained in 100% (2776.25g) level of supplementation, followed by 75% (2293.17g), 50% (2060.80g) and 25% (1586.09g). Feed cost per kilogram gain increased ($p < 0.05$) with an increase in the level of supplementation. Days taken by birds to reach market weight (2 kg) with 100%, 75%, 50% and 25% level of dietary supplementation were 16, 18, 20 and more than 20 weeks respectively. The survival rate for Sasso and Kuroiler was 99.8% and 97.1% respectively.

Furthermore, the results showed that breed, diet and level of dietary supplementation had a significant effect ($p<0.05$) on age at first lay and egg production parameters. Sasso matured earlier (156days) than Kuroiler (165days) and had higher egg production of 69.77% compared to 52.95% respectively. D1was associated with lower age at sexual maturity (ASM) and resulted to higher egg production, while ASM and egg production was significantly ($P<0.05$) improved as the level of supplementation increased. Sasso exhibited higher ($p < 0.05$) HDEP and HHEP values across all diets and levels of supplementation. Diet and levels of feed supplementation significantly ($P<0.05$) affected egg weight with 100% level of supplementation resulting in the heaviest eggs, while the 25% supplementation level led to production of smaller eggs. All internal egg qualities except Haugh Unit (HU) were significantly ($P<0.05$) increased by the level of

supplementation. The effect of diets on internal egg quality was only significant ($P<0.05$) for a few internal egg quality variables such as yolk weight and yolk diameter.

The cost of production was higher for commercial diet and highly supplemented birds. The dressing percentage (DP), pH, cooking loss, crude protein (CP) content of breast, thigh and drumstick joints were higher in Sasso than in Kuroiler. Slaughter weight decreased by 11.9%, 26.3% and 32.2% when supplementation level was reduced to 75%, 50% and 25%, respectively. The DP of chickens on D1 and D2 were comparable but higher than that of D3. The CP and ash contents in breast joints from D1 and D2 were higher than those from D3 ($P<0.05$). However, the values of ether extract for drumstick from D1 (3.98) and D2 (3.71) were comparable but higher than in D3 (3.38). Diets also influenced tenderness ($P<0.05$) whereby thigh muscle in birds fed D2 (33.37N) and D3 (32.93N) tended to be tougher than those fed D1 (30.32N). On meat colour, values for redness (a*) and yellowness (b*) were higher in Kuroiler than in Sasso. The L* and a* value in breast joint tended to increase with a reduction in the level of supplementation but it was the opposite in the case of the drumstick.

It is concluded that appreciable growth performance can be attained for semi-scavenging Sasso and Kuroiler chickens when supplemented with medium-cost or low-cost diets at the level of 50 to 75% of their daily feed requirements. Egg productivity and egg quality traits were significantly improved by breed, diet and higher levels of supplementation. However, less supplemented (25% and 50%) birds gave numerically higher income over feed compared to those on higher levels of supplementations for the first twenty weeks of production. It is therefore recommended that 50% level of supplementation using D2 be used in semi-intensive system of production because it is less costly than D1 for both egg and meat production.

DECLARATION

I, **YEREMIA DANIEL SANKA**, do hereby declare to the Senate of Sokoine University of Agriculture that this thesis is my own original work and that it has neither been nor concurrently being submitted for a degree award in any other institution.

_________________________________ ______________________

Yeremia Daniel Sanka Date

(PhD candidate)

The above declaration is confirmed by;

____________________________ ______________________

Prof. S. H. Mbaga Date

(Supervisor)

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DEDICATIONS

This thesis is dedicated to my beloved wife (Paschalina), my sons Ivan, Jesse and my daughter Irene and my wonderful parents Mzee Daniel Sanka Jorojick and Mama Katarina Hilonga Ako. I thank you for your love, support and encouragements which helped to make this study a little bit easier for me. I love you all.

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ORGANIZATION OF THE THESIS

This thesis is prepared according to “Published manuscript” format of the Sokoine University of Agriculture. It is organized into four chapters. Chapter one consists of the introduction which includes the background, problem statement and justification of the study. It also includes the objectives of the study and respective research hypothesis.

Chapter two covers the general methodology used to carry out the studies reported in this thesis. Chapter three presents research findings obtained from each specific study. Chapter four presents the conclusion drawn from the results and recommendation obtained from the study. Ahead of this chapter are published papers (Papers I, II and III) as indicated in the list of papers.

LIST OF PAPERS

Paper I: Sanka Y.D., Mbaga S.H., Mutayoba S.K., Katule A. M. and Goromela S. H. 2020. Evaluation of growth performance of Sasso and Kuroiler chickens fed three diets at varying levels of supplementation under semi-intensive system of production in Tanzania: Published in Tropical Animal Health and Production 52: 3315 – 3322. https:/ /doi.org /10.1007/s11250-020-02363-x.

Paper II: Sanka Y.D., Mbaga S.H. and Mutayoba S.K. 2021. Evaluation of egg production and egg quality of Sasso and Kuroiler chickens fed three diets at varying levels of supplementation under a semi-intensive system of production in Tanzania. Published in Animal Production Science 61: 1467- 1475. https://doi.org/10.1071/ AN20453.

Paper III: Sanka Y.D., Mbaga S.H., Mutayoba S.K. and Mushi D.E. 2021. Performance of Sasso and Kuroiler Chickens under Semi-Scavenging System in Tanzania: Carcass and Meat Quality: Published in Asian Journal of Poultry Science 15: 1-12. DOI: 10.3923/ajpsaj.2021.1.12.

LIST OF ABBREVIATIONS, ACRONYMS AND SYMBOLS

%	Percent
^{0}C	Degree Centigrade
ACGG	African Chicken Genetic Gain
AFE	Age at First Egg
AH	Albumin Height
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
ASM	Age at Sexual Maturity
CP	Crude Protein
DAARS	Department of Animal, Aquaculture and Range Sciences
DFD	Dark Firm Dry
DP	Dressing Percentage
FAO	Food and Agriculture Organization of the United Nations
FCR	Feed Conversion Ratio
FCR	Feed Conversion Ratio
GI	Gross Income
GLM	General Linear Model
HDEP	Hen-Day Egg Production
HHEP	Hen-Housed Egg Production
HU	Haugh Unit
ILRI	International Livestock Research Institute
KJ	Kilojoule

LSD	Least Significant Difference
N	Newton
NIR	Near-Infrared Reflectance
pH	Potential of Hydrogen
PSE	Pale Soft Exudative
SAS	Statistical Analysis Software
SDGs	Sustainable Development Goals
SEM	Standard Error of Mean
SUA	Sokoine University of Agriculture
TLMP	Tanzania Livestock Master Plan
TVC	Total Variable Cost
TVLA	Tanzania Veterinary Laboratory Agency
TWG	Total Weight Gain
WHC	Water Holding Capacity

CHAPTER ONE

1.0 GENERAL INTRODUCTION

1.1 Background of the Study

Semi-scavenging poultry production is a potential avenue for increasing poultry production and income and improving the livelihoods of members of poor rural households. In developing countries, the poultry subsector is dominated by indigenous chicken ecotypes that depend on scavenging for feeds with minimal feed supplementations. Consequently, the productivity of these chickens in terms of meat and eggs is characteristically low (Minga *et al.,* 2003 and Getiso *et al.*, 2017). For the commercial sector (broilers and layers) breeding has gone hand in hand with an improvement in nutrition to maximize the genetic potential.

For the local unimproved ecotypes, there have been efforts by individuals and projects to address the low productivity of the local chickens (Mutayoba *et al.,* 2012 and Sanka and Mbaga, 2014). From a genetic point of view, productivity can be improved through selection within a breed or adopting crossbreeding strategies. Reciprocal crossbreeding and the formation of hybrids or synthetic lines have been the main genetic interventions in poultry (Munisi *et al.,* 2015). Yet the products resulting from breeding must be able to remain productive under various agro-ecologies and different socio-economic settings (Zaman *et al.,* 2004). In an endeavor to address the low productivity of local chickens, hybrids such as Sasso and Kuroiler which are dual-purpose birds bred for meat and eggs were developed in recent past. Among the criteria were that the breed should be multi-colored and able to perform well under village conditions where the majority of the farming community resides. It has been demonstrated that with good supplementation breeds such as Sasso and Kuroiler are able to reach a market weight of 2 kg in 3 months and could lay an average of 150 eggs per annum (SASSO 2016 and Sharma *et al*., 2015). In this regard, both breeds provide an opportunity to farmers who want to take advantage of the in-betweens of the traditional free-range local chickens and the fast-growing hybrid broiler.

1.2 Problem Statement and Justification

1.2.1 Problem statement

In Tanzania, the main chicken production systems in rural and peri-urban communities are free-range and semi-scavenging which are characterized by low inputs and low outputs (Goromela *et al.,* 2007). Under the scavenging and semi-scavenging system, chickens do not receive adequate balanced diet throughout the production period (Mwalusanya *et al*., 2002[b] and King'ori *et al*., 2010). Reports by Wattanachatt *et al*. (2007) indicated that more intensive rearing systems in Thai chickens resulted in higher carcass weights. Rearing chickens with full-fed supplements resulted in village chickens with a high percentage of breast muscle, which was tenderer and of better quality than muscle from an extensive system (Wattanachatt, 2008). Furthermore, supplementing village chickens with commercial feed tended to give them more intramuscular fat and resulting in better sensory attributes (Wattanachatt, 2008). However, high supplementation of local chicken needs to address the availability of such supplements and the cost associated with such strategy for it to be cost effective and sustainable. Accounting for production cost will likely increase adoption rate thus, impacting positively the livelihoods of the smallholder farmers. FAO (2019) identified poor feeding as one of the major constraints in chicken production, in particular under rural setting due to a number of factors. These include seasonal variability in scavengable feed resources, non-commercial mentality of household raising chicken and poverty among others. Therefore, introduction of genetically improved chickens such as Sasso and Kuroiler which are much heavier than most of the local chicken ecotypes demands that strategic feeding packages need to be developed especially under a semi-intensive system for farmers to take advantage of the relative high productivity of these breeds compared to the local birds. While commercial diets give good performance in terms of meat and egg production, fully feeding commercial diets to dual-purpose birds such as Sasso and Kuroiler may not be cost-effective.

The recent introduction of the two dual-purpose breeds and their popularization has created a demand for low-cost feeds. Thus, some private individuals have taken the advantage and started formulating such diets to serve the growing market for these stocks. In general, there are no guidelines on how much improved breeds should be fed under a semi-intensive system. To address this challenge, it is important to evaluate strategic feeding regimes that could be affordable by smallholder farmers and yet able to meet a large part of the nutrient requirements of these birds.

1.2.2 Justification of the study

This study responds to the wide-ranging African Chicken Genetic Gain (ACGG) Program; Tanzania Livestock Master Plan (TLMP); and the Sustainable Development Goals (SDGs) targets for addressing poverty and hunger. It was undertaken as an on-station simulated semi-scavenging research focusing on smallholder chicken farmers. The information from this study is critical in designing nutritional packages that will meet the expectation of the smallholder farmers who opt to rear improved chickens. Therefore, the present study aimed to develop packages of low-cost diet and evaluate various feeding options on the growth performance, carcass characteristics and meat quality of Sasso and Kuroiler chickens. It is hypothesized that a suitable feed supplementation regime for genetically improved chickens could reduce feed costs and yet achieve a reasonable growth rate, slaughter weight and egg production. It is also expected that poultry producers will use the information to scale up the keeping of these breeds and ultimately contribute to income and food security of the households.

1.3 Objectives of the study

1.3.1 Overall objective

The overall objective of the present study was to develop feeding strategies that would help to increase the overall productivity of genetically improved breeds under a semi-scavenging system of poultry production in Tanzania.

1.3.2 Specific objectives

The specific objectives of the study were:

i. To formulate low-cost feed diets for supplementing Sasso and Kuroiler chickens under semi-scavenging system.

ii. To evaluate the growth performance of Sasso and Kuroiler chickens fed different levels of the three diets under a semi-scavenging system of production.

iii. To evaluate the egg production and egg quality of Sasso and Kuroiler chickens fed different levels of the three diets under a semi-scavenging system of production.

iv. To evaluate the effects of levels of supplementation on carcass characteristics and meat quality of Sasso and Kuroiler chickens; and

v. To determine the economics of levels of supplementation on semi-scavenging system on weight gain and egg production of Sasso and Kuroiler chickens.

1.4 Research Hypothesis

i. Ho: Different diets at varying levels of supplementation under a semi-intensive system of production have no effect on the growth performance of Sasso and Kuroiler chickens;

ii. Ho: Different diets at varying levels of supplementation under a semi-intensive system of production have no effect on the egg production and quality of Sasso and Kuroiler chickens; and

iii. Ho: Different diets at varying levels of supplementation under a semi-intensive system of production have no effect on the carcass characteristics and meat quality of Sasso and Kuroiler chickens.

CHAPTER TWO

2.0 GENERAL METHODOLOGY

2.1 Study Area

The experiment was conducted on-station at the Sokoine University of Agriculture, Department of Animal, Aquaculture and Range Sciences poultry unit. The area is situated 6ºS and 37ºE and it is about 3 km south of Morogoro town. The area lies on the foot of the slopes of Uluguru Mountain at an elevation of about 500-600m above sea level. The annual rainfall ranges between 600 and 1000 mm per annum and the temperature ranges between 30ºC - 35ºC during the hottest months (October to January) and 20 – 27ºC in the coolest months (April to August).

2.2 Objective I: Formulation of Medium-Cost and Low-Cost Diets and Determines their Nutritional Profile

Two diets were formulated, one of low-cost and the other of medium-cost. Feed ingredients for diet formulation were bought from input suppliers in Morogoro town. The third category of feed was a commercial brand produced by Silverland Tanzania, Poultry and Feed Production Company. The diets comprised of starter, grower and, layer mash for the three categories of feeds i.e. low-cost, medium-cost and commercial type. Samples of 500g from each diet were collected and taken to Tanzania Veterinary Laboratory Agency (TVLA) for proximate analysis, minerals and amino acid determination. The proximate analyses were done according to the procedures described by AOAC (2016). Minerals and amino acid profiles were determined by the near-infrared reflectance spectroscopy (NIR) technique.

2.3 Objective II: To evaluate the Growth Performance of Sasso and Kuroiler Chickens Fed Three Diets at Varying Levels of Supplementation under a Semi-Intensive System of Production

A total of 1060 day old chicks (530 Sasso and 530 Kuroiler) were obtained from Silverlands commercial hatchery in Iringa region and AKM Glitters commercial hatchery in Dar es Salaam, Tanzania respectively. On arrival, the day-old chicks were individually weighed by using a digital weighing balance; wing banded and brooded separately by strain for six weeks using three different starter diets viz. They were fed commercial feed (D1), medium-cost diet (D2) and low-cost formulated diet (D3) varying the diets at different stages of growth and production. During the brooding phase, the study adopted a 2 x 3 factorial design experiment with 2 breeds and 3 diets. All chickens were vaccinated against Marek's disease, Newcastle disease, Gumboro and Fowlpox according to manufacturer/company recommendations.

During the growing phase (6-20 weeks of age) a total of 960 birds (480 Sasso and 480 Kuroiler) were randomly selected from three dietary treatments and allotted to four dietary supplementation levels. In this phase, a 2 x 3 x 4 factorial arrangement with two breeds (Sasso and Kuroiler), three diets (D1= commercial, D2 = medium-cost and D3 = low-cost) and four supplementation levels per diet was adopted. In total there were 24 experimental units each replicated twice with 20 birds per replicate. Supplementation levels were 100, 75, 50 and 25% of recommended feed allowance per day (Appendices 1, 2, 3 and 4). At the beginning of week 7, birds were allowed to semi-scavenge from 6:00 am morning to 6:00 pm evening with free access to an open grass area of 1 bird/4m^2 (8m x 20m = 160m^2 for 40 birds). Grower rations based on the three categories of diets i.e. commercial, medium-cost and low-cost were fed from the 7th to the 20th week of age. Water was given *adlibitum* to all experimental birds. Individual weight measurements were recorded on weekly basis and the feed given was recorded on daily basis. The cost of the commercial feeds and those for ingredients used in compounding D2 and D3 were recorded. A General Linear Model (GLM) procedure of SAS was used to analyze the data. The breed, diet and level of supplementation were fitted as fixed factor and weights at Day 1 and at 6 week of age were used as covariate for brooding and growing phase respectively.

2.4 Objective III: To evaluate the Egg Production and Egg Quality of Sasso and Kuroiler Chicken Fed three Diets at Varying Levels of Supplementation under a Semi-Intensive System of Production

Layer rations were fed from 21st to 40th week of age to 480 birds (240 Sasso and 240 Kuroiler). A 2 x 3 x 4 factorial arrangement with two breeds (Sasso and Kuroiler), three diets (D1= commercial, D2 = medium-cost feed and D3 = low-cost feed), and four supplementation levels for each diet was adopted (Appendices 1, 2, 3 and 4). Data on bird’s weight, mortality, the number of hens housed, age at first lay, age at peak of lay, percent lay, hen-day egg and hen-housed egg production were collected. Age at first egg was considered at a point when egg production within replicate reached 5%. For the evaluation of egg quality traits, a total of 600 (300 eggs for each breed) freshly laid eggs were collected and evaluated for both internal and external egg quality traits. A General Linear Model fitting, breed, diet and level of supplementation as well as interactions of the factors were used to analyze the data.

2.5 Objective IV: To evaluate the Effects of Supplementation Levels on Carcass Characteristics and Meat Quality of Sasso and Kuroiler Chickens

At the age of 20 weeks, 480 male birds were randomly selected half of them being Sasso and the other half Kuroiler. A 2 x 3 x 4 factorial arrangement with two breeds (Sasso and

Kuroiler), three diets (D1 = commercial, D2 = medium-cost feed and D3 = low-cost feed), and four supplementation levels per diet was adopted (Appendices 1, 2, 3 and 4). Following 20 weeks of dietary treatments, a total of 120 male chickens (60 Sasso and 60 Kuroiler), five birds per treatment combinations, were randomly selected and sacrificed. Dressing percent, carcass part and non-carcass parts were weighed and expressed as a percent of slaughter weight. Samples of breast meat were taken for evaluation of meat quality. These include pH measurement, meat color, cooking loss, tenderness (shear force value), and meat chemical composition. Data on carcass traits and meat quality were analyzed using the General Linear Models (GLM) procedure of Statistical Analysis System. Breed, diet, level of supplementation and their interactions were considered as fixed effects.

2.6 Objective V: To determine the Economics of Various Supplementation Levels on Semi-Scavenging Sasso and Kuroiler Chicken Weight Gain and Egg Production

Economic analysis for each supplementation level was done by comparing the mean feed cost per kg live weight gain and cost per dozen eggs. The return overfeed was calculated as Net return = GI – TVC, where TVC = Feed cost, Gross income (GI) = Live weight*price and egg tray*price.

CHAPTER THREE

3.0 GENERAL FINDINGS AND DISCUSSION

3.1 Feed Formulation and Nutritional Profile

For improving the nutrient intake and economics of genetically improved chicken production, better use of low-cost feed formulation should be made available to poor resource farmers. Feed formulation is the process of quantifying the amounts of feed ingredients that need to be combined to form a single uniform mixture (diet) for poultry that supplies all of their nutrient requirements. Since feed accounts for 65-75% of total live production costs for most types of poultry throughout the world (FAO, 2008), it is imperative that the cost of formulated feed is reduced without compromising the bird's performance. Thus, low-cost feed formulation involves feed production at the most cost-effective level in terms of resource, time, energy and money by minimizing input while maximizing output.

The analysis was undertaken to know if the formulated the diets meet the nutritional requirements of chickens. Considerable variations were observed between commercial, medium-cost and low-cost diets on the nutritional values. Crude protein of commercial diet (D1) was 15.5%, medium-cost diet (D2) was 15.6% and low-cost diet (D3) was 15.3%, whereas Metabolizable Energy (ME) was 2887 KJ/kg, 2887 KJ/kg and 2627 KJ/kg respectively (Paper I and II). Values for fat in D1, D2 and D3 were 3.8, 3.0 and 4.3%, respectively. Total concentrations of critical Amino Acids (AA) of D1, D2 and D3 were: methionine, 0.66%, 0.75% and 0.67%; lysine, 0.72%, 0.82% and 0.74% and tryptophan, 0.18%, 0.20% and 0.18% respectively. Levels of Calcium (Ca) and Phosphorus (P) for D1 were 1.26% and 0.53%, for D2 were 1.82% and 1.03%, for D3 were 2.83% and 0.98% respectively. The comparability of CP, energy, Fat and Amino acid levels of the medium and low cost diets with the commercial diet gives promising outcomes in terms of growth and egg production.

So far, the production goals considered in feed formulations continue to regard weight gain, egg production, egg quality and meat quality as high priorities, but other outcomes of interest have emerged, such as health benefits and sustainability. The relative good performance of the semi-scavenging birds subjected to the low cost and medium cost feed as presented in Papers I, II and III demonstrated that the two diets can be adopted by smallholder farmers rearing the two dual-purpose birds under semi-scavenging system.

3.2 Growth Performance

The results in paper I showed that, Sasso chickens were heavier ($p<0.05$) at 20 weeks of age than Kuroiler chickens breed. The variability between breeds on body weight gain is supported by Magala *et al.* (2012) and Nakkazi *et al.* (2015). The amount of feed given to chicken per day has shown a great impact on the growth of birds as presented in paper I. According to Miah *et al.* (2016) reduced feed intake results in a slow growth rate hence, poor performance. Commercial and medium-cost diets gave a better performance than low-cost formulations. The final live weights of the birds at 20 weeks under the different dietary supplementation levels were statistically different and chickens that were full-fed (100%) exhibited higher live body weights at the end of the experimental period than their counterparts. However, feeding low-cost formulated diets (D3) led to a relatively long time to reach the target market weight of 2 kg. It is also vividly clear that time to reach market weight was highly influenced by level of supplementation; birds took more time to attain market weight when supplementation was low. Thus, the provision of supplementary feed enhances growth rate and possibly contributes to immunity boosting. Miah *et al.* (2016) also revealed a similar trend in the study of feed supplementation on the growth of village chicken and their slaughter performances. It should be noted that fencings adopted in the experimental set-up could have limited birds' to freely move around and access more scavengiable feed materials. However, fencing or confinement has an advantage in that it limits locomotor activity thus reduce energy expenditure compared to freely scavenging birds. Moreover, for resource-poor farmers, this is a tradeoff that has to be borne i.e. reduction in growth (loss) versus improved survivability (gain). Thus, supplementation of between 50 and 75% still gives higher growth performance using either a commercial diet or a medium-cost diet (D2). The values of mean body weight of Sasso and Kuroiler on 100% and 75% supplementation for D1 and D2 were within the range of 2355g and 2777g for female and male chickens respectively at 20 weeks kept under improved management in Ghana and Uganda as earlier reported by Osei-Amponsah *et al*. (2011) and Sharma *et al*. (2015). Performances of birds fed low energy diet (D3) were generally low. The finding implies that under smallholder conditions, one has to pay attention to the provision of adequate energy, especially during the season of energy feed deficiency. It is evident that the productivity of scavenging and semi-scavenging chickens could be improved by interventions in management systems and the quality and quantity of feed offered.

Supplementation level of 25% had the lowest FCR (2.41) compared to 50% (3.75), 75% (4.74) and 100% (5.52). Comparison between breed revealed that Sasso FCR (3.93) was more efficient in converting feed to body weight than Kuroilers FCR (4.10) which explains its higher weight at 20 weeks. The two breeds being dual purpose, they both excelled compared to unimproved local birds. Indeed, the development of the two breeds targeted smallholder farmers whose management is predominantly scavenging or semi-scavenging system (Sharma *et al*., 2015 and SASSO, 2016). Therefore, promotion of the two breeds should take into account the nutritional needs such that we take advantage of the inherent higher growth rates of the two breeds. This is even more critical in rural areas since the availability of scavengable feeds varies considerably between seasons.

Significant interaction ($p<0.05$) between breed, diet and level of supplementation was observed on body weight gain. At 100% level of supplementation by using D1 and D2, Sasso were heavier than Kuroiler, while Kuroiler excelled in weight gain than Sasso at 75%, 50% and 25% level of supplementation on using the two diets. However, the performance of Sasso given D3 at all levels of supplementation was higher compared to Kuroiler (Paper I, Table 4). The lower performance of Sasso in the lower level of supplementation shows higher sensitivity of the breed to variation in feed availability i.e. In other words Kuroilers are more adapted to scavenging than Sasso.

3.3 Egg Production and Egg Quality

The breed effect on age at sexual maturity (ASM) was positive, indicating the additive genetic potential for earlier sexual maturity and greater rate of egg production by the Sasso breed. Direct additive effects on the measures of egg weight and rate of lay also favoured the Sasso breed (Paper II). Evaluation of egg production and egg quality showed that Sasso reached the age at first lay much earlier than Kuroiler, especially when fed D1 (Commercial ration) as presented in Paper II. In general, there was a progressive increase in age at first lay when the level of supplementation was reduced. Under low supplementation (25%), there was a significant delay in age at first lay for Kuroiler fed D3. This indicates that the diet, level of supplementation as well as breed type have an influence on age at first lay. According to Ali *et al*. (2003) egg production is a function of feed consumed, age at point-of-lay, age at peak-of-lay, peak percent lay, percent hen-day egg production, laying period, rearing environment, health care and overall management of the flock. Likewise, variability in age at first egg between studies could also be explained by the type of management in which the birds were raised. It was further observed that regardless of breed or diets, the peak egg production was obtained between 32 and 34 weeks of age, which is normal even for commercial layers. The peak egg production was also influenced by diet and level of supplementation being achieved much earlier in birds fed D1 or D2 at 100 and 75% level of supplementation. The percent egg production at the peak was higher ($P<0.05$) in Sasso than that for Kuroiler. In general, a reduction in the level of supplementation led to delays in age at attaining peak laying percent concomitantly leading to a reduction in percent lay at peak production (Paper II). In general, most egg parameters measured in birds fed a low-cost diet (D3) and at a low level of supplementation (25%) resulted in poor percent lay (Paper II).

Other egg production traits such as percent Hen-day egg production (HDEP %) and Hen-housed egg production (HHEP) were affected in a similar manner. Sasso excelled in HDEP (Paper II); meanwhile, there was a consistent decline in HDEP with a reduction in supplementation levels. There were significant breed effects for HDEP between the periods of 24 to 40 weeks, with Sasso outperforming Kuroiler by 11% when birds were fed on D1. The difference in HHEP between the two breeds could be explained by high mortalities in Kuroiler (Paper II) and, from a cost of egg production standpoint, lower HHEP implies high mortalities in the laying flock.

With regard to egg quality, the mere physical appearance of an egg makes the first impression upon the consumer. If the product does not meet perceived expectations, consumer confidence diminishes (Nonga *et al.*, 2010). Therefore, external and internal characteristics of eggs are prerequisites for the safety, soundness and wholesomeness of the eggs. The results in paper II confirmed that, the mean egg weights were similar for the two breeds. However, diet and levels of feed supplementation significantly affected egg weight with 100% supplementation having the highest egg weight and 25% level had the lowest. The level of supplementation and breed also influenced positively the length of the egg and other important external egg characteristics such as eggshell thickness, results which are in agreement to those reported by several authors (Zaman *et al.*, 2004: Niraj *et al.,* 2014 and Fanu *et al*., 2019). Ketta and Tůmová (2016) concluded that the strength of egg shell depends on the amount of shell present, relative to the egg size, shape and thickness.

Nonetheless, the egg shape index in the two breeds, three dietary treatments and four levels of feed supplementation was not significantly different (Paper II). The egg shape index ranged from 74.6% to 78.4% (average 75%) which was considered to be normal. On the contrary, internal egg quality traits such as yolk weight, yolk diameter, yolk ratio, and albumen weight, albumen height and HU were not influenced by breed (Paper II). The positive effect of diets was only significant for a few variables such as yolk weight and yolk diameter. All internal egg qualities, except HU were significantly influenced by the level of supplementation. The reduction in internal egg quality parameters with a reduction in supplementation levels can be explained by the reduction in egg size (Paper II). It is therefore accepted that nutritional deficiencies and excesses can influence the quality of an egg.

Significant interaction ($p < 0.05$) between breed, diet and level of supplementation was observed on age at first egg and hen day egg production. In D1 and D2 at all levels of supplementation Sasso attained age at first egg early than Kuroiler, while in D3 at 50% level of supplementation Kuroiler reached age at first egg early than Sasso (Paper II). Also, Sasso had higher percentage of hen day egg production (HDEP) than Kuroiler when given D1 and D2 at all levels of supplementation, while Kuroiler tended to excel at 50%

level of supplementation when fed D3. Again, this observation may indicate that the Sasso breed is less adapted to scavenging conditions compared to Kuroiler.

3.4 Carcass Characteristic and Meat Quality

The results on carcass characteristics showed that Sasso and Kuroiler chickens were comparable in slaughter and carcass weight but different in dressing percent. The dressing percentage (DP) of Sasso was about 2 percent unit higher ($p < 0.05$) than that of Kuroiler (Paper III). In this regard, the higher carcass weight and breast weight of the Sasso and Kuroiler chickens obtained in the current study make them suitable as alternative meat birds compared to the indigenous chickens. More so, the fact that the birds are reared under semi-scavenging or full scavenging, the carcass and the meat quality attributes may meet the criteria desired by local chicken meat customers. The finding further observed that slaughter weight and carcass yield were influenced by the level of feeding which in turn influenced all other carcass components in that order.

As expected, weights of non-carcass components largely followed the pattern displayed by carcass traits except for the weight of the intestines (Paper III), probably because all birds were exposed to scavenging. Scavenging has been associated with the lengthening of the intestine in an attempt to increase digestive areas (Cheng *et al*., 2008). Due to increase in size, the weight also increased. Nevertheless, dressing percentage, spleen weight, and intestinal weight were similar for birds receiving 75% and 50% of level of supplementation. The results presented in Paper III revealed that meat pH values measured 45 minutes PM in the breast and thigh joints were similar in the two breeds and both were close to the pH of 6.00. pH is one of the most important physicochemical characteristics in meat since it is related to water holding capacity and color. Likewise, diets did not affect the pH values (Paper III) while there were differences among the carcass joints. This difference could be explained by the amount of reserved glycogen in the muscles and the extent of pre-slaughter stress (Ali *et al*., 2008). However, the pH-values observed in the present study are within acceptable standard meat quality properties (Paper III).

In the present study, values for redness (a*) and yellowness (b*) measured at breast and drumstick joints were higher ($p < 0.05$) in Kuroiler than in the Sasso breed (Paper III). However, the two breeds did not differ in values for lightness (L*) from all the joints or redness (a*) and yellowness (b*) from the thigh joint. Parameter such as meat color is important in meat quality and it was considered in the current study. The reason being that, meat color is a characteristic that is readily evaluated at the point of sale and any unfamiliar product color can negatively impact consumer expectations.

Diets also affected values for meat color and there were also differences depending on the carcass joint used in this study. Other scholars Smith *et al*. (2002); Fanatico *et al*. (2005) and Ponte *et al*. (2008) also reported that the composition of the poultry ration may affect meat color. Interestingly, the L* and b* values in the breast joint tended to increase with a reduction in supplementation level. The increase in yellowness (b*) value with a reduction in supplementation levels might be attributed to an increase in intake of fresh forages.

Green pasture is rich in beta carotenes, which is a precursor for vitamin A, a fat-soluble vitamin and tend to impart yellow color on carcass fat (Pont *et al*. (2004). In general, the values for color variables observed in the present study are within the range of acceptable levels of an international colour standard measurement (Yam and Papadakis, 2004). Regarding cooking loss, Sasso had a higher ($p < 0.05$) cooking loss value compared to

Kuroiler both for breast and drumstick joints (Paper III). Diets affected the cooking loss of the breast joint. Cooking loss in the breast and drumstick joints decreased with a decrease in the level of supplementation (Paper III). This difference could be explained by the fact that birds fed D1 probably met most of the nutrient requirements from the feed thus spent less time scavenging. Normally, meat with high-fat content tends to have low water content and lower cooking loss (Wattanachatt, 2008). The breast joint was observed to be relatively tougher in Sasso than Kuroiler chicken, while the two breeds did not differ in tenderness for the other joints (Paper III). However, meat from the two breeds can be considered tender because the amount of force required for shearing the sample was less than 50 N. The observed higher shear force value for thigh and drumstick joints when supplementation levels were reduced imply that birds under low supplementation levels had to scavenge more to meet their daily requirements.

Nutritional value chicken meat can be affected by several factors such as genotype, rearing condition and feeding regime. Proximate analysis of meat samples from the various treatments and treatment combinations showed that meat from the two breeds was comparable in dry matter and fat content, though the Sasso breed had higher ($p < 0.05$) ash and protein contents than Kuroiler (Paper III). The observed variation in protein contents of the joints is attributable to the difference in content and composition of dietary protein. Despite the fact that it is not customary to indicate proximate composition on meat products, the results obtained through laboratory analysis are still valid scientifically, as they allow one to explain the source of variation in meat quality. For example, D3 had no synthetic lysine and methionine and had lower energy content than the rest of the diets. Different levels of supplementation also influenced meat protein content reflecting the difference in the quality of protein obtained from concentrate and forages. Thus, any deficiency or excess nutrient will have an effect on the proximate composition of meat and possibly affect other meat-eating qualities. A comparable study was done by Minh and Ogle (2005) using improved dual-purpose chickens and they concluded that supplementation increases nutritional values of chicken meat under the scavenging system of production.

3.5 Survivability of Chickens

Lastly, the study compared the survivability rate among the breeds and three dietary treatments during growing and laying periods. It was observed that overall survivability was higher with an overall rate of 97.25% (Paper I). Breed-wise, there was less mortality in Sasso compared to Kuroiler during the laying period from 21 to 40 weeks of age (Paper II). It appears that the higher survivability of the two breeds even when raised under simulated scavenging conditions may connote that the two breeds have genes that confer adaptability under a semi-scavenging environment. Thus, they can be recommended for smallholders in rural areas as long as birds are vaccinated against most of the common diseases, provision of shelter and farmers adhere to other biosecurity measures.

3.6 Feed Cost Analysis

The study evaluated different diets with different supplementation levels in order to recommend the best option that will be cost-effective and a farmer will be able to generate profit from keeping either of the two breeds. The higher performance of the Sasso and Kuroiler breeds for carcass yield and egg production as observed in this study is financially promising compared to local chickens. Papers I and II supported the conclusion that Sasso and Kuroiler chickens are the most economic viable compared to local chicken with the highest probability of gaining more income for improved livelihood (Andew *et al*., 2019). The results showed that the feed cost per kg gain differed depending on the type of diet and the levels of supplementation, being higher in the commercial diet (D1) followed by D2 and lastly D3 (Paper I). For a smallholder none commercial farmers he/she has options to either adopt a medium-cost or low-cost diet depending on resources at hand.

The observed low-cost diet implies slower body weight gain, late age at sexual maturity, and lower egg production. The implication of such a choice is that keeping birds over a long period (say beyond 20 weeks) under low-cost feed will obviously increase cumulative feeding costs and also affect the quality of the meat (Paper III). Nevertheless, birds fed low-cost diets used less cost to lay a dozen eggs than those fed medium costs (D2) or commercial diet (D1) (Paper II). The Sasso breed under less supplementation plus scavenging group showed higher income than Kuroiler within the same group, but it was based on only 140 days of the experimental period. As expected less supplemented birds had higher income over feed compared to full-fed birds in all three experimental diets in 20 weeks of production period of the study. Therefore, the higher profit in less supplemented (25% and 50%) plus scavenging birds might not be consistent with the expected profit during a one-year laying period. Thus, the use of less costly feeds for dual-purpose birds such as those used in the current study could be recommended depending on available scavengeable feed resources.

CHAPTER FOUR

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusions

The following conclusions can be drawn from the study;

i. Sasso breed given D1and D2 at higher level of supplementation performed better in weight gain and egg productivity than Kuroiler breed. However, Kuroiler seemed to perform better when the level of supplementation was reduced.

ii. Commercial diet (D1) and medium-cost diet (D2) gave significantly higher slaughter and carcass weight than the low-cost diet (D3) in both breeds.

iii. Sasso breed performed better than kuroiler breed in weight gain and egg production performance.

iv. Medium cost (D2) diet supplementation at 50% of daily feed requirement gave relatively good financial returns compared to commercial (high cost) diet.

4.2 Recommendations

i. Medium cost diet (D2) at 50% level of supplementation is economical in feeding semi-intensive commercial chicken production for both egg and meat production.

ii. These findings have the potential to reduce the cost of egg production for dual-purpose improved chicken breeds, while maintaining good egg quality under a semi-intensive system of production.

iii. There is a need to validate the result of this study under farmers' condition (on-farm study).

REFERENCES

Ali, M., Farooq, M., Durrani, F. R., Chand, N., Sarbiland, K. and Riaz, A. (2003). Egg Production Performance and Prediction of Standard Limits for Traits of Economic Importance in Broiler Breeders, *International Journal of Poultry Science* 2(4): 275 – 279.

Ali, M. S., Kang, G. and Joo, S. (2008). Influences of Pre-slaughter Stress on Poultry Meat Quality: A Review. *Asian-Australasian Journal of Animal Science* 21(6): 912 – 916.

Andrew, R., Makindara, J., Said, H., Mbaga, S. H. and Alphonce, R. (2019). Economic viability of newly introduced chicken strains at village level in Tanzania: FARMSIM model simulation approach. *Agricultural Systems* 176: 102– 655.

AOAC (2016). Official Methods of Analysis. (20th ed), Association of Official Analytical Chemists, Washington, DC. [https://www.techstreet.com /standards/official-methods-of-analysis-of-aoac-international-20th-edition-2016?product _id=1937367]. Site visited on 2/1/2018.

Cheng, F. Y., Huang, C. W., Wan, T. C., Liu, Y. T., Lin, L. C. and Lou, C. Y. (2008). Effects of Free-range Farming on Carcass and Meat Qualities of Black-feathered Taiwan Native Chicken. *Asian-Australian Journal of Animal Science* 21(8): 1201 – 1206.

Fanatico, A. C., Cavitt, L. C., Pillai, P. B., Owens, C. M. and Emmert, J. L. (2005). Evaluation of slower-growing broiler genotypes grown with and without outdoor access: meat quality. *Poultry Science* 84: 1785–1790.

Fanu, W. M., Melkamu, B. Y. and Emana, G. (2019). Productivity and Egg Quality Traits of Sasso T44 Chicken in North Showa Zone, Ethiopia. *Journal of Animal and Plant Sciences* 39(3): 6478– 6486.

FAO (2008). Poultry production systems in Vietnam. Prepared by Nguyen Van Duc and T. Long. GCP/RAS/228/GER Working Paper No. 4. Rome. 22pp.

FAO (2019). Poultry Sector – The United Republic of Tanzania. FAO Animal Production and Health Livestock Country Reviews. No. 12. Rome. 89pp.

Getiso, A., Jimma, Asrat, A., Kebede, M., Zeleke, H. G. and Birhanu, T. (2017). Management Practices and Productive Performances of Sasso Chickens Breed under Village Production System in SNNPR, Ethiopia. *Journal of Biology, Agriculture and Healthcare* 7(7): 120 – 135.

Goromela, E. H., Kwakke, R. P., Verstegen, M. W. A. and Katule, A. M. (2007). Identification, characterization and composition of scavengeable feed resources for rural poultry production in Central Tanzania. *African Journal of Agricultural Research* 2 (8): 380 – 393.

Ketta, M. and Tůmová, E. (2016). Eggshell structure, measurements, and quality-affecting factors in laying hens: A review. *Czech Journal of Animal Science* 61 (7): 299–309.

King'ori, A. M., Wachira, A. M. and Tuitoek, J. K. (2010). Indigenous chicken production in Kenya : A Review. *International Journal of Poultry Science* 9(4): 309 – 316.

Magala, H., Kugonza, D. R., Kwizera, H. and Kyarisiima, C. C. (2012). Influence of varying dietary energy and protein on growth and carcass characteristics of Ugandan local chickens. *Journal of animal production Advances* 2(7): 316 – 324.

Miah, M. Y., Chowdhury, S. D. and Bhuiyan, A. K. H. (2016). Effect of feed supplementation of varying nutrient concentrations on growth performance and meat yield of indigenous (desi) chicken reared at rural households under tropical conditions. *Livestock Research for Rural Development* 28: 61.

Minh, D. V. and Ogle, B. (2005). Effect of Scavenging and Supplementation of Lysine and Methionine on the Feed Intake, Performance and Carcase Quality of Improved Dual-Purpose Growing Chickens. *Tropical Animal Health and Production* 37(7): 573–587.

Minga, U. M., Msoffe, P. L. M. and Gwakisa, P. S. (2003). Biodiversity (variation) in disease resistance and in pathogens within rural chicken populations. [http://www.infpd.net/filemanager/upload/research/it1340428928he.pdf]. Site visited on 1/1/2021.

Mutayoba, S. K., Katule, A. K., Minga, U. M., Mtambo, M. M. and Olsen, J. E. (2012). The effect of supplementation on the performance of free-range local chickens in Tanzania. *Livestock Research for Rural Development* 24: 5.

Munisi, W. G., Katule, A. M. and Mbaga, S. H. (2015). Additive, heterosis and reciprocal effects on egg production and quality of exotic x indigenous crossbred chickens in Tanzania. *Livestock Research for Rural Development* 27(161). [http://www.lrrd.org/lrrd27/8/muni27161.htm]. Site visited on 3/3/2022.

Mwalusanya, N. A., Katule, A. M., Mutayoba, S. K., Minga, U. M., Mtambo, M. M. A. and Olsen, J. E. (2002b). Nutrient status of crop contents of rural scavenging local chickens in Tanzania. *British Poultry Sciences* 43: 4 – 69.

Nakkazi, C., Kugonza, D. R., Kayitesi, A., Mulindwa, H. E. and Okot, M. W. (2015). The effect of diet and feeding system on the on-farm performance of local chickens during the early growth phase. *Livestock Research for Rural Development* 27: 204.

Niraj, K., Zinabu, N., Yohanes, T. and Etsay, K. (2014). Evaluation of Egg Quality Traits of Rhode Island Red and Bovans White under Intensive Management system. *Journal of Agriculture and Veterinary Science* 7(2): 71– 75.

Nonga, H. E, Kajuna, F. F., Ngowi, H. A. and Karimuribo, E. D. (2010). Physical egg quality characteristics of free-range local chickens in Morogoro Municipality, Tanzania. *Livestock Research for Rural Development* 22: 12.

Osei-Amponsah, R., Kayang, B. B. and Naazie, A. (2011). Age, genotype and sex effects on growth performance of local chickens kept under improved management in Ghana. *Tropical Animal Health and Production* 44: 29–34.

Petracci, M. and Baéza, E. (2011). Harmonization of methodologies for the assessment of poultry meat quality features. *World`s Poultry Science Journal* 67(1): 137– 151.

Ponte, P. I. P., Rosado, C. M. C., Crespo, J. P., Crespo, D. G., Mourao, M. A., Chaveiro-Soares, M. A., Bras, J. L. A., Mendes, I., Gama, L. T., Prates, A. M., Ferreira, L.M.A. and Fontes, C.M.G.A. (2008a). Pasture intake improves the performance and meat sensory attribute of free-range broilers. *Poultry Science* 87(1): 71– 79.

Ponte, P. I., Mendes, I., Quaresma, M., Aguiar, M. N., Lemos, J. P., Ferreira, L. M., Soares, M. A., Alfaia, C. M., Prates, J. A. and Fontes, C. M. (2004). Cholesterol levels and sensory characteristics of meat from broilers consuming moderate to high levels of alfalfa. *Poultry Science* 83(5): 810 – 814.

Sanka, Y. D. and Mbaga, S. H. (2014). Evaluation of Tanzanian local chicken reared under intensive and semi-intensive systems: I. Growth performance and carcass characteristics. *Livestock Research for Rural Development* 26: 27.

SASSO (2016) SASSO Breeding Company. [http://www.sasso.fr/best-meat-chicken-breeds-for-traditional-rearing-c44.html]. Site visited on 12/5/2019.

Sharma, J., Xie, J., Boggess, M., Galukande, E., Semambo, D. and Sharma, S. (2015). Higher weight gain by Kuroiler chickens than indigenous chickens raised under scavenging conditions by rural households in Uganda. *Livestock Research for Rural Development* 27: 9.

Shim, M. Y., Tahir M., Karnuah, A. B., Miller, M., Pringle, T. D., S. E. Aggrey, T. D. and Pesti, G. M. (2012). Strain and sex effects on growth performance and carcass traits of contemporary commercial broiler crosses. *Poultry Science* 91: 2942–2948.

Smith, D., Lyon, C. and Lyon, B. (2002). The effect of age, dietary carbohydrate source, and feed withdrawal on broiler breast fillet colour. *Poultry Science* 81: 1584 – 1588.

Wattanachatt, C., Wattanasit, S., Wattanachant, S. and Songsang, A. (2007). Carcass characteristics, physical property and chemical composition of Naked-Neck and Thai indigenous chickens muscles reared under backyard production systems. Songklanakarin. *Journal of Science and Technology* 29(2): 321–337.

Wattanachant, S. (2008). Factors affecting the quality characteristics of Thai indigenous chicken meat. *Journal of Science and Technology* 15(4): 317–322.

Yam, K. I. and Papadakis, S. E. (2004). A simple digital imaging method for measuring and analyzing colour of food surfaces. *Journal of food engineering* 61: 137–142.

Zaman, M. A., Sørensen, P. and Howlider, M. A. R. (2004). Egg production performances of a breed and three crossbreeds under semi-scavenging system of management. *Livestock Research for Rural Development* 16: 60.

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REGULAR ARTICLES

Evaluation of growth performance of Sasso and Kuroiler chickens fed three diets at varying levels of supplementation under semi-intensive system of production in Tanzania

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Abstract
The experiment was conducted to evaluate the effect of breed, diet, and level of feed supplementation on growth performance, feed conversion ratio, and survivability of Sasso and Kuroiler chicken. The study was conducted in two separate phases, i.e., the starter phase (0–6 weeks of age) and grower phase (6–20 weeks of age). One thousand sixty–day-old Sasso and Kuroiler chicks were raised until 6 weeks under intensive management system with three dietary treatments. At the age of 6 weeks, a total of 960 birds (480 Sasso and 480 Kuroiler) were randomly selected from each treatment diet and assigned to four feed supplementation levels, i.e., 25%, 50%, 75%, and 100% with two replicates each having 20 birds. Beginning week 7, birds were allowed to semi-scavenge from 6:00 am in the morning to 6:00 pm in the evening with free access to open grass area of 1 bird/4 m^2. Grower rations based on the three categories, i.e., commercial, medium-cost, and low-cost formulation, were fed from 7th to the 20th week of age. During 0 to 6 weeks of the growing phase, the breed and diet significantly ($p < 0.05$) influenced 6-week live weight, live weight gain, and feed conversion ratio. Birds given commercial diet (D1) excelled in live weight, total live weight gains, and feed conversion ratio followed by medium-cost (D2) and low-cost (D3) diet respectively. During the 7th to 20th weeks of the growing phase, the breed, diet, and supplementation levels had a significant influence ($p < 0.05$) on the live weight and weight gain at 20 weeks of age. Feed cost per kilogram gain increased with an increase in the level of supplementation. Days taken by birds to reach market weight (2 kg) with 100%, 75%, 50%, and 25% level of dietary supplementation were 16, 18, 20, and more than 20 weeks respectively. The survival rate for Sasso and Kuroiler was 99.80% and 97.13% respectively. It is concluded that appreciable growth performance can be attained for semi-scavenging Sasso and Kuroiler chickens when supplemented with medium- or low-cost diets at the level of 50 to 75% of their daily feed requirements.

Keywords Growth rate · Improved dual-purpose chicken · Semi-scavenging · Low-cost diet · Survivability

Introduction

In developing countries, local chickens, in particular, provide an important food resource to the rural poor and hence, a hedge against food insecurity and poverty (Nakkazi et al. 2015). The advantage of poultry over other livestock is primarily due to their short and relatively quick turnover on investments and the production of high-quality protein products (FAO 2014). Recently, the demand for poultry products has been increasing as a result of the growing human population (FAO 2014). However, this demand cannot be met easily by using indigenous or local chickens which have low genetic potential in terms of growth and egg production (Reta 2009; Bamidele et al. 2019). More so, high mortality and low productivity of local chickens reduce the incentive for farmers to invest significant effort in caring for birds impacting negatively on productivity. In realization of the shortfalls, crossbreeding, selection, and creation of synthetic lines have been undertaken to address the low genetic potential of the local strains (Dana et al. 2011). The breeders have incorporated the duality in economic traits (meat and eggs) and also ensured that the

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resulting chickens can adapt well in often low-input-low-output production systems (Dessie et al. 2013).

Likewise, consumers have also developed the preference on chicken products grown from alternative farming systems, which can be defined as production totally extensive (free-range) or semi-intensive (Tavares et al. 2015). These systems are in favor of the environment of the creation system which has a direct influence on the condition of comfort and animal welfare and to some extent reduces the amount of feed consumed by birds. Sasso and Kuroiler chickens are among the improved strains that have been tested in Tanzania recently and are currently being distributed at a large scale by the ACGG project. The strains are said to be suitable for the backyard system and can be used for meat and egg production with minimal provision of commercial feeds (Sharma et al. 2015; SASSO 2016). However, there is no guidance on how best to feed these birds for farmers who wish to raise them commercially under a semi-scavenging environment. It is also a known fact that feed cost is often a major limiting factor in chicken production and can account up to 70% of the total variable cost under intensive production (Tavares et al. 2015). Thus, the provision of fairly balanced low-cost diets based on farm produce that matches the genetic potential of the improved chickens is utmost important so as to minimize production cost and yet achieve reasonable profit from the enterprise. It is hypothesized that farmers, who operate at a small- or medium-scale level and do not produce their own feeds but rely on relatively expensive commercial feeds, may be incurring higher feed costs than necessary (Sanusi et al. 2015). Additionally, there has been a concomitant increase in demands for low-cost feed formulations following an increase in the number of farmers raising genetically improved local chickens. This study was therefore conducted to determine the effect of low-cost formulations and different levels of feed supplementation on the growth performance of genetically improved dual-purpose chickens under a semi-scavenging system.

Materials and methods

Study area

This study was conducted at the Poultry Unit of the Department of Animal, Aquaculture and Range Sciences (DAARS) of Sokoine University of Agriculture (SUA). The University lies at the foot of the Uluguru Mountains, at an altitude of about 500–600 m above sea level. The area is situated 6° S and 37° E and it is 3.0 km away from the town center of the Morogoro region, Tanzania. The annual rainfall ranges between 600 and 1000 mm per annum and the temperature ranges between 30 and 35 °C during the hottest months (October to January) and 20 to 27 °C during the coolest months (April to August).

Birds management and treatment allocations

A total of 1060-day-old chicks (530 Sasso and 530 Kuroiler) were obtained from Silverlands commercial hatchery in the Iringa region and AKM Glitters commercial hatchery in Dar es Salaam, Tanzania, respectively. On arrival, the day-old chicks were individually weighed by using a digital weighing balance; wing banded and brooded separately by strain for 6 weeks using three different starter diets viz. commercial feed (D1), medium-cost diet (D2), and low-cost formulated diet (D3) as indicated in Table 2. During the brooding phase, the study adopted a 2 × 3 factorial design experiment with 2 breeds and 3 diets. All chickens were vaccinated against Marek's disease, Newcastle disease, Gumboro, and Fowl pox according to manufacturer/company recommendations.

During the growing phase (6–20 weeks of age), a total of 960 birds (480 Sasso and 480 Kuroiler) were randomly selected from three dietary treatments and allotted to four dietary supplementation levels. In this phase, a 2 × 3 × 4 factorial arrangement with two breeds (Sasso and Kuroiler), three diets (D1 = commercial, D2- medium-cost, and D3-low- cost), and four supplementation levels per diet was adopted. In total, there were 24 experimental units each replicated twice with 20 birds per replicate. Supplementation levels were 100, 75, 50, and 25% of recommended feed allowance per day.

At the beginning of week 7, birds were allowed to semi-scavenge from 6:00 am in the morning to 6:00 pm evening with free access to open grass area of 1 bird/4 m^2 (8 m × 20 m = 160 m^2 for 40 birds). Birds had access to the pens through a cut-door, where feed and water were placed, and were free to move in and out of the assigned pen during the day time. The main types of grasses available in the scavenging area were Rhodes grass, star grass, and scotch grass, and some legume plants like Desmodium. Grower rations based on the three categories of diets, i.e., commercial, medium-cost, and low-cost, were fed from 7th to the 20th week of age. Table 1 presents the gross composition of D2 and D3 for the two phases while Table 2 shows the analyzed proximate composition of the three diets. Estimated daily feed intake was split into two portions, one-half was fed in the morning and the other half during the evening. The daily total allocation was adjusted weekly based on the breeder's recommendations. In all phases, water was provided ad libitum. Ground predators in the scavenging areas were excluded using chicken wire fencing and birds were confined indoor at night.

Data collection

Individual weight measurements were recorded on a weekly basis and feed given was recorded on a daily basis. Before weight taking, birds were fasted overnight and weighed on empty crops the following morning. The collected data was

Table 1 Gross composition of medium-cost diets (D2) and low-cost diets (D3)

Ingredients (kg)	Diet 2		Diet 3	
	Starter (0–6 weeks)	Grower (7–20 weeks)	Starter (0–6 weeks)	Grower (7–20 weeks)
Maize	40	30	35	30
Maize bran	20	40	20	25
Sorghum	0	0	0	2
Broken rice	0	0	5	4
Rice polish	0	0	0	8
Sunflower seed cake	15	12	15	13
Cotton seed cake	0	0	0	2
Soya bean meal	12	7	12	1.5
Fish meal	7	5	5	1.5
Shrimps	0	0	0	4
Blood meal	0	0	2	3
Bone meal	2	2	2	3
Limestone	2	2	2	2
DCP	0.5	0.5	0.5	0
Vitamin premix	0.5	0.5	0.5	0.5
Methionine	0.25	0.25	0.25	0
Lysine	0.25	0.25	0.25	0
Salt	0.5	0.5	0.5	0.5
Total	100	100	100	100

used to compute the mean live weight, total weight gain (TWG), feed consumption, and feed conversion ratio (FCR). Mortality was recorded as it occurred during the brooding and growing phases of the birds. The cost of the commercial feeds and those for ingredients used in compounding D2 and D3 was recorded.

Data analyses

Data were subjected to analysis of variance using a general linear model (GLM) procedure of the SAS Software System (SAS 2008). Least significant means were compared using the LSD test. Statistical model 1 was used to test the effect of breed, diet, and feeding levels on growth traits. For the brooding phase, only breed and diet effects were included in the model. Weights at day 0 and at 6 weeks of age were used as a covariate for brooding and growing phase respectively.

$$Y_{ijkl} = \mu + B_i + D_j + F_k + (B^*D)_{ij} + (B^*F)_{ik} + (B^*D^*F)_{ijk} + b(x - \sum x/n)_{ijk} + e_{ijkl} \quad (1)$$

where,

Table 2 Analyzed nutrient composition of different starter and grower diets

Nutrient composition	Starter (0–6 weeks)			Grower (7–20 weeks)		
	Commercial (D1)	Medium-cost formulation (D2)	Low-cost formulation (D3)	Commercial (D1)	Medium-cost formulation (D2)	Low-cost formulation (D3)
ME (kcal/kg)	2775	2789	2775	2887	2887	2627
CP (%)	20.3	19.5	19.2	15.5	15.6	15.3
Fat (%)	1.9	3.7	5.0	3.8	3.0	4.3
Ca (%)	1.17	1.09	1.45	1.26	1.82	2.83
Total P (%)	0.63	0.57	0.55	0.53	1.03	0.98
Lysine (%)	1.23	1.19	1.17	0.72	0.82	0.74
Methionine (%)	0.86	0.83	0.81	0.66	0.75	0.67
Tryptophan (%)	0.23	0.22	0.22	0.18	0.20	0.18

Y_{ijkl} observation of the *i*th breed, *j*th diet at *k*th level of feed supplementation on body weight and weight gain.
μ overall mean.
B_i effect of the *i*th breed (*i*: 1 = Sasso, 2 = Kuroiler).
D_j effect of the *k*th diet (*k*: 1 = commercial diet, 2 = own formulation, and 3 = low-cost formulation).
F_k effect of the *l*th feed supplementation level (*l*: 1 = 100%, 2 = 75%, 3 = 50%, and 4 = 25%).
$(B^*D)_{ij}$ effect of interaction between breed and diet.
$(B^*F)_{ik}$ effect of interaction between breed and feed supplementation level.
$(B^*D^*F)_{ijkl}$ effect of interaction between breed, diet, and level of feed supplementation.
$b(x-\sum\ )_{ijk}$ initial weight as covariate.
x initial weight of chicken.
$\sum$ average initial weight of chicken.
b regression coefficient.
e_{ijkl} residual random effect peculiar to each observation.

Model 2 presented below was used to test the effects of breed, diet, and feeding levels on feed intake and feed convention ratio.

$$Y_{ijkl} = \mu + B_i + D_j + F_k + (B^*D)_{ij} + (B^*F)_{ik} + (B^*D^*F)_{ijk} + e_{ijkl} \quad (2)$$

where,

Y_{ijkl} observation of the *i*th breed, *j*th diet at *l*th level of feed supplementation on feed intake and feed conversion ratio.
μ overall mean.
B_i effect of the *i*th breed (*i*: 1 = Sasso, 2 = Kuroiler).
D_j effect of the *j*th diet (*j*: 1 = commercial diet, 2 = own formulation, and 3 = low-cost formulation).
F_k effect of the *k*th feeding level (*k*: 1 = 100%, 2 = 75%, 3 = 50%, and 4 = 25%).
$(B^*D)_{ij}$ effect of interaction between breed and diet.
$(B^*F)_{ik}$ effect of interaction between breed and feed supplementation level.
$(B^*D^*F)_{ijk}$ effect of interaction between breed, diet, and level of feed supplementation.
e_{ijkl} residual random effect peculiar to each observation.

The survivability rate was tested by using chi-square (χ^2) test.

Results

Performance and survivability during brooding period of 0–6 weeks

The growth performances of genetically improved dual-purpose (Sasso and Kuroiler) chicks during the brooding phase (0–6 weeks) are shown in Table 3. The initial live weights did not differ significantly ($p > 0.05$) between breed and diets. The breed and diet significantly ($p < 0.05$) influenced final live weight, total live weight gain, and feed conversion ratio. Birds given commercial diet (D1) excelled in body weight, total gains, and feed conversion ratio followed by medium-cost diet (D2) and low-cost diet (D3) respectively. Birds fed a commercial diet (D1) and medium-cost diets (D2) were more efficient in feed utilization than birds under a low-cost diet (D3) (Table 3). The interaction effects between breed and diet were significant ($p < 0.05$) for 6 weeks live weight, weight gain, average daily gain, and feed conversion efficiency, except initial weight and survival rate (Table 3). Survivability was generally high and there was no significant difference ($p > 0.05$) between breed or diet.

Performance and survivability during growing period of 6–20 weeks under semi-scavenging rearing system

The overall results for growth performance in terms of live body weight, body weight gain, feed consumption (g/bird/day), and efficiency of feed utilization and survivability of genetically improved dual-purpose chicken are presented in Table 4. Breeds, diets, and supplementation levels influenced significantly ($p < 0.05$) the final live weight at 20 weeks of age. Within supplementation levels, birds fed D1 were much heavier followed by those fed D2 and D3 were the lightest. A similar trend was observed for total body weight gains. The lowest live weight gain (935.24 g) was observed in D3 at a 25% level of feed supplementation. Also, full-fed (100%) birds with D1 and D2 attained 2-kg live weight early (16 weeks) than D3 (18 weeks) which is similar to birds fed 75% level of feed supplementation with D1 and D2, while those in D3 at 75% attained the same weight at the age of 20 weeks (Table 4). Interaction effects between breed, diet, and feed supplementation levels were significant ($p < 0.05$) for live body weight, total weight gain, and feed efficiency, except for survival rate (Table 4).

Feed intake and FCR were calculated on the basis of supplied feed only (excluding the scavenging feeds). The analysis showed that Sasso birds were more efficient ($p < 0.05$) in feed utilization compared with Kuroiler. Birds fed D1 and D2 were more efficient in utilizing feed compared with birds fed low-cost formulation (D3).

With regard to survivability, the result showed that Sasso breed had slightly better survival than Kuroiler breed, with the

Table 3 Growth performance, survivability, and feed efficiency of Sasso and Kuroiler chicks fed on different diets during the brooding phase (0–6 weeks)

Parameters	Breed	Diet			SEM	*p* value		
		D1	D2	D3		*Breed*	*Diet*	*B*D*
Initial live weight(g)	Sasso	34.75	35.35	34.29	3.12	*0.3363*	*0.3748*	*0.3106*
	Kuroiler	35.92	36.03	34.77	2.87			
Live weight at week 6 (g)	Sasso	580.27^a	497.65^b	488.04^c	75.96	*< 0.0001*	*< 0.0001*	*< 0.0001*
	Kuroiler	533.78^a	511.60^b	479.40^c	75.52			
TWG (g)	Sasso	545.52^a	462.30^b	453.75^c	80.02	*< 0.0001*	*< 0.0001*	*< 0.0001*
	Kuroiler	497.86^a	475.57^b	444.63^c	77.49			
FCR(g/g)	Sasso	2.79^b	3.36^a	3.40^a	0.56	*0.0019*	*< 0.0001*	*< 0.0001*
	Kuroiler	3.26^b	3.29^b	3.38^a	0.65			
Survival Rate (%)	Sasso	95.09	98.06	95.45	0.07	*0.9270*	*0.2436*	*0.7567*
	Kuroiler	*94.76*	*98.39*	*96.03*	*0.09*			

[abcd] Least significant means values having different superscripts in a row differ significantly at $p < 0.05$

*B*D*, interaction between breed and diets

average survival rate of 99.80% and 97.13% for Sasso and Kuroiler respectively. Diets and levels of supplementation did not show a significant effect ($p > 0.05$) on the survivability of the two chicken breeds reared under the semi-scavenging system (Table 4).

*B*D*, interaction between breed and diet; *D*L*, interaction between diet and level; and *B*D*L*, interaction between breed, diet, and level of feed supplementation

Feed costs

Cost of the diets was calculated based on purchase cost (D1) and formulation costs for D2 and D3. Results in Table 5 present cost variables by breed, diet, and supplementation levels. Diet 1 (D1) was relatively more expensive followed by D2 and D3 respectively. This influenced the cost per kilogram gain in a similar manner, i.e., birds fed low-cost diets used less cost to gain a kilogram than those fed medium-cost (D2) or commercial diet (D1). However, birds under full feeding were able to reach a target market weight of 2 kg earlier than those under 75%, 50%, and 25% supplementation levels.

Discussion

Growth performance

The growth performance of Sasso and Kuroiler chickens in the current study were found to be significantly influenced by diet and dietary supplementation levels. According to Miah et al. (2016), reduced feed intake results into slow growth rate, hence poor performance. Commercial and medium-cost diets gave a better performance than low-cost formulations. The final live weights of the birds at 20 weeks under the different dietary supplementation levels were statistically different and chickens that were fully fed (100%) exhibited higher live body weights at the end of the experimental period. Feeding low-cost formulated diets (D3) led to a relatively longer time to reach the target market weight of 2 kg. It is also vividly clear that time to reach market weight was highly influenced by dietary supplementation level, birds taking more time when supplementation was low. According to Magala et al. (2012) and Nakkazi et al. (2015), the growth rate of chickens is influenced by a number of factors including genotype, system of production, diet, age and sex, and stocking density. Ogle et al. (2004) reported that chickens given supplementary feed grow faster than those not receiving supplements. They are also less prone to diseases and parasites. Miah et al. (2016) also revealed a similar trend in the study of feed supplementation on the growth of village chicken and their slaughter performances. Fencing as was the case in the current study limits the birds to vast access of scavengeable feed resources to complement for restricted feeding. However, fencing or confinement has an advantage in that it limits locomotor activity thus reduces energy expenditure compared with freely scavenging birds. Moreover, for resource-poor farmers, this is a tradeoff that has to be borne, i.e., reduction in growth (loss) versus improved survivability (gain). Thus, a supplementation of between 50 and 75% still give good growth performance using either a commercial diet or medium cost diet (D2).

The current study showed that Sasso chickens were heavier than Kuroiler chickens at the age of 20 weeks, probably because Sasso has more broiler genes and often termed as "semi-broiler." The body weight of Sasso on 100% and 75% supplementation for D1 and D2 is within the range of 2355 g and 2777 g for female and male Sasso chickens at 20 weeks kept under improved management in Ghana (Osei-Amponsah et al. 2011). Likewise, the result of this study for 100% and 75% D1 and D2 supplementations conforms to the finding of Sharma et al. (2015) for Kuroiler birds though weighed at a relatively

Table 4 Growth performances of Sasso and Kuroiler chickens fed on different diets with different levels of feed supplementation during the growing phase (6–20 weeks)

Parameters	Breed	Diet	Level of feed supplementation				SEM	*p* value					
			100%	75%	50%	25%		*Breed*	*Diet*	*Level*	*B*D*	*D*L*	*B*D*L*
Initial live weight at 6 weeks (g/bird)	Sasso	D1	579.12	575.98	575.94	578.75	10.23	*0.0001*	*0.0001*	*0.9988*	*0.0001*	*0.9766*	*0.9988*
		D2	508.47	501.94	506.46	507.26	10.23						
		D3	499.38	497.25	500.84	499.57	10.23						
	Kuroiler	D1	522.45	519.27	515.87	506.82	10.23						
		D2	517.26	521.88	521.50	498.77	10.27						
		D3	507.18	511.15	500.08	484.28	10.22						
Live weight at week 20 (g/bird)	Sasso	D1	2776.25^{a}	2293.17^{b}	2060.80^{c}	1586.09^{d}	42.31	*0.0073*	*0.0001*	*0.0001*	*0.0950*	*0.0001*	*0.0034*
		D2	2704.06^{a}	2214.58^{b}	1951.88^{c}	1674.05^{d}	41.62						
		D3	2165.51^{a}	2016.42^{b}	1772.14^{c}	1556.61^{d}	40.31						
	Kuroiler	D1	2509.54^{a}	2323.15^{b}	2124.88^{c}	1634.62^{d}	42.13						
		D2	2339.43^{a}	2273.60^{a}	2076.58^{b}	1731.40^{c}	41.22						
		D3	2039.65^{a}	1895.32^{b}	1741.81^{b}	1454.86^{c}	39.47						
TWG (g/bird)	Sasso	D1	2256.63^{a}	1773.55^{b}	1454.69^{c}	1066.46^{d}	41.23	*0.0073*	*0.0001*	*0.0001*	*0.0950*	*0.0001*	*0.0034*
		D2	2184.43^{a}	1694.95^{b}	1432.25^{c}	1154.43^{d}	39.93						
		D3	1645.88^{a}	1496.80^{b}	1252.52^{c}	1036.99^{d}	39.52						
	Kuroiler	D1	1989.91^{a}	1803.52^{b}	1605.25^{c}	1114.99^{c}	42.13						
		D2	1819.80^{a}	1753.97^{a}	1556.96^{b}	1211.77^{c}	41.53						
		D3	1520.02^{a}	1376.19^{b}	1222.18^{c}	935.24^{d}	39.17						
FCR(g/g)	Sasso	D1	4.34^{a}	4.19^{b}	3.39^{c}	2.25^{d}	0.11	*0.0001*	*0.0001*	*0.0001*	*0.0184*	*0.0033*	*0.1279*
		D2	4.61^{a}	4.54^{a}	3.53^{b}	2.15^{c}	0.11						
		D3	6.10^{a}	5.08^{b}	4.07^{c}	2.45^{d}	0.11						
	Kuroiler	D1	5.11^{a}	4.26^{b}	3.18^{c}	2.29^{d}	0.12						
		D2	5.39^{a}	4.39^{b}	3.28^{c}	2.05^{d}	0.12						
		D3	6.62^{a}	5.60^{b}	4.24^{c}	2.80^{d}	0.11						
Survival rate (%)	Sasso	D1	100.00	100.00	100.00	100.00	0.00	*0.0002*	*0.1411*	*0.0941*	*0.2581*	*0.4002*	*0.2864*
		D2	100.00	100.00	100.00	100.00	0.00						
		D3	100.00	97.56	100.00	100.00	0.14						
	Kuroiler	D1	97.50	95.35	95.12	95.24	0.16						
		D2	100.00	100.00	97.50	92.31	0.20						
		D3	95.00	100.00	100.00	97.50	0.15						

[abcd] Least significant means values having different superscripts in a row differ significantly at $p < 0.05$

older age of 25 weeks of age under scavenging system in Uganda.

The poor performance of D3 could be explained by the relative low energy density of the diets compared with D1 and D2. In contrast to the present findings, Islam et al. (2017) reported lower average body weight (1705.5 g) of Kuroiler birds at 20 weeks of age under the backyard system of rearing in Dhubri district of Assam, India. This difference can be explained by the system of production, quality and quantity of supplementary feeds, and availability of scavenging feed resource base.

Feed conversion ratio showed that the supplementation level of 25% had the lowest FCR (2.41) compared with 50% (3.75), 75% (4.74), and 100% (5.52). The best feed conversion ratio was also observed in Sasso (3.93) chickens compared with Kuroiler (4.10) chickens which explain its higher weight at 20 weeks. Moreover, the general performance is much better than that for local unimproved birds (Sanka and Mbaga 2014). Sasso and Kuroiler are dual-purpose birds and have been bred targeting smallholder whose management is predominantly scavenging or semi-scavenging system (Sharma et al. 2015; SASSO 2016). According to Goromela et al. (2007) availability of scavengeable feeds in the rural area varies considerably between seasons. Thus, there is a need to optimize nutrient requirements both in terms of quality and level of supplementations to achieve the expected bird's performance. This sentiment resonates with findings of Hossen (2003) and Das et al. (2018) who contended that birds reared under a semi-scavenging system and supplemented with balanced feed

Table 5 Economic evaluation of feeds at different levels of supplementation

Variable	Commercial diet (D1)				Medium-cost diet (D2)				Low-cost diet (D3)			
	100%	75%	50%	25%	100%	75%	50%	25%	100%	75%	50%	25%
Sasso												
Total feed consumed (kg)	11.21	8.69	6.17	3.64	11.21	8.69	6.17	3.64	11.21	8.69	6.17	3.64
Total feed cost (Tshs/bird)	13,452	10,428	7404	4368	11,210	8690	6170	3640	8968	6952	4936	2912
Feed cost per kg (Tshs)	1200	1200	1200	1200	1000	1000	1000	1000	800	800	800	800
Weight gain (kg) in 20 weeks	2.74	2.26	2.02	1.55	2.67	2.18	1.92	1.64	2.13	1.98	1.74	1.52
Cost per kg gain (Tshs)	4909	4614	3665	2818	4198	3986	3214	2220	4210	3511	2837	1916
Revenue (Tshs)	19,180	15,820	14,140	10,850	18,690	15,260	13,440	11,480	14,910	13,860	12,180	10,640
Income over feed (Tshs)	5728	5392	6736	6482	7480	6570	7270	7840	5942	6908	7244	7728
Age at 2 kg market weight	16	18	20	> 20	16	18	20	> 20	18	20	> 20	> 20
Kuroiler												
Total feed consumed (kg)	11.21	8.69	6.17	3.64	11.21	8.69	6.17	3.64	11.21	8.69	6.17	3.64
Total feed cost (Tshs/bird)	13,452	10,428	7404	4368	11,210	8690	6170	3640	8968	6952	4936	2912
Feed cost per kg (Tshs)	1200	1200	1200	1200	1000	1000	1000	1000	800	800	800	800
Weight gain (kg) in 20 weeks	2.47	2.29	2.09	1.59	2.30	2.24	2.04	1.69	2.01	1.86	1.71	1.42
Cost per kg gain (Tshs)	5446	4554	3543	2747	4874	3879	3025	2154	4462	3738	2887	2051
Revenue (Tshs)	17,290	16,030	14,630	11,130	16,100	15,680	14,280	11,830	14,070	13,020	11,970	9940
Income over feed (Tshs)	3838	5602	7226	6762	4890	6990	8110	8190	5102	6068	7034	7028
Average age at 2 kg market weight	16	18	20	>20	16	18	20	>20	20	>20	>20	>20

showed better performance in feed conversion efficiency than those under complete scavenging and supplementation.

A farmer also needs to pay attention to cost if she/he has to maximize profit. From the results, the feed cost per kilogram gain differed depending on the type of diet and the levels supplementation, being higher in the commercial diet (D1) followed by D2 and lastly D3. However, assuming that birds are sold live and have attained at least 1.5 kg, low-cost diet (D3) and medium-cost (D2) diets gave numerically higher income over feed than commercial (D1) diet. For a smallholder non-commercial farmer, it is possible to sacrifice lost time of 2 to 4 weeks by feeding less costly feeds or staggering supplementary levels if the availability of supplementary feed is constrained. Keeping birds over a long period (say beyond 20 weeks) under low-cost feed will obviously increase cumulative feeding costs and may also impair the quality of the meat (Hossen 2003; Sanka and Mbaga 2014).

Statistical analysis showed no significant difference in survivability among the three dietary treatments with overall survivability of 97.25%. The level of survivability observed in the current study conforms to a value of 95% at the age of 7–19 weeks for Sasso (FAO 2008) and 96.76% reported by Islam et al. (2017). Sharma et al. (2015) also observed higher survivability (85%) at the age of 7 months for Kuroiler reared under the scavenging system in rural households of Uganda. It appears that better survivability obtained in this study and other authors could be explained by the inherent adaptability of the two breeds under a semi-scavenging environment. Notwithstanding, the birds have to be vaccinated against most of the common diseases and adherence to other biosecurity measures as was the case for the current study.

Conclusion

It is concluded that growth parameters were influenced by diets and supplementation levels for birds raised under a semi-scavenging system. Birds reached 2-kg weight between 16 and 20 weeks depending on diet and level of supplementation, with extended time when supplementation was 25%. Medium- or low-cost diet supplementation at 50 to 75% of daily feed requirement gave relatively good financial returns compared with commercial (high cost) diet. Furthermore, survivability for both breeds and in different feeding regimes was generally high and acceptable.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Statement of animal rights All the procedures have been conducted in accordance with the guidelines laid down by the Institutional Ethics Committee. The study was approved by the International Livestock Research Institute Institutional Animal Care and Use Committee (ILRI IACUC) with reference number: IACUC-RC2016.26.

References

Bamidele, O., Sonaiya, E. B., Adebambo, O. A. and Dessie, T. 2019. On-station performance evaluation of improved tropically adapted chicken breeds for smallholder poultry production systems in Nigeria. *Tropical Animal Health and Production*. https://doi.org/10.1007/s11250-019-02158-9.

Dana, N., vander Waaij, L. H. and van Arendonk, J.A.M. 2011. Genetic and phenotypic parameter estimates for body weights and egg production in Horro chicken of Ethiopia. *Tropical Animal Health and Production* 43: 21–28.

Das, S. C., Akhter, A., Hasan, M. S., Akter, T., Sultana, M., Faruque, S., Rashid, M. A., Dey B., Hossain, M. A., Akter, S. and Retee, N. N. 2018. Growth performance of local and genetically improved chicken of Bangladesh. *Bang. Journal of Animal Sciences 2018.* 47 (2): 76-84. http://www.banglajol.info/index.php/BJAS.

Dessie, T., Esatu, W., Waaij, L.V., Zegeye, F., Gizaw, S., Mwai, O. and van Arendonk, J. 2013. Village chicken production in the central and western highlands of Ethiopia: Characteristics and strategies for improvement. Nairobi, Kenya: *International Livestock Research Institute*.

FAO. 2008. Poultry production systems in Viet Nam. Prepared by Nguyen Van Duc and T. Long. GCP/RAS/228/GER Working Paper No. 4. Rome.

FAO 2014. Decision tools for family poultry development. FAO Animal Production and Health Guidelines No. 16. Rome, Italy.

Goromela E.H, Kwakke R.P, Verstegen M.W.A, Katule A.M. 2007. Effect of season and farming system on the quantity and nutritional quality of scavengeable feed resources and performance of village poultry in central Tanzania. *J. Cell. Anim. Biol.* 2(3): 063-071.

Hossen, M. J. 2003. Profitability by feed supplementation to crossbred chicks (sonali) under semi-scavenging system. MSc. Thesis, Department of Animal Science, Bangladesh Agricultural University, Mymensingh.

Islam, R., Deka, C. K., Rahman, M., Deka, B.C., Hussain, M. and Paul, A. 2017. Comparative performances of Kuroiler, Rainbow Rooster and Indigenous birds under backyard system of rearing in Dhubri district of Assam. *Journal of Rural and Agricultural Research* 17 (1): 40 - 43.

Magala, H., Kugonza D. R., Kwizera, H. and Kyarisiima, C. C. 2012. Influence of varying dietary energy and protein on growth and carcass characteristics of Ugandan local chickens. *Journal of animal production Advances* 2(7): 316-324.

Miah, M.Y., Chowdhury, S. D. and Bhuiyan, A.K.F.H. 2016. Effect of feed supplementation of varying nutrient concentrations on growth performance and meat yield of indigenous (*desi*) chicken reared at rural households under tropical conditions. *Livestock Research for Rural Development* 28 (4).

Nakkazi, C., Kugonza, D. R., Kayitesi, A., Mulindwa, H. E. and Okot, M. W. 2015. The effect of diet and feeding system on the on-farm performance of local chickens during the early growth phase. *Livestock Research for Rural Development.* 27: 204. Retrieved November 6, 2019, from http://www.lrrd.org/lrrd27/10/nakka27204.html.

Ogle, B., Minh, D.V. and Lindberg, J. E. 2004. Effect of scavenging and protein supplement on the feed intake and performance of improved pullets and laying hens in northern Vietnam. *Asian-Australasian Journal of Animal Science* 17(11): 1553-1561.

Osei-Amponsah, R., Kayang, B. B. and Naazie, A. 2011. Age, genotype and sex effects on growth performance of local chickens kept under improved management in Ghana. *Tropical Animal Health and Production* 44: 29–34.

Reta D. 2009. Understanding the role of indigenous chickens during the long walk to food security in Ethiopia. *Livestock Research for Rural Development* 21: http://www.cipav.org/lrrd/lrrd21/8/dugu21161.htm.

Sanka, Y. D. and Mbaga, S. H. (2014). Evaluation of Tanzanian local chicken reared under intensive and semi-intensive systems: I. Growth performance and carcass characteristics. *Livestock Research for Rural Development* 26(127). http://www.lrrd.org/lrrd26/7/sank26127.htm.

Sanusi M., Rabi A., Doma U.D. and Haruna J. 2015. Comparative effect of self–formulated and four commercial diets on the growth performance, carcass and haematological parameters of broiler finishers in the tropics. *Sokoto Journal of Veterinary Sciences* 13(2): 14-19. https://doi.org/10.4314/sokjvs.v13i2.3.

SAS 2008. Statistical Analysis Systems. SAS User's Guide: Version 9.2, 2nd edition. SAS Inst. Inc. USA.

SASSO 2016. SASSO Breeding Company. http://www.sasso.fr/best-meat-chicken-breeds-for-traditional-rearing-c44.html.

Sharma, J., Xie, J., Boggess M., Galukande, E., Semambo, D. and Sharma S. 2015. Higher weight gain by Kuroiler chickens than indigenous chickens raised under scavenging conditions by rural households in Uganda. *Livestock Research for Rural Development* 27: 9.

Tavares, F. B., Santos, M. S. V., Araújo C. V., Costa, H. S., Loureiro, J. P. B., Lima, E. M., Lima, K. R. S. 2015. Performance, growth and carcass characteristics of alternatives lineages of broiler chickens created with access to paddock. *Rev. Bras. Saúde Prod. Anim., Salvador* 16(2): 420 – 429. http://www.rbspa.ufba.br.https://doi.org/10.1590/S1519-99402015000200016.

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Evaluation of egg production and egg quality of Sasso and Kuroiler chickens fed three diets at varying levels of supplementation under a semi-intensive system of production in Tanzania

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Abstract

Context. Genetically improved chickens raised under a semi-intensive system have been shown to maintain performance in terms of egg production and egg quality by feeding low-cost diets at different levels of supplementation, but reports on the supplementation regimes by using low-cost diets are limited.

Aim. This study aimed to evaluate the effect of dietary supplementation regimes on egg production and egg quality of genetically improved dual-purpose chickens under a semi-intensive system.

Methods. A total of 480 female chickens aged 20 weeks were randomly assigned to 24 treatment combinations in a $2 \times 3 \times 4$ factorial experiment with two replicates each. The treatments were breeds (Sasso and Kuroiler), diets (D1 – commercial, D2 – medium-cost and D3 – low-cost) and levels of supplementation (100%, 75%, 50% and 25%).

Key results. The results show that breed, diet and level of dietary supplementation had a significant effect ($P < 0.05$) on age at first lay and egg production parameters. Sasso chickens showed higher hen-day egg production and hen housed egg production values across all diets and levels of supplementation. Diet and levels of feed supplementation significantly affected egg weight ($P < 0.05$), with 100% supplementation level resulting in the heaviest eggs and 25% supplementation level resulting in the lightest eggs. All internal egg qualities except Haugh units were significantly ($P < 0.05$) influenced by the level of supplementation, whereas the effect of diets was only significant ($P < 0.05$) for a few internal egg quality variables, such as yolk weight and yolk diameter. The cost of production was higher for commercial diet-fed and highly supplemented birds.

Conclusion. Egg productivity and egg quality traits were significantly improved by breed, diet and higher levels of supplementation. However, less-supplemented (25% and 50%) birds gave numerically higher income over feed compared with those on higher levels of supplementations for the first 20 weeks of production.

Implication. These findings have the potential to reduce the cost of egg production for dual-purpose improved chicken breeds while maintaining good egg quality under a semi-intensive system of production.

Keywords: egg production, egg quality, dual-purpose breed, low-cost diet, supplementation.

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Introduction

Chickens are prolific, easy to raise, and their numbers can be expanded easily and more rapidly than other livestock species (Dessie and Getachew 2016; Fanu *et al*. 2019). Several improved chicken breeds have been disseminated to Tanzanian farmers to increase both egg and meat production in the country (FAO 2019). In the recent past, The African Chicken Genetic Gains project tested two strains of dual-purpose chickens – Sasso and Kuroiler breeds – which are deemed to grow faster and produce more eggs compared with local chicken types (www.africacgg.net). The project also engaged with the private sector in multiplying and ensuring delivery of these strains at scale to rural and peri-urban areas. Ultimately, the strains are expected to contribute significantly to income and meet the nutritional needs of the growing population.

However, uptake and sustainability of innovation (breeds) need to take into account the production environment and markets. In developing countries, chickens are generally owned and managed by women, who cannot easily afford the high input production costs in terms of feeds, day-old-chicks and veterinary drugs (FAO 2008). Nonetheless, opportunities do exist to lower such costs, depending on the production model adopted, with either full or partial confinement. In both cases, one has to pay attention to nutrition to optimise birds' performance, among others. Improving the quality of feed and reducing its cost can be attained by increasing the availability of cheaper and better quality raw materials, such as soya meals, amino acids, vitamins, minerals, enzymes and so on (Shim *et al*. 2013). To economically exploit the improved strain, chicken producers need to find a balance between optimal performance and feeding cost. Sasso and Kuroiler chickens are dual-purpose birds, and have a good scavenging ability similar to local chickens (Sharma *et al*. 2015; SASSO 2016). To optimise performance, the scavenging quality can be integrated with low-cost feed formulations depending on the available scavengable feed resource base. Scavenging birds raised without supplementation often have poor performance in terms of weight gain and egg production (Goromela *et al*. 2007). Likewise, the availability of supplementary feed resources depends on season, and competition between humans and livestock, and the tendency is for farmers to practice supplementation during the harvesting period and much less during the wet season (Pius and Mbaga 2018). Nutrition also influences egg quality in terms of size and quality characteristics (Zaman *et al*. 2004).

According to Sharma *et al*. (2015) and SASSO (2016), Kuroiler and Sasso chickens can grow under all manner of rearing systems of production. Although Sasso and Kuroiler breeds have been distributed widely, there is still limited information on their egg production performance, especially under semi-intensive production with dietary supplementation regimes. Such information is considered to be critical in advising farmers on the supplementation strategies focusing on the cost of diets and levels of feed supplementation. This study, therefore, focuses on the comparative evaluation of different breeds fed diets at varying levels of supplementation under a simulated semi-intensive system of production.

Materials and methods

Description of the study area

This study was conducted at the Poultry Unit of the Department of Animal, Aquaculture and Range Sciences of Sokoine University of Agriculture. The university lies at the foot of the Uluguru Mountains, at an altitude of ~500–600 m above sea level. The area is situated 6°S and 37°E, and it is 3.0 km away from the town centre of Morogoro region, Tanzania. The annual rainfall ranges between 600 and 1000 mm per annum, and the temperature ranges between 30°C and 35°C during the hottest months (October to January) and 20 to 27°C during the coolest months (April to August).

Bird management and treatment allocations

A total of 1060-day-old chicks (530 Sasso and 530 Kuroiler) were obtained from Silverlands commercial hatchery in Iringa region, Tanzania, and AKM Glitter commercial hatchery in Dar es Salaam respectively. The study adopted a 2 × 3 × 4 factorial design experiment with two breeds, three diets and four levels of supplementation, as described below. For each supplementation level, the treatment unit was replicated twice and each replicate had 20 chickens.

On arrival, the day-old chicks were individually weighed; they were wing banded and brooded separately by strain for 6 weeks, and fed three different starter diets – commercial feed (D1), medium-cost formulated diet (D2) and low-cost formulated diet (D3) – as indicated in Table 1. During the brooding phase, feeds were provided according to the developed feeding regime (Sanka *et al.* 2020), and water was on an *ad libitum* basis. All chickens were vaccinated against Marek's disease, Newcastle disease, Gumboro disease

Table 1. Gross composition of medium-cost formulation diets (D2) and low-cost formulation diets (D3)

Ingredients (kg)	Medium-cost formulation diets (D2)			Low-cost formulation diets (D3)		
	Starter (0–6 weeks)	Grower (6–20 weeks)	Layer (21–40 weeks)	Starter (0–6 weeks)	Grower (6–20 weeks)	Layer (21–40 weeks)
Maize	40	30	40	35	30	30
Maize bran	20	40	25	20	25	35
Sorghum	0	0	0	0	2	2
Broken rice	0	0	0	5	4	0
Rice polish	0	0	0	0	8	4
Sunflower seed cake	15	12	15	15	13	10
Cottonseed cake	0	0	0	0	2	2
Soya bean meal	12	7	5	12	1.5	1.5
Fish meal	7	5	5	5	1.5	1.5
Shrimps	0	0	0	0	4	4
Blood meal	0	0	0	2	3	3
Bone meal	2	2	4	2	3	3
Limestone	2	2	4	2	2	3
Dicalcium phosphate	0.5	0.5	0.5	0.5	0	0.25
Vitamin premix	0.5	0.5	0.5	0.5	0.5	0.25
Methionine	0.25	0.25	0.25	0.25	0	0
Lysine	0.25	0.25	0.25	0.25	0	0
Salt	0.5	0.5	0.5	0.5	0.5	0.5
Total	100	100	100	100	100	100

and fowl pox according to manufacturer/company recommendations. All the procedures were conducted following the guidelines laid down by the Institutional Ethics Committee. The study was approved by the International Livestock Research Institute Institutional Animal Care and Use Committee (ILRI IACUC) with reference number: IACUC-RC2016.26.

At the age of 6 weeks, a total of 480 female birds (240 Sasso and 240 Kuroiler) were randomly selected from each treatment diet and assigned to four feed supplementation levels; that is, 25%, 50%, 75% and 100%, with 20 birds per group. At the beginning of Week 7, birds were allowed to semi-scavenge from 0600 hours in the morning to 1800 hours in the evening, with free access to an open grassy area of one bird/4 m^2 (4 m × 20 m = 80 m^2 for 20 birds). Birds had access to the pens through a cut-door, where feed and water were placed, and were free to move in and out of the assigned pen during the day time. Grower rations based on the three categories; that is, commercial (D1), medium-cost (D2) and low-cost formulation (D3), were fed from the 7th to the 20th week of age, whereas layer rations were fed from the 21st to 40th week of age. The proximate composition of the diets is as indicated in Table 2. Birds were fed half of the amount allocated during the morning and the other half during the evening, and water was provided *ad libitum*. Ground predators in the scavenging areas were prevented by using chicken wire fencing, and birds were confined indoor at night.

Data collection

Data on birds weight, mortality, the number of hens housed, age at first lay, age at peak of lay, percent lay, hen-day egg production (HDEP) and hen-housed egg production (HHEP) were collected. Age at first lay was considered at a point when egg production within replicate reached 5%. Hen-day egg production was calculated by adopting Formula 1 below:

$$\text{HDEP} = \frac{\text{Total number of eggs produced on a day}}{\text{Total number of hens present on that day}} \times 100 \quad (1)$$

= Hen-housed egg production was calculated using Formula 2;

$$\text{HHEP} = \frac{\text{Total number of eggs laid on a day}}{\text{Total number of hens housed at the beginning of the laying period}} \times 100 \quad (2)$$

For the evaluation of egg quality traits, a total of 600 (300 eggs for each breed) freshly laid eggs were collected and evaluated for both internal and external egg quality traits.

Evaluation of external egg quality

The external egg quality measurements included egg weight, egg length, egg width, shell weight and shell thickness. External egg quality traits, such as egg weight and shell weight, were measured using a digital balance (g; PRC-B1200, China). Other external egg quality traits; that is, egg length, egg width and shell thickness, was measured using Digital Vernier Calliper (mm; DC 0–150, Walter Ireland). The shell thickness was measured at the three points (centre, broad and tip or end), and the values were averaged and expressed as eggshell thickness. The egg shape index (%) was calculated as the proportion of egg width to egg length.

Evaluation of internal egg quality

A total of 600 eggs were used to determine the internal egg quality traits. The eggs were broken onto a flat surface. Albumen height (AH) was measured at its widest part at a position halfway between the yolk and the outer margin. Yolk height was measured at the centre part of the yolk. The yolk was carefully separated from the albumen and each part was weighed using an electronic sensitive balance. Individual Haugh units (HU) were calculated from the two parameters; the AH and egg weight (EW; Haugh 1937) using the formula:

$$\text{HU} = 100\text{Log}\left(\text{AH} - 1.7\text{EW}^{0.37} + 7.6\right),$$

where HU is Haugh unit, AH is the albumen height (mm) and EW is the egg weight (g).

The yolk ratio and albumen ratio were expressed as a percentage of the egg weight.

Statistical analyses

Data were subjected to analysis of variance using a general linear model procedure of the SAS Software System (SAS 2008). The least significant means were compared using the least significant difference test. The following statistical model was used to test the effect of breed, diet, feed supplementation levels, and their interaction on egg production and quality traits:

$$\text{Y}_{\text{ijkl}} = \mu + \text{B}_\text{i} + \text{D}_\text{j} + \text{F}_\text{k} + (\text{B} \times \text{D})_{\text{ij}} + (\text{B} \times \text{F})_{\text{ik}} + (\text{B} \times \text{D} \times \text{F})_{\text{ijk}} + \text{e}_{\text{ijkl}},$$

where Y_{ijkl} is the observation of the ith breed, jth diet at kth level of feed supplementation on egg production and quality traits; μ is the overall mean; B_i is the effect of the ith breed (i: 1 = Sasso, 2 = Kuroiler); D_j is the effect of the jth diet (j: 1 = commercial diet, 2 = medium-cost and 3 = low-cost

Table 2. Analysed nutrient composition of starter, grower and layer diets

Nutrient composition	Starter (0–6 weeks)			Grower (6–20 weeks)			Layer (21–40 weeks)		
	D1	D2	D3	D1	D2	D3	D1	D2	D3
Metabolisable energy (kcal/kg)	2775	2789	2775	2887	2887	2627	2965	2975	2968
Crude protein (%)	20.3	19.5	19.2	15.5	15.6	15.3	18.5	17.6	15.2
Fat (%)	1.9	3.7	5.0	3.8	3.0	4.3	6.6	8.2	8.8
Ca (%)	1.17	1.09	1.45	1.26	1.82	2.83	2.16	2.34	1.96
Total P (%)	0.63	0.57	0.55	0.53	1.03	0.98	0.31	0.59	0.75
Lysine (%)	1.23	1.19	1.17	0.72	0.82	0.74	1.10	1.04	0.90
Methionine (%)	0.86	0.83	0.81	0.66	0.75	0.67	0.78	0.75	0.64
Tryptophan (%)	0.23	0.22	0.22	0.18	0.20	0.18	0.24	0.22	0.19

formulation); F_k is the effect of the kth feed supplementation level (k: 1 = 100%, 2 = 75%, 3 = 50% and 4 = 25%); $(B \times D)_{ij}$ is the effect of the interaction between breed and diet; $(B \times F)_{ik}$ is the effect of the interaction between breed and feed supplementation level; $(B \times D \times F)_{ijk}$ is the effect of the interaction between breed, diet and level of feed supplementation; and e_{ijkl} is the residual random effect peculiar to each observation.

The survivability and or mortality rate was tested by using the Chi-square test.

Results and discussion

Age at lay and egg production performance

Age at first lay and egg production parameters are presented in Table 3 and Fig. 1. Breed, diet and level of dietary supplementation had significant effects ($P < 0.05$) on age at first lay and egg production parameters, except age at peak egg production, which was not significantly ($P > 0.05$) affected by breed. The earliest age at first lay was at 151 days, exhibited by Sasso birds fed D1 at the level of 100%, followed by 75% and 50% plus semi-intensive in both breeds. Kuroiler birds fed D3 at 25% exhibited late age at first lay (~193 days). Contrarily, Bamidele *et al.* (2020) reported lower age at first lay for Kuroiler (120 days) and Sasso chickens (133 days) raised under the intensive production system in Nigeria. However, the age at first lay obtained in the current study for D1 conformed to values reported by Ibrahim *et al.* (2019) for the Koekoek breed in Ethiopia – 152 days – whereas Aman *et al.* (2017) reported 5.9 months (177 days) in Sasso chickens under a village production system in Ethiopia. Islam *et al.* (2017) reported 184.65 ± 1.02 days of age at first lay in Kuroiler chickens reared under scavenging production in India. The value is almost close to 185 days recorded in Kuroiler chickens fed D3 under 50% supplementation with scavenging. The difference between the results in the current study and other studies was probably due to breed, type of production system, climatic conditions and the general management, especially the quantity and quality of feed given. The effect of feed supplementation on age at first lay was demonstrated by Zaman *et al.* (2004), whereby birds receiving 15 g, 30 g and 45 g of supplementary feeds per day attained sexual maturity at 210.6, 205.0 and 198.6 days respectively. Moreover, the late sexual maturity reported in the current study at varying levels of supplementation might be due to the poor scavenging feed resource base in the respective areas. The interactions between the factors were significant, with dietary supplementation level being the major influential factor contributing to the difference in age at sexual maturity of the birds.

Regardless of breed or diets, the peak egg production was obtained between 32 and 34 weeks of age, being achieved much earlier in birds fed D1 or D2 at 100% and 75% level of supplementation. A reduction in supplementation level to 25% was generally associated with an increase in days to reach peak production (up to 36 weeks; Table 3 and Fig. 1). This result concurs with those of Zaman *et al.* (2004), that birds receiving the highest level of supplementation tended to mature earlier

Table 3. Production performance of Sasso and Kuroiler chickens given three diets in different feeding supplementation levels under a semi- intensive system

Least significant means values with different lowercase letters in a row differ significantly at $P < 0.05$

Traits	Commercial diet (D1)				Medium-cost diet (D2)				Low-cost diet (D3)				s.e.m.	*P*-value
	100%	75%	50%	25%	100%	75%	50%	25%	100%	75%	50%	25%		
						Sasso								
Age at first lay (days)	151g	157e	164d	176c	154f	153f	175c	177c	164d	176c	186b	189a	0.82	0.0001
Age at peak egg-laying (weeks)	32d	32d	33c	34b	32d	32d	33b	34b	32d	32d	34b	36a	0.00	0.0001
Percent peak egg production	92.06a	89.47ab	87.96ab	66.42c	91.27a	83.46b	71.43c	61.65d	88.24ab	83.33b	61.43d	42.12e	3.20	0.0001
Hen day egg production (%)	73.48a	73.45a	70.22ab	55.37c	75.24a	62.82b	53.11c	45.37d	66.05b	64.56b	43.85d	33.19e	2.10	0.0001
Hen housed egg production (%)	69.77a	66.71a	66.13a	55.37bc	67.71a	59.68b	53.11c	43.11d	59.44b	54.87bc	43.85d	33.19e	2.01	0.0001
						Kuroiler								
Age at first lay (days)	156h	161g	164f	171d	159g	166ef	173d	179c	165f	168e	185b	193a	0.82	0.0001
Age at peak egg-laying (weeks)	32e	32e	33d	34c	32e	32e	33d	34c	32e	35b	36a	36a	0.00	0.0001
Percent peak egg production	89.28a	67.22c	67.13c	57.14d	86.61a	79.46b	57.14d	49.62e	67.86c	58.64d	55.24d	36.43f	3.20	0.0001
Hen day egg production (%)	61.57ab	57.39b	56.56b	49.12c	62.79a	60.01ab	46.78c	46.65c	47.90c	46.91c	44.76c	30.06d	1.75	0.0001
Hen housed egg production (%)	52.95a	50.21ab	49.26b	44.20c	54.15a	48.01bc	44.32c	37.43d	45.51bc	38.15d	33.57e	30.06e	1.51	0.0005

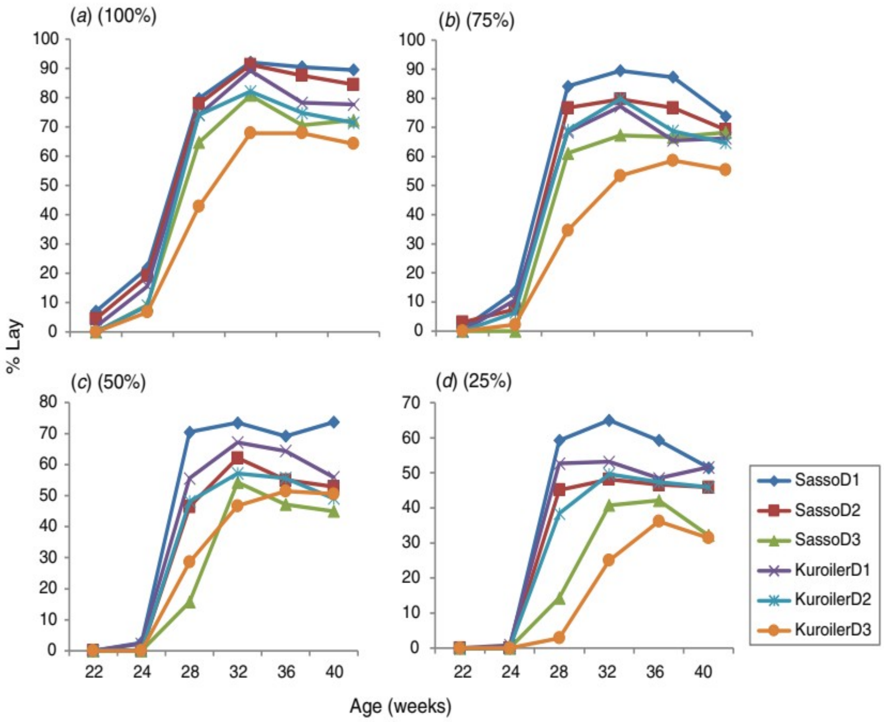

Fig. 1. (*a–d*) Average lay percentage (hen-day) of Sasso and Kuroiler hens given three different diets each with four feed supplementation levels, from the start (22 weeks) to the end (40 weeks) of the trial. (a) Full fed (100%); (b) 75% supplementation; (c) 50% supplementation; and (d) 25% supplementation + semi-intensive.

than those on low supplementation. Moreover, Sasso birds fed D1 and D2 and Kuroiler birds fed D1 attained peak laying at ~90%, followed by Kuroiler birds fed D2 and Sasso birds fed D3 (80%). A lower laying rate (68%) was obtained in Kuroiler birds fed D3. A reduction in the level of supplementation led to delays in age at attaining peak laying percentage, especially for birds fed D3, concomitantly there was a reduction in lay percentage at peak production (Fig. 1*b–d*). The decline in lay percentage at peak production was more marked for birds on 25% supplementation, with a drop ranging from 65% for D1 Sasso birds to 25% for D3 Kuroiler birds (Fig. 1*d*). In general, Sasso birds excelled in percentage of peak egg production compared with Kuroiler birds for all dietary treatments and levels of supplementation. As in other parameters measured, low-cost diet (D3) and a low level of supplementation (25%) resulted in poor lay percentage (Table 3). The difference in performance between the two breeds might be due to intrinsic genetic factors, as well as adaptation to scavenging conditions.

HDEP percentage differed between breeds, with Sasso birds having relatively higher HDEP than Kuroiler birds (Table 3). Meanwhile, there was a consistent decline in HDEP with a reduction in supplementation levels. The highest HDEP was obtained in Sasso birds fed D1 at 100% and 75% supplementation levels, whereas the lowest was obtained in Kuroiler birds given D3 at 25% supplementation level. There were significant breed effects for HDEP between the period of 24 to 40 weeks, with Sasso birds outperforming Kuroiler birds by 11% when birds were fed on D1. HDEP percentages reported in these findings are higher than 36.5% (30 weeks) and 64.5% (29 weeks) for Sasso and Kuroiler birds respectively from that reported by Bamidele *et al.* (2020). HHEP was also significantly affected by breed, diet and dietary supplementation levels (Table 3). The lowest

Table 4. Mortality rate (%) of genetically improved chickens as affected by breed, diet and dietary supplementation level

Least significant percentage values with different lowercase letters in a column differ significantly at $P < 0.05$

Factors	Mortality (%)	χ^2	*P*-value
Breed			
Sasso	2.92a	9.9662	0.0016
Kuroiler	10.00b		
Diet			
D1	6.21	0.0479	0.9764
D2	6.37		
D3	6.79		
Level of supplementation			
100%	8.20	1.8593	0.6020
75%	5.93		
50%	4.20		
25%	7.44		

HHEP (30%) was exhibited for birds under 25% supplementation levels, due to delay of onset of lay (28 weeks) and poor laying consistency. The difference in HHEP between the breeds was influenced by the higher mortality (Table 4) among Kuroiler birds (10.00%) than Sasso birds (2.92%). From a cost of egg production standpoint, lower HHEP reflects the effects of high mortality in the laying flock.

Despite some similarities in age at onset of lay and lay percentage at peak in both Sasso and Kuroiler birds, full-fed and 75% supplemented hens produced more eggs because their lay percentage elevated faster, and was significantly higher than hens at 50% and 25% supplementations during the 24–40 weeks production period (Fig. 1). Three-way interaction effects between breed, diet and level of dietary supplementation were significant, with Sasso birds fed D1 and D2 under 100% performing better than Kuroiler birds in the same group. Thus, the current results suggest that low levels of total egg production were mainly due to late onset of lay and slow elevation in the laying rate.

External egg quality traits

Table 5 presents the mean of external egg quality traits. Egg weights were similar for the two breeds ($P > 0.05$). However, diet and levels of feed supplementation significantly affected egg weight ($P < 0.05$), with 100% supplementation having the highest egg weight, and 25% level had the lowest. These differences might be due to different levels of feed intake and nutritional contents of the diets. Furthermore, 100% and 75% of supplemented birds produced longer eggs ($P < 0.05$) compared with those under 50% and 25%. Nevertheless, egg width was not significantly influenced ($P > 0.05$) by breed, diet or level of feed supplementation. Ali (2002) studied the effect of increasing amounts of feed supplementation (0, 30, 60 and 120 g) on crossbred (Rhode Island Red × Fayoumi) hens, and reported that the birds supplemented with 60 g of feed improved egg production, egg weight and egg mass production (32.8%, 46 g and 15.1 g/hen.day, respectively) compared with those of fully scavenging birds (21.2%, 45.3 g and 9.15 g/hen.day). Egg weights obtained in the current study are within the range of values reported by FAO (2008) and Fanu *et al*. (2019) for Sasso chickens. FAO (2008) reported the average mean of egg weight of 57.5 g for the Sasso breed, and Fanu *et al*. (2019) reported the value of 57.43 g for egg weight of Sasso T44 chickens under the traditional production system in North Shewa Zone, Ethiopia.

Eggshell quality is an important criterion, and has economic implications in egg packaging and marketing. Eggs with poor quality shells are downgraded and rejected by consumers. The current study shows that the trait was not affected ($P > 0.05$) by breed, diet and dietary supplementation level. Moreover, eggshell thickness for Sasso and Kuroiler birds reported in the current study was slightly greater than the values reported by Fanu *et al*. (2019) ranging from 0.32 mm to 0.35 mm, but closer to the value of 0.41 mm for Rhode Island Red reported by Niraj *et al*. (2014). The variations from other studies might be due to breed, feeding management adopted and age at which the eggs are sampled (Padhi *et al*. 2013).

Table 5. External egg quality traits of Sasso and Kuroiler chickens fed three diets in different feeding supplementation levels under the semi-intensive system
Least significant means values with different lowercase letters in a row differ significantly at $P < 0.05$

Traits	Commercial diet (D1)				Medium-cost diet (D2)				Low-cost diet (D3)				s.e.m.	*P*-value
	100%	75%	50%	25%	100%	75%	50%	25%	100%	75%	50%	25%		
Sasso														
Egg weight (g)	59.95a	51.70c	49.05cd	46.90d	55.60b	50.45c	50.25c	47.65c	55.80b	49.35c	48.70c	45.75d	0.91	0.0641
Egg length (cm)	5.70a	5.65a	5.35b	5.25b	5.60a	5.55ab	5.50ab	5.15b	5.65a	5.45ab	5.30b	5.35b	0.11	0.0653
Egg width (cm)	4.15a	4.05b	4.01b	4.00b	4.05b	4.00b	3.99b	3.99b	4.00b	4.00b	3.99b	3.98b	0.03	0.0818
Egg shape index (%)	78.40	77.00	77.00	75.70	76.75	75.45	76.40	75.90	75.50	75.70	75.50	74.65	0.79	0.2214
Egg shell weight (g)	6.40a	6.00b	5.85b	5.80b	5.95b	5.90b	5.85b	5.85b	6.15ab	6.00b	5.80b	5.75b	0.12	0.0100
Egg shell thickness (mm)	0.46	0.47	0.45	0.43	0.47	0.47	046	0.46	0.46	0.45	0.46	0.45	0.12	0.4500
Egg shell ratio (%)	10.75	11.80	12.05	12.60	10.80	11.75	11.85	12.65	11.15	11.80	12.45	12.85	0.28	0.9698
Kuroiler														
Egg weight (g)	57.65a	50.60b	50.25b	48.40bc	59.75a	50.70b	49.70bc	47.30c	57.75a	49.55b	48.90b	46.25c	1.16	0.0001
Egg length (cm)	5.75ab	5.60ab	5.50b	5.45b	5.85a	5.45b	5.45b	5.35b	5.65ab	5.55ab	5.45b	5.30b	0.11	0.0014
Egg width (cm)	4.05	4.00	4.00	4.00	4.05	4.03	4.00	4.00	4.05	4.00	4.00	4.00	0.04	0.7389
Egg shape index (%)	76.90	75.65	75.90	75.85	76.20	75.45	75.80	75.05	75.35	74.40	76.45	75.25	0.74	0.2797
Egg shell weight (g)	6.15a	5.90b	5.80b	5.80b	6.35a	6.10ab	5.90b	5.70b	6.20a	5.80b	5.85b	5.70b	0.12	0.0425
Egg shell thickness (mm)	0.48	0.48	0.47	0.46	0.47	0.47	0.46	0.45	0.46	0.47	0.46	0.46	0.12	0.8834
Egg shell ratio (%)	10.70	11.70	11.75	12.15	10.70	12.30	12.00	12.15	10.90	11.80	11.80	12.95	0.30	0.4807

Furthermore, the egg shape index in the two breeds, three dietary treatments and four levels of feed supplementation was not significantly different ($P > 0.05$). The egg shape index ranged from 74.6% to 78.4% (average 75%), which was considered to be normal. The result conforms to values of <72, 72–76 and >76 for eggs that are sharp, normal and round respectively, as reported by Duman *et al.* (2016) and Fanu *et al.* (2019) for Sasso T44 chickens under the traditional production system in North Shewa Zone of Ethiopia. Thus, round eggs and unusually long eggs have poor appearances and do not fit well in egg trays; therefore, they are much more likely to be broken during transportation than the eggs of normal shape.

Internal egg quality traits

Internal egg quality traits of Sasso and Kuroiler chickens are presented in Table 6. Breed had no significant effect ($P > 0.05$) on yolk weight, yolk diameter, yolk ratio, albumen weight, AH and HU. The effect of diets was only significant for a few variables, such as yolk weight and yolk diameter. All internal egg qualities, except HU, were significantly ($P < 0.05$) influenced by the level of supplementation. The reduction in internal egg quality parameters with a reduction in supplementation levels can be explained by the reduction in egg size (Table 5). This observation conforms to that reported by Zaman *et al.* (2004,) where they observed similar trends under a semi-intensive system in crossbreed hens whereby less-supplemented birds performed poorly compared with highly supplemented birds. Yolk height and yolk diameter followed the trend observed in yolk weight, with birds fed 100% supplementation having high values and 25% supplementation having the lowest values.

Albumen weight ranged from 25.3 to 34.9 g depending on diet, breed and level of supplementation. The values are within the range of 33.41–34.47 g reported by Fanu *et al.* (2019) for Sasso chickens. Similarly, Zaman *et al.* (2004) observed the same trend of performance on the low level of supplementation in the study of egg production performances of crossbreeds under the semi-intensive system of management in Bangladesh. Average means of HU in Sasso and Kuroiler were 84.8% and 84.2% respectively, which is slightly lower than the value of 87.58% reported by Fanu *et al.* (2019) and 87.45% by Taddesse *et al.* (2015), and slightly higher than 82.15% reported by Niraj *et al.* (2014) in the Bovans brown breed. The yolk ratio tended to increase with a reduction in supplementation levels, with values ranging from 29.4% to 33.5%. Whereas the albumen ratio decreased with a reduction in dietary supplementation levels with values ranging from 53.9% to 58.3% in both breeds. Fanu *et al.* (2019) reported yolk ratio values of 24.9%, 27.83% and 26.79% in Tarmaber, Ankober and Kewet districts respectively, which were lower than the results of the current study, but concur with Sinha *et al.* (2017), who reported a ratio of 33.85 for birds raised under an intensive production system.

An economic evaluation of feed costs

The cost of the diets was calculated based on purchase cost (D1), and formulation costs for D2 and D3. The results in

Table 6. Internal egg quality traits of Sasso and Kuroiler chickens fed three diets in different feeding supplementation levels under the semi-intensive system

Least significant means values with different lowercase letters in a row differ significantly at $P < 0.05$

Traits	Commercial diet (D1) 100%	75%	50%	25%	Medium-cost diet (D2) 100%	75%	50%	25%	Low-cost diet (D3) 100%	75%	50%	25%	s.e.m.	*P*-value
Sasso														
Yolk weight (g)	17.75a	15.80bc	15.50 c	15.30c	17.20ab	16.45b	15.95bc	15.60bc	17.30ab	16.15bc	15.95bc	14.70c	0.32	0.0001
Yolk height (mm)	18.10a	16.75b	15.90b	15.75b	17.90a	16.45b	16.40b	15.80b	18.15a	16.50b	15.90b	15.85b	0.34	0.0001
Yolk diameter (mm)	39.40a	37.40b	36.75bc	36.15c	39.25a	37.60b	37.50b	36.65bc	39.15a	37.15bc	36.45bc	35.65c	0.37	0.0018
Yolk ratio (%)	29.75	30.60	31.35	33.35	30.90	32.75	31.75	32.80	31.00	32.95	32.90	31.90	0.69	0.1329
Albumen weight (g)	35.10a	29.85bc	28.10c	25.65d	31.55b	28.40c	27.70cd	26.25cd	31.90b	27.25cd	27.15cd	25.30d	0.83	0.0001
Albumen height (mm)	7.65a	6.80c	6.35de	6.15e	7.30b	6.70c	6.60c	6.40d	7.25b	6.50cd	6.50cd	6.35de	0.12	0.0270
Haugh unit (%)	87.20	85.25	84.05	83.95	85.75	84.50	84.35	84.10	85.70	84.45	84.45	84.10	0.61	0.5219
Albumin ratio (%)	58.30	57.60	56.90	54.60	56.75	54.60	56.15	54.95	57.10	55.60	55.40	54.85	0.88	0.4693
Kuroiler														
Yolk weight (g)	18.35a	16.65bc	16.05bc	15.75c	17.60ab	16.60bc	15.75c	15.60c	17.05b	16.00bc	15.35c	14.90c	0.40	0.0001
Yolk height (mm)	18.10a	16.40b	16.40b	15.80b	18.45a	16.50b	16.05b	15.85b	17.90a	16.30b	16.00b	15.80b	0.34	0.0001
Yolk diameter (mm)	39.50a	37.35b	36.50bc	36.45bc	39.45a	37.25b	36.70bc	36.55bc	39.20a	36.35bc	36.30bc	36.05c	0.42	0.0001
Yolk ratio (%)	32.00	32.10	32.25	32.50	29.45	32.95	31.60	33.50	29.55	32.50	31.35	31.95	0.74	0.1340
Albumen weight (g)	32.60a	28.55b	28.40b	26.20c	34.95a	28.20b	27.75b	25.85b	32.95a	27.75b	27.05bc	25.45c	0.95	0.0001
Albumen height (mm)	7.15a	6.50bc	6.35c	6.20c	7.40a	6.70b	6.55bc	6.25c	7.25a	6.50bc	6.50bc	6.20c	0.13	0.0004
Haugh unit (%)	84.45	83.55	83.45	83.35	85.80	85.05	84.90	82.70	85.45	84.15	83.95	83.85	0.64	0.4214
Albumen ratio (%)	56.45	56.40	56.10	53.95	58.35	55.60	55.30	54.40	56.90	55.80	55.30	55.00	0.89	0.6498

Table 7 present cost variables by breed, diet and supplementation levels. D1 was relatively more expensive, followed by D2 and D3 respectively. This influenced the cost per egg production in a similar manner; that is, birds fed low-cost diets used less cost to lay a dozen eggs than those fed medium-cost (D2) or commercial diet (D1). The Sasso breed under the less-supplemented diet plus the scavenging group showed higher income than the Kuroiler breed within the same group, but it was based on only 140 days of the experimental period. Similarly, birds under full feeding laid more eggs than those under 75%, 50%, and 25% supplementation levels. However, less-supplemented birds had higher income over feed compared with full-fed birds in all three experimental diets in 20 weeks of the production period of the study. From Fig. 1, it is seen that the egg production of less supplemented plus scavenging birds is much lower, especially from Weeks 36–40, due to a comparatively lower amount of feed, which may cause declined egg production of the birds. Therefore, the higher profit in less-supplemented (25% and 50%) plus scavenging birds might not be consistent with the expected profit during a 1-year laying period.

A farmer needs to pay attention to cost if she/he has to maximise profit. From the results, the feed cost per dozen eggs differed depending on the type of diet and the levels of supplementation, being higher in the commercial diet (D1) followed by D2 and finally D3. However, assuming that birds are given D1 at 100%, 75%, 50% and 25% dietary supplementation level, 25% gave numerically higher income over feed than other supplementation levels for the first 20 weeks of production. As indicated in Table 1, the production increasingly declines as the age increases, hence the income will also slightly decrease. For smallholder farmers, it is promising to use less costly feeds for dual-purpose birds, such as those used in the current study, although the overall outcome will depend on the available scavengeable feed resources.

Conclusions

From the results obtained in this study, it was concluded that egg productivity of the Sasso chickens was better than Kuroiler chickens under semi-intensive management conditions. Diets had a significant influence on egg production parameters, but did not have a great influence on the egg internal qualities. Likewise, both egg productivity and egg quality traits were significantly improved by increasing the level of supplementation. However, less-supplemented birds gave numerically higher income over feed than other highly supplemented birds for the first 20 weeks of production.

Implications of the study

These findings have the potential to reduce the cost of egg production for dual-purpose improved chicken breeds while maintaining good egg quality under a semi-intensive system of production. The study will also serve as baseline information for developing strategic feeding of dual-purpose birds intended for egg production.

Table 7. An economic evaluation of feeds at different levels of supplementation during egg production

Variables	Commercial diet (D1)				Medium-cost diet (D2)				Low-cost diet (D3)			
	100%	75%	50%	25%	100%	75%	50%	25%	100%	75%	50%	25%
						Sasso						
Total feed consumed (kg)/bird	19.6	14.7	9.8	4.9	19.6	14.7	9.8	4.9	19.6	14.7	9.8	4.9
Feed cost per kg (Tshs)[A]	1100	1100	1100	1100	900	900	900	900	700	700	700	700
Total feed cost (Tshs/bird)	21 560	16 170	10 780	5390	17 640	13 230	8820	4410	13 720	10 290	6860	3430
Average eggs laid in 20 weeks/bird	98	93	93	78	95	84	74	60	84	77	61	46
Cost per egg (Tshs)	300	300	300	300	300	300	300	300	300	300	300	300
Revenue (Tshs)	29 400	27 900	27 900	23 400	28 500	25 200	22 200	18 000	25 200	23 100	18 300	13 800
Income over feed (Tshs)	7840	11 730	17 120	18 010	10 860	11 970	13 380	13 590	11 480	12 810	11 440	10 370
						Kuroiler						
Total feed consumed (kg)/bird	19.6	14.7	9.8	4.9	19.6	14.7	9.8	4.9	19.6	14.7	9.8	4.9
Feed cost per kg (Tshs)	1100	1100	1100	1100	900	900	900	900	700	700	700	700
Total feed cost (Tshs/bird)	21 560	16 170	10 780	5390	17 640	13 230	8820	4410	13 720	10 290	6860	3430
Average eggs laid in 20 weeks/bird	74	70	69	62	76	67	62	52	64	53	47	42
Cost per egg (Tshs)	300	300	300	300	300	300	300	300	300	300	300	300
Revenue (Tshs)	22 200	21 000	20 700	18 600	22 800	20 100	18 600	15 600	19 200	15 900	14 100	12 600
Income over feed (Tshs)	640	4830	9920	13210	5160	6870	9780	11190	5480	5610	7240	9170

[A]1USD = 2340Tshs.

Conflicts of interest

The authors declare no conflicts of interest.

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References

Ali MS (2002) Study on the effect of feed supplementation to laying hen under the rural condition of Bangladesh. MSc Thesis, The Royal Veterinary and Agricultural University, Copenhagen, Denmark.

Aman G, Bangu B, Bereket Z, Desta G, Abiti T, Edget A, Hamid J (2017) Production performance of Sasso and Bovans brown chickens breed under the village production system in three agroecologies of Southern Nations, Nationalities, and Peoples' Regional State (SNNPR), Ethiopia. *International Journal of Livestock Production* **8**, 145–157. doi:10.5897/IJLP2017.0391

Bamidele O, Sonaiya EB, Adebambo OA, Dessie T (2020) On-station performance evaluation of improved tropically adapted chicken breeds for smallholder poultry production systems in Nigeria. *Tropical Animal Health and Production* **52**, 1541–1548. doi:10.1007/s11250-019-02158-9

Dessie T, Getachew F (2016) 'The Kuroiler breed. African Chicken Genetic Gains Factsheet 2.' (ILRI: Nairobi, Kenya)

Duman M, Sekeroglu A, Yildirim A, Elenoglu H, Camci O (2016) Relation between egg shape index and egg quality characteristics. *Archiv für Geflügelkunde* **80**, doi:10.1399/eps.2016.117

Fanu WM, Melkamu BY, Emana G (2019) Productivity and Egg Quality Traits of Sasso T44 Chicken in North Showa Zone, Ethiopia. *Journal of Animal and Plant Sciences* **39**, 6478–6486.

FAO (2008) Poultry production systems in Vietnam. Prepared by Nguyen Van Duc and T. Long. GCP/RAS/228/GER Working Paper No. 4. Rome.

FAO (2019) 'Poultry Sector – The United Republic of Tanzania. FAO Animal Production and Health Livestock Country Reviews. No. 12.' (FAO: Rome, Italy).

Goromela EH, Kwakkel RP, Verstegen MWA, Katule AM (2007) Identification, characterization and composition of scavengeable feed resources for rural poultry production in Central Tanzania. *African Journal of Agricultural Research* **2**, 380–393.

Haugh R (1937) The Haugh unit for measuring egg quality. *The US Egg & Poultry Magazine* **43**, 552–573.

Ibrahim D, Goshu G, Esatu W, Cahaner A (2019) Dual-purpose production of genetically different chicken crossbreeds in Ethiopia. 1. Parent stocks' feed intake, body weight, and reproductive performance. *Poultry Science* **98**, 3119–3129. doi:10.3382/ps/pez136

Islam R, Deka CK, Rahman M, Deka BC, Hussain M, Paul A (2017) Comparative performances of Kuroiler, Rainbow Rooster and Indigenous birds under backyard system of rearing in Dhubri district of Assam. *Journal of Rural and Agricultural Research* **17**, 40–43.

Niraj K, Zinabu N, Yohanes T, Etsay K (2014) Evaluation of Egg Quality Traits of Rhode Island Red and Bovans White under Intensive Management system. *Journal of Agriculture and Veterinary Science* **7**, 71–75.

Padhi MK, Chatterjee RN, Haunshi S, Rajkumar U (2013) Effect of age on egg quality in chicken. *Indian Journal of Poultry Science* **48**, 122–125.

Pius LO, Mbaga SH (2018) Variations in village chicken management packages in two agro-ecological zones of Tanzania. *International Journal of Livestock Production* **9**, 42–49. doi:10.5897/IJLP2017.0422

Sanka YD, Mbaga SH, Mutayoba SK, Katule AM, Goromela SH (2020) Evaluation of growth performance of Sasso and Kuroiler chickens fed three diets at varying levels of supplementation under semi-intensive system of production in Tanzania. *Tropical Animal Health and Production* **52**, 3315–3322. doi:10.1007/s11250-020-02363-x

SAS (2008) 'Statistical Analysis Systems. SAS User's Guide: Version 9.2.' 2nd edn. (SAS Institute: Cary, NC)

SASSO (2016) SASSO Breeding Company. Available at http://www.sasso.fr/best-meat-chicken-breeds-for-traditional-rearing-c44.html.

Sharma J, Xie J, Boggess M, Galukande E, Semambo D, Sharma S (2015) Higher weight gain by Kuroiler chickens than indigenous chickens raised under scavenging conditions by rural households in Uganda. *Livestock Research for Rural Development* **27**, 9.

Shim MY, Song E, Billard L, Aggrey SE, Pesti GM, Sodsee P (2013) Effects of balanced dietary protein levels on egg production and egg quality parameters of individual commercial layers. *Poultry Science* **92**, 2687–2696. doi:10.3382/ps.2012-02569

Sinha B, Mandal KG, Kumari R (2017) Effect of Egg Weight on Egg Quality Traits of Laying Hens. *Internaional Journal of Pure & Applied Bioscience* **5**, 293–300. doi:10.18782/2320-7051.2639

Taddesse D, Esatu W, Girme M, Dessie T (2015) Comparative study on some egg quality trait of exotic chickens in different production system in East Shewa. *African Journal of Agricultural Research* **10**, 1016–1021. doi:10.5897/AJAR2014.9373

Zaman MA, Sørensen P, Howlider MAR (2004) Egg production performances of a breed and three crossbreeds under semi-scavenging system of management. *Livestock Research for Rural Development* **16**, 8.

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Research Article
Performance of Sasso and Kuroiler Chickens under Semi-Scavenging System in Tanzania: Carcass and Meat Quality

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Abstract

Background and Objective: Throughout the world, consumers are increasingly being attracted to chicken meat from naturally grown birds. A study was therefore conducted to evaluate the effect of dietary regimes on carcass and meat quality of genetically improved dual-purpose chicken. **Materials and Methods:** In total, 480 day-old male chicks were randomly assigned to 24 treatment combinations in a 2×3×4 factorial experiment. The treatments were breeds (Sasso and Kuroiler), diets (D_1, D_2 and D_3) and levels of supplementation (100, 75, 50 and 25%). At the age of 20 weeks, five male chickens were randomly selected from each treatment combination and sacrificed for detailed carcass and meat quality assessment. **Results:** The Dressing Percentage (DP), pH, cooking loss, Crude Protein (CP) content of breast, thigh and drumstick joints were higher in Sasso than in Kuroiler. Values for redness (a*) and yellowness (b*) were higher in Kuroiler than in Sasso. Thigh muscle in birds fed D_2 and D_3 tended to be tougher than those fed D_1. CP and ash contents in breast joints from D_1 and D_2 were higher than in D_3 chickens. The ether extract values for drumstick from D_1 and D_2 were comparable but higher than in D_3. The L* and a* value in the breast joint tended to increase with a reduction in the level of supplementation but it was the opposite in the case of the drumstick. **Conclusion:** It is concluded that the feeding regime affects the meat quality of genetically improved dual-purpose chicken in a joint-specific fashion.

Key words: Carcass traits, meat quality, improved dual-purpose chicken, low-cost diet, semi-scavenging, supplementation, breast joints

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Chicken meat is a source of high-quality protein with a relatively low content of fat[1]. Fortunately, the expectation of modern consumers has evolved toward the demand for traditional products, usually more respectful of the environment and animal welfare and this is an opportunity for expansion of the local chicken industry[2]. Although local chicken breeds and their hybrids show lower weight gain and a smaller proportion of breast muscle in the carcass compared to fast-growing broilers, their meat has many quality characteristics valued by consumers[3]. Despite their taste and other attributes, the production of local chicken is low due to the inherent low genetic potential for growth, poor feed and feeding practice[4]. As such genetic improvements have focused primarily on selection for growth rate, feed conversion efficiency[5-7], more muscle yield and meat quality traits. Selection within the breed is cumbersome and often takes a long time to achieve significant genetic gain and crossbreeding has been adopted as a way to speed up genetic gains. Sasso and Kuroiler breeds are among the genetically improved dual-purpose chicken for the production of more meat and eggs. These strains have been tested in Tanzania, Nigeria and Ethiopia and are deemed to do fairly well under smallholder semi-scavenging conditions in rural areas[5].

Several studies demonstrated the existence of differences in meat quality between fast and slow-growing chicken breeds, particularly on chemical composition and physical traits as well as consumer preferences[6]. Other factors affecting meat quality include sex, age, feeding and rearing systems[1,7]. The most important meat quality traits preferred by consumers include appearance, juiciness, tenderness, flavor, water holding capacity and colour[8]. Some studies on meat quality have focused on the broiler and local chicken types[7,9,10]. Sasso and Kuroiler are relatively new strains in Tanzania and have been promoted as an alternative to local chicken since they have good scavenging ability. However, there is a scarcity of information on the effect of management on meat quality characteristics. Therefore, this study aimed to evaluate the effect of breed, diet and different feed supplementation levels on carcass characteristics and meat quality traits of genetically improved dual-purpose chickens.

MATERIALS AND METHODS

Study area: This research project was conducted from July, 2018-June, 2019. The experiment was conducted at the Poultry Unit of the Department of Animal, Aquaculture and Range Sciences of the Sokoine University of Agriculture, Tanzania.

Experimental layout: A flock of 480 male birds was used, with 240 birds per breed and reared for 20 weeks. An experiment was designed in a 2×3×4 factorial arrangement with two breeds (Sasso and Kuroiler), three diets (D_1-commercial, D_2-medium-cost feed and D_3-low-cost feed) and four supplementation levels per diet, amounting to 24 treatment combinations each with 20 birds. Birds were fed starter (0-6 weeks) and growers diets (7-20 weeks). Supplementation levels were 100, 75, 50 and 25% of the recommended daily feed allowance for each strain. The grower feed had the energy densities of 2887, 2887 and 2627 kcal kg^{-1} DM for D_1, D_2 and D_3, respectively. Protein contents were 15.5, 15.6 and 15.3% for D_1, D_2 and D_3, respectively. One half of the feed was provided in the morning and the remaining half in the evening while water was given *ad libitum*. All birds had access to a fenced range area (1 bird/4 m^2) during the day, where they scavenged for greens, worms and insects.

Carcass traits: Following 20-weeks on dietary treatments, a total of 120 male chickens (60 Sasso and 60 Kuroiler) and five birds per treatment combinations, were randomly selected and sacrificed. Before slaughter, the birds were fasted for 12 hrs, weighed individually and slaughtered by manual exsanguinations. They were then bled for 5 min before being weighed again to get blood weight and de-feathered. After de-feathering they were weighed and the difference in weight was considered as a featherweight. The carcasses were eviscerated, dissected and the carcass parts weighed the same day of slaughter. Weight after de-feathering (before evisceration) and weights for carcass (dressed weight), intestines, breasts, drumsticks, wings, thighs, back, liver, gizzard, heart, neck and shanks were recorded. Carcass weight was taken after evisceration and the carcass yield (dressing percentage) was calculated as a percentage of pre-slaughter body weight.

Meat quality traits

pH measurement: A spear-end digital portable pH meter (Knick Portamess® 910, Germany) was used to measure the pH of the breast, thigh and drumstick joints of each bird at 45 min post-mortem. The pH meter was standardized before the measurement of each sample using two buffer solutions, one with pH 4.0 and another one with pH 7.0. In this regard, a total of 120 samples for each joint were used.

Color measurement: Meat color was measured on the internal surface of the breast, thigh and drumstick joints, using a portable colorimeter (MINOLTA CR 200b colorimeter, Osaka-Japan) based on CIELAB system with (L*) for relative lightness, a* for relative redness and b* for relative yellowness.

Readings were made at three different areas of the selected muscle[11]. The averages of the three readings for color were used for statistical analysis. In this method, the L* value ranges from 0-100 (from black to white), a* and b* both range from (-120) - (+120) with a* ranging from green if negative to red if positive and b* ranging from blue if negative to yellow if positive[12].

Cooking loss measurement: After 4 hrs post-slaughter, raw breast, thigh and drumstick joints (20-30 g) from the right side of the carcass were cut, weighed and sealed in a plastic bag (30 microns) and cooked in a thermostatically controlled water bath (Fisher Scientific, Pittsburgh, PA) at 75°C for 45 min as described by Rizz *et al.*[13]. Then, the samples were cooled in running water for 15 min, dried with soft tissue and weighed. Cooking loss was calculated as a percentage loss of weight during cooking relative to the weight of raw muscle[14].

Tenderness (shear force value) measurement: Strips measuring about 1.0×1.0×2.5 cm parallel to the muscle fiber direction were prepared from the breast, thigh and drumstick joints and sheared across the muscle fiber direction using Warner-Bratzler shear blade attached to Zwick/Roell (Z2.5, Germany) instrument. The sheer force values were recorded in Newtons (N).

Meat chemical composition analysis: For proximate analysis, a total of 120 breasts, thigh and drumstick joints were skinned, de-boned and frozen at -20°C awaiting further analysis. Individual samples were thawed for 24 hrs, 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 dry matter, ash, crude protein and fat content[15]. The dry matter of fresh samples was analyzed by the oven method set at 105°C. Ash was determined after subjecting the samples to a furnace set at 500°C. Protein was analyzed by the Kjeldahl method using a 2200 Foss Tecator Kjeltec distillation unit (Foss, Höganäs, Sweden). Fat contents were analyzed by the Soxhlet method using a 2050 Soxtec Avanti Extract unit (Foss, Höganäs, Sweden).

Statistical data analysis: Data on carcass traits and meat quality were analyzed using the General Linear Models (GLM) procedure of Statistical Analysis System[16]. Breed, diet, level of supplementation and their interactions were considered as fixed effects while the error was considered random. The least-square means were separated by the PDIFF test. Interaction between the factors was tested and found not statistically significant.

RESULTS AND DISCUSSION

Effects of breed on killing out characteristics: Results presented in Table 1 reveals that the Dressing Percentage (DP) of Sasso (68.8%) was about 2 percent unit higher ($p<0.001$) than that of Kuroiler. At 20 weeks, body weights were slightly above 2 kg for both breeds and the slaughter weight and carcass weight were near similar. Values for slaughter weight and DP observed in this study are higher than that of local chicken reported by Sanka and Mbaga[7]. This is attributable to lower carcass weights of local chicken due to the lower growth rate[17]. Since Sasso and Kuroiler chickens are heavier than the local chickens, it is logical that their carcass portions are more than those of the local chickens. Moreover, the results for carcass weight observed in the present study are within the range of 900-1900 g reported by Yaussao *et al.*[18] and Franco *et al.*[17] in local, Label Rouge chickens and Sasso T-44 hybrid line respectively. Also, Aline[19] reported a higher dressing percentage of Kuroiler breed than the local breed.

Sasso and Kuroiler were comparable ($p>0.05$) in carcass joint weights as well as non-carcass portions. According to Sante *et al.*[20], the breast weight to carcass weight is an important criterion in broiler poultry production. Sanka and Mbaga[7] reported the average weight of carcass and breast in local chickens to be 1414.00g and 352.51 g, which is 35.09% and 12.21% lower than that of Sasso and Kuroiler birds obtained in the current study. Thus, Sasso and Kuroiler chickens could be taken as alternative meat birds owing to their high carcass weight compared to the indigenous chickens.

Effects of breed on meat quality: In the present study the pH values measured 45 min Postmortem (PM) in the breast and thigh joints were similar between the two breeds and both were close to 6.0 (Table 2). Higher pH values were reported by Castellini *et al.*[21], with means ranging between 6.02 and 6.25 and by Souza *et al.*[22], with means varying from 5.93-6.22 for broiler under organic production system. The pH values recorded 45 min PM at drumstick was higher ($p<0.05$) for Sasso (6.22) than Kuroiler (6.00). According to Ristic and Damme[23] threshold pH ranges to be considered for standard meat properties are 5.9-6.2, while meat with pH-value $\leq$5.8 is considered Pale, Soft and Exudative (PSE) condition and $\geq$6.3 Dark, Firm and Dry (DFD) condition. Thus,

Table 1: Effect of breed on carcass characteristics and non-carcass traits

	Breeds			
Carcass traits	Sasso	Kuroiler	SEM	p-value
Slaughter weight (g)	2178.33	2169.53	43.70	0.9588
Carcass weight (g)	1498.72	1449.68	33.55	0.5420
Dressing percent (%)	68.80[a]	66.84[b]	0.34	0.0009
Breast weight (g)	401.55	375.40	10.72	0.0876
Thigh weight (g)	247.02	252.67	6.06	0.5116
Drumstick weight (g)	236.95	240.87	4.92	0.5747
Back weight (g)	307.30	313.02	8.24	0.6248
Wing weight (g)	192.30	187.67	4.17	0.4344
Neck weight (g)	93.83	95.58	2.61	0.6369
Non-carcass traits				
Head weight (g)	68.13	71.40	1.24	0.0666
Shank weight (g)	86.85	88.93	1.46	0.3155
Gizzard weight (g)	56.12[b]	61.05[a]	1.22	0.0050
Liver weight (g)	42.32	44.53	1.55	0.3137
Heart weight (g)	9.48	9.80	0.32	0.4858
Spleen weight (g)	3.10	3.07	0.11	0.8277
Intestine weight (g)	133.95	141.50	3.83	0.1664
Blood weight (g)	72.73[a]	67.52[b]	1.66	0.0288
Feather weight (g)	226.63	231.40	6.33	0.5959

[ab] Least significant means values having different superscripts in a row differ significantly at p<0.05

Table 2: Effect of breed on chicken meat tenderness, pH and meat color

		Breeds			
Quality traits	Joint	Sasso	Kuroiler	SEM	p-value
pH	Breast	5.80	5.81	0.02	0.5706
	Thigh	6.01	6.03	0.02	0.5224
	Drumstick	6.22[a]	6.00[b]	0.02	0.0001
Colour					
L*	Breast	55.64	55.29	0.80	0.7577
	Thigh	49.99	50.15	0.61	0.8530
	Drumstick	56.49[b]	58.18[a]	0.60	0.0523
a*	Breast	4.48[b]	7.32[a]	0.35	0.0001
	Thigh	13.36	13.84	0.53	0.5237
	Drumstick	10.31[b]	12.60[a]	0.48	0.0010
b*	Breast	5.80[b]	8.71[a]	0.37	0.0001
	Thigh	7.90	8.40	0.35	0.3075
	Drumstick	9.71[b]	11.21[a]	0.39	0.0075
Cooking loss (%)	Breast	20.15[a]	15.80[b]	0.53	0.0001
	Thigh	23.46	22.28	0.64	0.1944
	Drumstick	21.24[a]	18.61[b]	0.60	0.0026
Shear force (N)	Breast	36.20[a]	32.86[b]	0.86	0.0051
	Thigh	32.44	31.90	0.56	0.4961
	Drumstick	27.73	27.79	0.54	0.9364

[ab]Least significant means values having different superscripts in a row differ significantly at p< 0.05. L*: Lightness, a*: Redness, b*: Yellowness

the pH-values observed in the present study are within acceptable standard meat properties quality.

Values for redness (a*) and yellowness (b*) measured at breast and drumstick joints were higher ($p<0.05$) in Kuroiler than in the Sasso breed (Table 2). However, the two breeds did not differ in values for lightness (L*) from all the joints or redness (a*) and yellowness (b*) from the thigh joint. Results from the present study differ from the observation by Bianchi *et al.*[24], who compared Cobb 500 and Ross 508 strains and found no difference in broiler breast meat color based on the genotype of the bird. Brewer *et al.*[25] found that the strain of broiler did not have a major effect on breast filet color. Contrary to the present findings, Abdullah *et al.*[26] found that the breast meat in Lohmann broilers was less light in color (L* value 51.14) than in Hubbard (L* value 53.32), even though the pH of the breast meat was essentially identical. Comparing a slow-growing French label-type line and a fast-growing standard line of commercial chickens, Debut *et al.*[27] found that

Table 3: Effect of breed on proximate composition of meat from genetically improved chicken

		Breeds			
Parameters (%)	Joint	Sasso	Kuroiler	SEM	p-value
Dry matter	Breast	26.44	25.92	0.46	0.4278
	Thigh	25.7	24.42	0.29	0.0735
	Drumstick	24.58	24.37	0.27	0.5590
Ash	Breast	4.99[a]	3.84[b]	0.17	0.0001
	Thigh	5.36[a]	4.29[b]	0.16	0.0001
	Drumstick	5.19[a]	4.39[b]	0.17	0.0015
Crude protein	Breast	23.91[a]	22.51[b]	0.23	0.0001
	Thigh	21.61[a]	20.64[b]	0.23	0.0029
	Drumstick	21.28[a]	20.18[b]	0.23	0.0010
Ether extract	Breast	3.39	3.32	0.15	0.7649
	Thigh	3.96	3.72	0.13	0.2123
	Drumstick	3.78	3.59	0.13	0.2769

[ab]Least significant means values having different superscripts in a row differ significantly at p<0.05

the breast and thigh meat of the fast-growing line was lighter (L* values 52.82 and 51.22, respectively) than that of the slow-growing line (L* values 50.76 and 50.07, respectively). However, a lack of difference in relative lightness (L*) observed in the present study agrees with the findings reported by Mehaffey *et al.*[28] when comparing five commercial broiler strains using breast joint. Lonergan *et al.*[29] compared inbred Leghorn, inbred Fayoumi, commercial broilers, F5 broiler inbred Leghorn cross and F5 broiler-inbred Fayoumi cross and determined that the breast meat of all strains had equivalent L* values but the inbred leghorns had a more intense red color. Color is one of the main indicators of the quality of most foods. This sensorial quality has a high influence on the meat purchase decision and its acceptance by consumers. It is an important functional quality and it is closely related to other qualities, such as pH, water holding capacity, emulsifying capacity and texture[30]. In most cases, color can be considered as an indicator of these properties, which together, will affect acceptability to consumers, shelf life, tenderness, juiciness and suitability of meat for further processing.

Regarding cooking loss, an indicator for water holding capacity, significant (p<0.05) difference was noted between breeds on breast and drumstick joints but not on thigh joint (Table 2). Sasso had a higher cooking loss value compared to Kuroiler both for breast and drumstick joints. Water Holding Capacity (WHC) is affected by several factors including rate and extent of pH decline, sarcomere length, ionic strength and proteolysis[31-33]. The fast decline of pH while the carcass temperature is still high leads to protein denaturation, lower WHC and Pale, Soft and Exudative (PSE) meat. On the other hand, the lower extent of pH decline postmortem leads to higher ultimate pH, higher WHC and Dark, Firm and Dry (DFD) meat[34].

Breast joint was observed to be relatively tougher in Sasso than Kuroiler chicken, whereas the two breeds did not differ in tenderness in other joints (Table 2). The values for the two strains are higher than that of semi-scavenging local chickens (26.5N) slaughtered at 20 weeks as reported by Sanka and Mbaga[7] but lower compared to the same birds slaughtered at 28 weeks (43.9 N). The findings are in accordance with Fengli *et al.*[35], who demonstrated that breed had a significant effect on the tenderness of meat in the slow-growing chickens. However, meat from the two breeds can be considered tender because the amount of force required for shearing the sample was less than 50 N. In general, meat with Warner–Bratzler shear force values that exceed 55 N would be considered as objectionably tough both by a trained sensory panel and by consumers[36,37].

Although meat from the two breeds was comparable in dry matter and fat content, Sasso breed had higher (p<0.05) ash and protein contents than Kuroiler (Table 3). The values obtained for protein, fat, ash and dry matter contents are within the range of 20-27, 3-9, 4-12 and 24-30%, respectively reported by Sogunle *et al.*[38]. Ash content in meat determines largely the extent to which the dietary minerals would be available in a particular food sample. The variability in the proximate composition of different meat has also been reported by Wattanachant[34], Tougan *et al.*[39] and Mbaga *et al.*[40]. This implies that consumers can have a choice on the meat cut based on its expected nutritional value in addition to other physical attributes, such as tenderness and color.

Effects of diet on carcass characteristic: Birds in D_1 and D_2 were comparable but superior (p<0.05) over those in D_3 in terms of killing out characteristics and weights of different carcass joints (Table 4). The superiority of birds in D_1 and D_2

over those in D_3 can be associated with the difference in energy content of the diets whereby D_1 and D_2 had 2887 KCl kg^{-1} ME while D_3 had 2627 kCl kg^{-1} ME. Low cost-formulation (D_3) had low nutrient density, possibly it can be used for local chickens or Sasso and Kuroiler if scavengeable feed resources are adequate. Similar observations were found by Miah *et al.*[41] and Miah *et al.*[42] in the study of indigenous (Desi) chickens reared in rural households in Bangladesh. Weights of non-carcass components largely followed the pattern displayed by killing out characteristics except for the weight of the intestines. Intestine weights were not influenced by the three dietary groups (Table 4) probably because all birds were exposed to scavenging. Scavenging has been associated with lengthening of the intestine in an attempt to increase digestive areas[43].

Effects of diet on meat quality: Diets did not affect (p>0.05) the pH value recorded on three carcass joints (Table 5). However, the obtained values are within the range of acceptable pH for quality chicken meat[23]. Diets affected (p<0.05) values for lightness (L*) recorded at the thigh joint, redness (a*) recorded at the thigh and drumstick and yellowness recorded at breast and drumstick. Thigh joints from D_1 and D_2 were comparable in lightness (L*) but with lower (p<0.05) values than that from D_3. On the other hand, thigh joints from D_1 and D_2 were comparable in redness (a*) but with higher (p<0.05) values than that from D_3. Similarly, breast joints from D_1 and D_2 were comparable in yellowness (b*) but with lower (p<0.05) values than that from D_3. Smith *et al.*[44] reported that the composition of the poultry ration may affect meat color, whereby poultry fed a wheat-based diet produced significantly lighter colored fillets than poultry fed a corn-based diet. Also according to Fanatico *et al.*[45] and Ponte *et al.*[46] meat color can be influenced by management factors such as feeds and feeding systems. In the present study, the relatively high values of yellowness of breast joint, compared to observations reported in the literature may be due to the access of pastures. Pasture is rich in beta carotenes, a precursor for vitamin A, which are deposited in fat tissue of scavenging/grazing animals as they are fat-soluble. Overall, values for color variables observed in the present study are within the range for acceptable levels as described by Wattanachant *et al.*[10]. Scavenging chickens cannot find all nutrients they need under scavenging land all year round. Moreover, the nutritional quality of scavenging village chickens is low. Thus, there is a need for adopting nutrient supplementation strategies to improve village chicken meat productivity and quality.

Diets affected (p<0.05) cooking loss of the breast joint and tenderness of the thigh joint (Table 5). Diet D_2 had the least cooking loss, whereas those on D_1 had the least shear

Table 4: Effect of dietary treatments on carcass characteristics and non-carcass traits of sasso and kuroiler chickens

	Dietary treatments				
Carcass traits	Commercial (D_1)	Medium-cost formulated (D_2)	Low-cost formulated (D_3)	SEM	p-value
Slaughter weight (g)	2362.15^a	2245.92^a	1931.72^b	53.53	0.0001
Carcass weight (g)	1625.32^a	1540.37^a	1286.90^b	41.09	0.0001
Dressing percent (%)	68.81^a	68.58^a	66.62^b	0.42	0.0008
Breast weight (g)	426.70^a	403.92^a	334.80^b	13.12	0.0001
Thigh weight (g)	273.75^a	259.20^a	216.57^b	7.43	0.0001
Drumstick weight (g)	259.37^a	250.80^a	206.55^b	6.02	0.0001
Back weight (g)	343.32^a	323.85^a	263.30^b	10.09	0.0001
Wing weight (g)	204.80^a	195.80^a	169.35^b	5.11	0.0001
Neck weight (g)	108.92^a	94.97^b	80.22^c	3.20	0.0001
Non-carcass traits					
Head weight (g)	76.67^a	69.92^b	62.70^c	1.52	0.0001
Shank weight (g)	91.07^a	90.20^a	82.40^b	1.79	0.0013
Gizzard weight (g)	61.65^a	57.47^b	56.62^b	1.49	0.0424
Liver weight (g)	45.30^a	47.15^a	37.82^b	1.89	0.0018
Heart weight (g)	10.30^a	10.32^a	8.30^b	1.39	0.0003
Spleen weight (g)	3.65^a	3.02^b	2.57^c	0.13	0.0001
Intestine weight (g)	140.75	140.67	131.75	4.69	0.3003
Blood weight (g)	77.47^a	70.67^b	62.22^c	2.04	0.0001
Feather weight (g)	256.17^a	231.25^b	199.62^c	7.56	0.0001

^{abc}Least significant means values having different superscripts in a row differ significantly at p<0.05

Table 5: Effect of Dietary treatments on genetically improved chicken meat tenderness, pH and meat color

		Dietary treatments				
Quality traits	Joint	D_1	D_2	D_3	SEM	p-value
pH	Breast	5.82	5.80	5.78	0.02	0.2637
	Thigh	6.06	6.02	5.97	0.03	0.0847
	Drumstick	6.13	6.11	6.09	0.03	0.5752
Colour						
L*	Breast	55.71	55.89	54.79	0.98	0.6988
	Thigh	48.87^b	49.78^b	51.56^a	0.75	0.0394
	Drumstick	57.09	57.84	57.07	0.74	0.7079
a*	Breast	5.13	6.51	6.06	0.43	0.0742
	Thigh	14.85^a	14.35^a	11.60^b	0.65	0.0013
	Drumstick	12.29^a	10.07^b	12.01^a	0.58	0.0164
b*	Breast	6.94^b	6.58^b	8.25^a	0.45	0.0269
	Thigh	8.38	8.07	7.99	0.42	0.7916
	Drumstick	10.90^a	8.69^b	11.78^a	0.48	0.0001
Cooking loss (%)	Breast	17.92^b	16.16^c	19.85^a	0.65	0.0006
	Thigh	22.13	22.39	24.10	0.78	0.1579
	Drumstick	19.78	19.14	20.84	0.74	0.2600
Shear force (N)	Breast	34.63	35.91	33.05	1.03	0.1531
	Thigh	30.32^b	33.27^a	32.93^a	0.68	0.0031
	Drumstick	28.66	26.95	27.67	0.65	0.1727

^{abc}Least significant means values having different superscripts in a row differ significantly at $p<0.05$, L*: Lightness, a*: Redness, b*: Yellowness

Table 6: Effect of dietary treatments on genetically improved chicken meat proximate composition and meat bone ratio

		Dietary treatments				
Parameters (%)	Joint	D_1	D_2	D_3	SEM	p-value
Dry matter	Breast	25.85	25.73	26.94	0.57	0.2573
	Thigh	25.01	24.95	24.42	0.36	0.4375
	Drumstick	24.06	24.49	24.87	0.33	0.2312
Ash	Breast	4.74^a	4.58^a	3.93^b	0.21	0.0166
	Thigh	4.76	5.13	4.58	0.20	0.1351
	Drumstick	4.89	4.88	4.61	0.21	0.5835
Crude protein	Breast	23.84^a	23.05^{ab}	22.74^b	0.28	0.0202
	Thigh	20.89	21.04	21.44	0.28	0.3617
	Drumstick	20.71	20.71	20.78	0.28	0.9823
Ether extract	Breast	3.36	3.66	3.05	0.18	0.0596
	Thigh	3.78	3.78	3.96	0.16	0.6693
	Drumstick	3.98^a	3.71^{ab}	3.38^b	0.16	0.0261

^{abc}Least significant means values having different superscripts in a row differ significantly at $p<0.05$

force. This difference could be explained by the fact that birds fed D_1 probably met most of the nutrient requirements from the feed, thus spent less time scavenging. The intensity of activity to which meat-producing animal is subjected to affect meat tenderness by influencing the degree of crosslink formation in the collagen fibres[47,48]. The shear-force and cooking loss values obtained in the present study are within the range of the values reported by Sanka and Mbaga[49] in the study of meat quality attributes of Tanzanian local chicken reared under the intensive and semi-intensive system of production.

Birds on D_1 and D_2 diets were comparable but higher ($p<0.05$) in ash and crude protein contents in the breast joint and fat content in the drumstick than D_3 birds (Table 6). The observed variation in protein contents of the joints is attributable to the difference in content and composition of dietary protein. According to Hussain *et al.*[50] and Ferreira *et al.*[51] amino acid deficiency can lead to protein decrease in meat. D_3 diet had no synthetic lysine and methionine and was lower in energy content than the rest. This indicates that variation in the dietary concentration of essential dietary amino acids has a significant impact on the proximate composition of meat. The observed variation in fat content is consistent with the difference in energy contents among diets, with D_1 having similar energy content to D_2, both of which were higher than that of D_3. In agreement with an observation

Table 7: Effect of level of feed supplementation on carcass characteristics and non-carcass traits of sasso and kuroiler chickens

	Level of feed supplementation					
Carcass traits	Full feeding (100%)	75%	50%	25%	SEM	p-value
Slaughter weight (g)	2647.23^{a}	2330.40^{b}	1949.07^{c}	1793.03^{c}	61.81	0.0001
Carcass weight (g)	1825.20^{a}	1596.70^{b}	1318.10^{c}	1196.80^{c}	47.44	0.0001
Dressing percent (%)	68.79^{a}	68.35^{ab}	67.27^{bc}	66.28^{c}	0.48	0.0018
Breast weight (g)	477.83^{a}	420.17^{b}	341.80^{c}	314.10^{c}	15.15	0.0001
Thigh weight (g)	301.93^{a}	269.53^{b}	226.07^{c}	201.83^{d}	8.58	0.0001
Drumstick weight (g)	292.43^{a}	257.43^{b}	215.60^{c}	190.17^{d}	6.96	0.0001
Back weight (g)	369.73^{a}	337.83^{b}	277.57^{c}	255.50^{c}	11.65	0.0001
Wing weight (g)	232.90^{a}	200.70^{b}	172.33^{c}	154.00^{d}	5.90	0.0001
Neck weight (g)	122.87^{a}	101.37^{b}	81.27^{c}	73.33^{c}	3.69	0.0001
Non-carcass traits						
Head weight (g)	81.93^{a}	72.27^{b}	63.80^{c}	61.07^{c}	1.76	0.0001
Shank weight (g)	101.97^{a}	93.93^{b}	80.13^{c}	75.53^{c}	2.06	0.0001
Gizzard weight (g)	62.43^{a}	64.47^{a}	57.07^{b}	50.37^{c}	1.72	0.0001
Liver weight (g)	46.20^{a}	51.13^{a}	39.03^{b}	37.33^{b}	2.19	0.0001
Heart weight (g)	11.70^{a}	10.13^{b}	8.83^{c}	7.90^{c}	0.45	0.0001
Spleen weight (g)	4.20^{a}	3.00^{b}	2.60^{bc}	2.53^{c}	0.15	0.0001
Intestine weight (g)	154.73^{a}	145.67^{ab}	133.57^{b}	117.13^{c}	5.41	0.0001
Blood weight (g)	96.13^{a}	74.77^{b}	59.97^{c}	49.63^{d}	2.35	0.0001
Feather weight (g)	270.80^{a}	253.70^{a}	198.77^{b}	192.80^{b}	8.96	0.0001

^{abcd}Least significant means values having different superscripts in a row differ significantly at p<0.05

from the present study, Ferreira *et al.*[51] reported lower fat content in meat from birds fed diets with lower energy levels.

Effects of level of feed supplementation on carcass characteristics: Slaughter weight decreased by 12, 26 and 32% when the feed was reduced to 75, 50 and 25% of recommended daily allowance, respectively (Table 7). Thus, the higher the level of feeding, the higher the slaughter weight and carcass yield which in turn influenced all other carcass components in that order. However, there was no significant difference in dressing percentage, spleen weight and intestinal weight between birds receiving 75 and 50% supplementation levels. Miah *et al.*[42] fed diets of different energy levels to Desi chicken reared at rural households under tropical conditions in Bangladesh and found a similar trend of higher meat yield with higher levels of supplementation. Jahanpour *et al.*[52] also reported that birds kept on a feeding program regime with just 75% of the daily feed allowance had heavier carcasses than those in the less fed group.

Effects of level of feed supplementation on meat quality: Thigh and drumstick joints from birds receiving 100% supplementation level had lower (p<0.05) pH at slaughter than the rest (Table 8). pH at slaughter is affected by several factors including glycogen reserves in muscles and the extent of pre-slaughter stress[53]. Since birds were subjected to similar pre-slaughter handling, the observed difference in pH may be attributable to glycogen reserves, which might have been higher in birds receiving a 100% supplementation level. The L* and b* value in the breast joint tended to increase with a reduction in supplementation level. The increase in yellowness (b*) value with a reduction in supplementation levels might be attributed to an increase in the intake of fresh forages. As indicated above, fresh forages are rich in beta carotenes (vitamin A precursors) that impart yellow color on carcass fat[54]. Cooking loss in the breast and drumstick joints decreased (p<0.05) with a decrease in the level of supplementation. As mentioned above, cooking loss, which is a measure of the water holding capacity of meat, is affected by several factors. Normally, meat with high-fat content tends to have low water content and lower cooking loss[34]. However, based on the proximate composition meat from birds on different levels of supplementation in the present study did not differ in fat content (Table 9). The shear force value for thigh and drumstick joints increased (p<0.05) when supplementation levels were reduced. The birds under low supplementation levels had to scavenge more to meet their daily requirements and hence exercised more than those on high levels of supplementation. However, meat from all the experimental groups can be considered tender as it required less than 50N to shear through[14].

Results presented in Table 9 show that birds on a 100% level of supplementation had the highest content of crude protein for all the three carcass joints but, the lowest dry matter content in the breast joint. The observed variation in meat protein content in birds on different levels of supplementation might reflect the difference in the quality of protein obtained from concentrate and forages. Birds on a

Table 8: Effect of level of feed supplementation on genetically improved chicken meat tenderness, pH and meat color

		Level of feed supplementation					
Quality traits	Joint	Full feeding (100%)	75%	50%	25%	SEM	p-value
pH	Breast	5.79	5.79	5.80	5.79	0.02	0.3837
	Thigh	5.91^{b}	6.00^{a}	6.08^{a}	6.07^{a}	0.03	0.0013
	Drumstick	5.97^{b}	6.14^{a}	6.15^{a}	6.19^{a}	0.03	<.0001
Color							
L*	Breast	52.11^{b}	54.91^{ab}	57.20^{a}	57.63^{a}	1.13	0.0016
	Thigh	50.73^{ab}	51.30^{a}	48.02^{c}	50.22^{b}	0.87	0.0478
	Drumstick	60.32^{a}	55.36^{c}	50.29^{d}	57.37^{b}	0.85	0.0006
a*	Breast	5.55	6.40	5.76	5.90	0.49	0.6575
	Thigh	13.71	12.95	15.24	12.49	0.76	0.0614
	Drumstick	9.78^{c}	12.31^{a}	12.59^{a}	11.13^{b}	0.67	0.0162
b*	Breast	5.93^{b}	7.80^{a}	6.97^{b}	8.34^{a}	0.52	0.0089
	Thigh	7.18^{b}	7.77^{a}	8.94^{a}	8.70^{a}	0.49	0.0447
	Drumstick	8.91^{b}	10.85^{a}	11.44^{a}	10.63^{a}	0.55	0.0109
Cooking loss (%)	Breast	20.23^{a}	18.22^{b}	17.41^{bc}	16.06^{c}	0.75	0.0017
	Thigh	23.74	23.65	22.45	21.65	0.90	0.2977
	Drumstick	22.69^{a}	20.17^{b}	18.81^{c}	18.01^{c}	0.85	0.0011
Shear force (N)	Breast	33.05	33.75	33.45	33.96	1.18	0.1918
	Thigh	29.13^{c}	31.95^{bc}	32.85^{b}	34.76^{a}	0.83	<.0001
	Drumstick	25.09^{c}	26.62^{bc}	27.76^{b}	31.57^{a}	0.76	<.0001

^{abcd}Least significant means values having different superscripts in a row differ significantly at $p<0.05$. L*: Lightness, a*: Redness, b*: Yellowness

Table 9: Effect of Level of feed supplementation on genetically improved chicken meat proximate composition and meat bone ratio

		Level of feed supplementation					
Parameters	Muscle	Full feeding (100%)	75%	50%	25%	SEM	p-value
Dry matter (%)	Breast	24.75^{b}	28.12^{a}	26.20^{b}	25.63^{b}	0.65	0.0039
	Thigh	24.31	25.26	25.21	24.40	0.41	0.2132
	Drumstick	24.47	24.88	24.54	23.99	0.38	0.4235
Ash (%)	Breast	3.91	6.62	4.62	4.51	0.24	0.1218
	Thigh	5.00	4.55	4.68	5.06	0.23	0.3195
	Drumstick	4.57	4.68	4.71	5.20	0.24	0.2740
Crude protein (%)	Breast	24.63^{a}	22.29^{c}	23.20^{b}	22.72^{bc}	0.35	0.0001
	Thigh	22.26^{a}	21.16^{b}	20.86^{bc}	20.22^{c}	0.34	0.0008
	Drumstick	21.71^{a}	20.71^{b}	20.01^{b}	20.50^{b}	0.35	0.0116
Ether extract (%)	Breast	3.65	3.35	3.16	3.25	0.21	0.3745
	Thigh	4.02	3.79	3.78	3.76	0.19	0.7245
	Drumstick	3.75	3.63	3.91	3.48	0.18	0.3903

^{abcd} Least significant means values having different superscripts in a row differ significantly at $p<0.05$

lower level of supplementation scavenged more on forages to meet their daily requirements, including protein. The contents of proteins, lipids and minerals observed in the present study are within the range (18.4-23.4, 1.3-6.0 and 0.8-1.2%) recommended for good quality chicken meat[43,55]. Minh and Ogle[56] studied improved dual-purpose growing chickens and concluded that supplementation increases the nutritional values of chicken meat under the scavenging system of production.

The results from this study imply that supplementation of scavenging chickens is required to balance for missing nutrients from scavenged feeds. Consequently, balanced nutrients will improve both the yield and quality of meat. To improve meat yield and quality of dual-purpose improved chickens under a semi-intensive system of production, it is recommended that a cost-effective supplementation strategy be adopted depending on available scavengable feed resources.

CONCLUSION

The question of what diet and at what level of supplementation to be used for semi-scavenging improved dual-purpose chickens has been studied in the current study. It is concluded that commercial (D_1) and medium-cost formulated feed (D_2) gave significantly higher slaughter and carcass weight than the low-cost formulations (D_3). Hence, for semi-scavenging chickens, a higher level of supplementation influenced positively both carcass and non-carcass yields. Feeding regime affects meat colour, cooking loss, tenderness and proximate composition of genetically improved dual-purpose chicken in a joint-specific fashion. Therefore, the choice of what type of feed and levels of supplementation will depend on cost-benefit analysis and availability of scavengable feed resources.

SIGNIFICANCE STATEMENT

This study discovers the effects of the plane of nutrition of supplementary feeds on carcass and meat quality of semi-scavenging genetically improved dual-purpose chicken. The findings from this study will serve poultry keepers with options to choose from when deciding on the strategy to finish feed dual-purpose chickens such as Sasso and Kuroiler.

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REFERENCES

1. Petracci, M., M. Bianchi and C. Cavani, 2010. Pre-slaughter handling and slaughtering factors influencing poultry product quality. World's Poult. Sci. J., 66: 17-26.
2. Castellini, C., A.D. Bosco, C. Mugnai and M. Pedrazzoli, 2006. Comparison of two chicken genotypes organically reared: Oxidative stability and other qualitative traits of the meat. Ital. J. Anim. Sci., 5: 29-42.
3. Sokolowicz, Z., J. Krawczyk and S. Swiatkiewicz, 2016. Quality of poultry meat from native chicken breeds-a review. Ann. Anim. Sci., 16: 347-368.
4. Mutayoba, S.K., A.K. Katule, U. Minga, M.M. Mtambo and J.E. Olsen, 2012. The effect of supplementation on the performance of free range local chickens in Tanzania. Livestock Res. Rural Dev., Vol. 24.
5. Bamidele, O., E.B. Sonaiya, O.A. Adebambo and T. Dessie, 2019. On-station performance evaluation of improved tropically adapted chicken breeds for smallholder poultry production systems in Nigeria. Trop. Anim. Health Prod., 52: 1541-1548.
6. Jaturasitha, S., T. Srikanchai, M. Kreuzer and M. Wicke, 2008. Differences in carcass and meat characteristics between chicken indigenous to Northern Thailand (black-boned and thai native) and imported extensive breeds (bresse and rhode island red). Poult. Sci., 87: 160-169.
7. Sanka, Y.D. and S.H. Mbaga, 2014. Evaluation of Tanzanian local chicken reared under intensive and semi-intensive systems: I. Growth performance and carcass characteristics. Livest. Res. Rural Dev., Vol. 26.
8. Fanatico, A.C., P.B. Pillai, J.L. Emmert, E.E. Gbur, J.F. Meullenet and C.M. Owens, 2007. Sensory attributes of slow and fast-growing chicken genotypes raised indoors or with outdoor access. Poult. Sci., 86: 2441-2449.
9. Khan, U., J. Hussain, A. Mahmud, A. Khalique and S. Mehmood *et al.*, 2019. Comparative study on carcass traits, meat quality and taste in broiler, broiler breeder and Aseel chickens. Braz. J. Poult. Sci., Vol. 21. 10.1590/1806-9061-2018-0770.
10. Wattanachant, S., S. Benjakul and D.A. Ledward, 2004. Composition, color and texture of Thai indigenous and broiler chicken muscles. Poult. Sci., 83: 123-128.
11. Baeza, E., 2004. Measuring Quality Parameters. In: Poultry Meat Processing and Quality, Mead, G.C. (Ed.)., CRC Press, Cambridge, UK pp: 305-331.
12. Yam, K.L., E. Spyridon and E. Papadakis, 2004. A simple digital imaging methods for measuring and analyzing colour of food surfaces. J. Food Eng., 61: 137-142.
13. Rizzi, C., A. Marangon and G.M. Chiericato, 2007. Effect of genotype on slaughtering performance and meat physical and sensory characteristics of organic laying hens. Poult. Sci., 86: 128-135.
14. Petracci, M. and E. Baéza, 2011. Harmonization of methodologies for the assessment of poultry meat quality features. World's Poult. Sci. J., 67: 137-151.
15. AOAC, 2016. Official Methods of Analysis. 20th Edn., Association of Official Analytical Chemists, Washington, DC.
16. SAS, 2006. Statistical Analysis Software. The SAS system for Windows (Release 9.1). SAS Institute, Cary, NC, USA.
17. Franco, D., D. Rois, J.A. Vazquez and J.M. Lorenzo, 2012. Comparison of growth performance, carcass components and meat quality between Mos rooster (*Galician indigenous* breed) and Sasso T-44 line slaughtered at 10 months. Poult. Sci., 91: 1227-1239.
18. Youssao, A.K.I., N.M. Assogba, T.I. Alkoiret, M. Dahouda and N.D. Idrissou *et al.*, 2012. Comparison of growth performance, carcass characteristics and sensory characters of Benin indigenous chickens and Label Rouge (T55xSA51). Afr. J. Biotechnol., 11: 15569-15579.
19. Aline, K., 2015. Management systems and location effects on growth and carcass traits of Kuroiler and local chickens. MSc. Thesis, Makerere University,
20. Santé, V., X. Fernandez, G. Monin and J.P. Renou, 2001. New methods of measuring the quality of poultry meat. INRA Prod. Anim., 14: 247-254.
21. Castellini, C., C. Mugnai and A. Dal Bosco, 2002. Effect of organic production system on broiler carcass and meat quality. Meat Sci., 60: 219-225.

22. Souza, X.R., P.B. Faria and M.C. Bressan, 2011. Proximate composition and meat quality of broilers reared under different production systems. Braz. J. Poult. Sci., 13: 15-20.
23. Ristic, M. and K. Damme, 2013. Significance of pH-value for meat quality of broilers: Influence of breed lines. Veterinarski Glasnik, 67: 67-73.
24. Bianchi, M., M. Petracci and C. Cavani, 2006. The influence of genotype, market live weight, transportation and holding conditions prior to slaughter on broiler breast meat color. Poult. Sci., 85: 123-128.
25. Brewer, V.B., J.L. Emmert, J.F.C. Meullenet and C.M. Owens, 2012. Small bird programs: Effect of phase-feeding, strain, sex, and debone time on meat quality of broilers. Poult. Sci., 91: 499-504.
26. Abdullah, A.Y., M.M. Muwalla, H.O. Maharmeh, S.K. Matarneh and M.A. Abu Ishmais, 2010. Effects of strain on performace, and age at slaughter and duration of post-chilling aging on meat quality traits of broiler. Asian Australas. J. Anim. Sci., 23: 1645-1656.
27. Debut, M., C. Berri, E. Baeza, N. Sellier and C. Arnould *et al.*, 2003. Variation of chicken technological meat quality in relation to genotype and preslaughter stress conditions. Poult. Sci., 82: 1829-1838.
28. Mehaffey, J.M., S.P. Pradhan, J.F. Meullenet, J.L. Emmert, S.R. McKee and C.M. Owens, 2006. Meat quality evaluation of minimally aged broiler breast fillets from five commercial genetic strains. Poult. Sci., 85: 902-908.
29. Lonergan, S.M., N. Deeb, C.A. Fedler and S.J. Lamont, 2003. Breast meat quality and composition in unique chicken populations. Poult. Sci., 82: 1990-1994.
30. Garcia, R.G., L.W. de Freitas, A.W. Schwingel, R.M. Farias and F.R. Caldara *et al.*, 2010. Incidence and physical properties of PSE chicken meat in a commercial processing plant. Braz. J. Poult. Sci., 12: 233-237.
31. Huff-Lonergan, E. and S.M. Lonergan, 2005. Mechanisms of water-holding capacity of meat: The role of postmortem biochemical and structural changes. Meat Sci., 71: 194-204.
32. Cheng, Q. and D.W. Sun, 2008. Factors affecting the water holding capacity of red meat products: A review of recent research advances. Crit. Rev. Food Sci. Nutr., 48: 137-159.
33. Puolanne, E. and M. Halonen, 2010. Theoretical aspects of water-holding in meat. Meat Sci., 86: 151-165.
34. Wattanachant, S., 2008. Factors affecting the quality characteristics of Thai indigenous chicken meat. Suranaree J. Sci. Technol., 15: 317-322.
35. Fengli, A., X. Kang, L. Zhang, W.J. Leilei, B. Shao and J. Wang, 2013. Comparison of muscle properties and meat quality between Jing Ning chicken and Ling Nan Huang Yu meat chicken. J. Food Agric. Environ., 11: 54 -58.
36. Jacob, R., K. Rosenvold, M. North, R. Kemp, R. Warner and G. Geesink, 2012. Rapid tenderisation of lamb *M. longissimus* with very fast chilling depends on rapidly achieving sub-zero temperatures. Meat Sci., 92: 16-23.
37. Pen, S., Y.H.B. Kim, G. Luc and O.A. Young, 2012. Effect of pre rigor stretching on beef tenderness development. Meat Sci., 92: 681-686.
38. Sogunle, O.M., L.T. Egbeyale, O.A. Alajo, O.O. Adeleye and A.O. Fafiolu *et al.*, 2010. Comparison of meat composition and sensory values of two different strains of broiler chicken. Arch. Zootec., 59: 311-314.
39. Tougan U.P., M. Dahouda, C.F.A. Salifou, G.S. Ahounou and T.M. Kpodekon *et al.*, 2013. Conversion of chicken muscle to meat and factors affecting chicken meat quality: A review. Int. J. Agron. Agric. Res., 3: 1-20.
40. Mbaga, S.H., Y.D. Sanka A.M. Katule and D. Mushi, 2014. Effects of storage time on the quality of local chicken meat. Tanzania J. Agric. Sci., 13: 48-54.
41. Miah, M.Y., S.D. Chowdhury, A.K.F.H. Bhuiyan and M.S. Ali, 2014. Effect of different levels of dietary energy on growth performance of indigenous desi chicks reared in confinement up to target weight of 950g. Livest. Res. Rural Dev., Vol. 26.
42. Miah, M.Y., S.D. Chowdhury and A.K.F.H. Bhuiyan, 2016. Effect of feed supplementation of varying nutrient concentrations on growth performance and meat yield of indigenous (desi) chicken reared at rural households under tropical conditions. Livest. Res. Rural Dev., Vol. 28.
43. Cheng, F.Y., C.W. Huang, T.C. Wan, Y.T. Liu, L.C. Lin and C.Y.L. Chyr, 2008. Effects of free-range farming on carcass and meat qualities of black-feathered taiwan native chicken. Asian Australas. J. Anim. Sci., 21: 1201-1206.
44. Smith, D.P., C.E. Lyon and B.G. Lyon, 2002. The effect of age, dietary carbohydrate source and feed withdrawal on broiler breast fillet color. Poult. Sci., 81: 1584-1588.
45. Fanatico, A.C., L.C. Cavitt, P.B. Pillai, J.L. Emmert and C.M. Owens, 2005. Evaluation of slower-growing broiler genotypes grown with and without outdoor access: Meat quality. Poult. Sci., 84: 1785-1790.
46. Ponte, P.I.P., C.M.C. Rosado, J.P. Crespo, D.G. Crespo and J.L. Mourao *et al.*, 2008. Pasture intake improves the performance and meat sensory attributes of free-range broilers. Poult. Sci., 87: 71-79.
47. Ngapo, T.M., P. Berge, J. Culioli, E. Dransfield, S. De Smet and E. Claeys, 2002. Perimysial collagen crosslinking and meat tenderness in Belgian Blue double-muscled cattle. Meat Sci., 61: 91-102.
48. Purslow, P.P., 2005. Intramuscular connective tissue and its role in meat quality. Meat Sci., 70: 435-447.
49. Sanka, Y.D. and S.H. Mbaga, 2014. Evaluation of Tanzanian local chicken reared under intensive and semi-intensive systems: II. Meat quality attributes. Livestock Res. Rural Dev., 26: 78-81.
50. Hussain, M., A. Mahmud, J. Hussain and S.N. Qaisrani, 2018. Effect of dietary lysine regimens on growth performance and meat composition in aseel chicken. Braz. J. Poult. Sci., 20: 203-210.

51. Ferreira, G.D., M.F. Pinto, M.G. Neto, E.H. Ponsano, C.A. Goncalves, I.L. Bossolani and A.G. Pereira, 2015. Accurate adjustment of energy level in broiler chickens diet for controlling the performance and the lipid composition of meat. Cienc. Rural, 45: 104-110.
52. Jahanpour, H., A. Seidavi, A.A.A. Qotbi, D.H.R. Van, S.R. Silva, V. Laudadio and V. Tufarelli, 2015. Effects of the level and duration of feeding restriction on carcass components of broilers. Arch. Fuer Tierzucht, 58: 99-105.
53. Ali, M.S., G.H. Kang and S.T. Joo, 2008. A review: Influences of pre-slaughter stress on poultry meat quality. Asian-Aust. J. Anim. Sci., 21: 912-916.
54. Ponte, P.I.P., I. Mendes, M. Quaresma, M.N.M. Aguiar and J.P.C. Lemos *et al.*, 2004. Cholesterol levels and sensory characteristics of meat from broilers consuming moderate to high levels of alfalfa. Poult. Sci., 83: 810-814.
55. Culioli, J., C. Berri and J. Mourot, 2003. Muscle foods: Consumption, composition and quality. Sci. Aliments, 23: 13-34.
56. Minh, D.V. and B. Ogle, 2005. Effect of scavenging and supplementation of lysine and methionine on the feed intake, performance and carcase quality of improved dual-purpose growing chickens. Trop. Anim. Health Prod., 37: 573-587.

APPENDICES

Appendix 1: 100% feeding scheme developed for experimental birds

Weeks	Amount/Day(g)	Amount/Week(g)	Amount/Day(Kg)
W1	16	112	0.112
W2	24	168	0.168
W3	32	224	0.224
W4	40	280	0.28
W5	48	336	0.336
W6	54	378	0.378
W7	60	420	0.42
W8	66	462	0.462
W9	72	504	0.504
W10	78	546	0.546
W11	84	588	0.588
W12	90	630	0.630
W13	96	672	0.672
W14	102	714	0.714
W15	108	756	0.756
W16	114	798	0.798
W17	120	840	0.840
W18	126	882	0.882
W19	132	924	0.924
W20	140	980	0.980
TOTAL		**11214**	**11.214**

Appendix 2: 75% feeding scheme for experimental birds

Days (Weeks)	Amount/Day (g)	Amount/Week (g)	Amount/Week (Kg)

W1	16	112	0.112
W2	24	168	0.168
W3	32	224	0.224
W4	40	280	0.28
W5	48	336	0.336
W6	40.5	283.5	0.2835
W7	45	315	0.315
W8	49.5	346.5	0.3465
W9	54	378	0.378
W10	58.5	409.5	0.4095
W11	63	441	0.441
W12	67.5	472.5	0.4725
W13	72	504	0.504
W14	76.5	535.5	0.5355
W15	81	567	0.567
W16	85.5	598.5	0.5985
W17	90	630	0.63
W18	94.5	661.5	0.6615
W19	99	693	0.693
W20	105	735	0.735
TOTAL		**8690.5**	**8.6905**

Appendix 3: 50% feeding scheme for experimental birds

Days (Weeks)	Amount/Day (g)	Amount/Week (g)	Amount/Week (Kg)
W1	16	112	0.112

W2	24	168	0.168
W3	32	224	0.224
W4	40	280	0.28
W5	48	336	0.336
W6	27	189	0.189
W7	30	210	0.21
W8	33	231	0.231
W9	36	252	0.252
W10	39	273	0.273
W11	42	294	0.294
W12	45	315	0.315
W13	48	336	0.336
W14	51	357	0.357
W15	54	378	0.378
W16	57	399	0.399
W17	60	420	0.42
W18	63	441	0.441
W19	66	462	0.462
W20	70	490	0.49
TOTAL		**6167**	**6.167**

Appendix 4: 25% feeding scheme for experimental birds

Days (Weeks)	Amount/Day (g)	Amount/Week (g)	Amount/Week (Kg)
W1	16	112	0.112

W2	24	168	0.168
W3	32	224	0.224
W4	40	280	0.28
W5	48	336	0.336
W6	13.5	94.5	0.0945
W7	15	105	0.105
W8	16.5	115.5	0.1155
W9	18	126	0.126
W10	19.5	136.5	0.1365
W11	21	147	0.147
W12	22.5	157.5	0.1575
W13	24	168	0.168
W14	25.5	178.5	0.1785
W15	27	189	0.189
W16	28.5	199.5	0.1995
W17	30	210	0.21
W18	31.5	220.5	0.2205
W19	33	231	0.231
W20	35	245	0.245
TOTAL		**3643.5**	**3.6435**