COMPARATIVE PERFORMANCE OF TWO IMPROVED CHICKEN BREEDS REARED UNDER DIFFERENT AGRO-ECOLOGIES AND MANAGEMENT SYSTEMS IN TANZANIA

FADHILI SAID GUNI

A THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2021

EXTENDED ABSTRACT

In recent decades the demand for poultry and livestock products has increased significantly. Likewise, poultry rearing has been adopted as a tool for poverty alleviation and has led some development agencies to promote the intensification of improved poultry systems. Two genetically improved chicken breeds (Sasso and Kuroiler) have been introduced in Tanzania as a way of improving the productivity of the poultry industry and improve people's livelihoods. Performance of any breed is a function of both genotype and the environment in which the birds are raised. This means that breeds that perform better in one environment may not necessarily perform better in another environment. It is for this reason that Kuroiler and Sasso chickens were evaluated to establish their suitability under different agro-ecologies and management systems in Tanzania. The selected agro-ecologies in the current study were the highland and lowland areas of Mvomero district in Morogoro region, Eastern Tanzania. The two agro-ecologies were purposively selected based on their differences in temperature, altitude, vegetation type, and farming systems. Alongside, two varied management conditions i.e. on-station (controlled management) and on-farm (farmer management) conditions were also considered for performance evaluation of these breeds. The on-station study was conducted at Sokoine University of Agriculture in Morogoro region. The study was conducted to evaluate the effects of management, breeds and interaction on growth performance, egg production, egg quality and survivability.

A total of 1800 day old chicks comprised of 900 Sasso and 900 Kuroiler were procured from Silverlands Tanzania in Iringa region and AKM Glitters company in Dar es Salaam region respectively. The chicks were brooded for six weeks at the Poultry farm of Sokoine University of Agriculture (SUA). Sexing of the chicks was done at end of the 6^{th} week.

The birds of each breed were divided into two groups, one for on-station and the other one for on-farm evaluation.

The sampling frame under farmer management (on-farm) in the two agro-ecological zones consisted of two villages per zone, 16 farmers per village and 18 birds per farmer; thus making a total of 64 farmers and 1152 birds. The farmers involved in the study were randomly selected from the list of farmers that had more than ten chickens and had been keeping chickens for at least five years. Birds were raised under a semi-scavenging system and supplemented with kitchen leftovers, maize bran, and other crop by-products in addition to scavenged feeds. For on-station study, birds were raised in six replicates per breed of 40 birds each, thus making a total of 12 pens and 480 birds. They were raised in deep litter pens and fed a commercial ration.

Production traits that were evaluated and compared under both environments include growth, egg production, egg quality and survivability. The growth performance traits were body weight at 6, 8, 12, 16 and 20 weeks of age, total weight gain (TWG) and average daily gain (ADG). The traits considered for egg production were age at first egg, age at peak egg production, hen-housed egg production (HHEP), hen-day egg production (HDEP) and egg production rate. On the other hand, the quality of eggs was evaluated for eggs from both on-farm and on-station management and they involved both external traits (egg weight, length, width, shape index, shell weight, shell thickness and shell ratio) and internal traits (yolk weight, albumen weight, yolk ratio, albumen ratio, albumen height and Haugh unit). Mortalities were recorded during the growing and laying periods in both environments. Additional data for the on-station study were feed conversion ratio (FCR) and carcass traits. Evaluation of the carcass traits involved slaughtering of male chickens of the two breeds at the 16^{th} week of age. The traits measured were body weight at

slaughter (BWS), carcass weight (CW) and carcass parts yield including breast, thighs, drumsticks, wings, back and neck. Data were subjected to analysis of variance using the General Linear Models (GLM) procedure of SAS software (SAS 2009), while mortality data were analyzed in accordance to frequency procedure of SAS software (SAS 2009) using a chi-square ($\chi 2$) test.

Results show that agro-ecological zones differed significantly ($p<0.05$) with respect to growth performance and survivability. Birds raised in the highland zone were heavier (2021.7 g) than those raised in the lowland areas (1873.6 g). Similarly, birds raised in the highland zone had lower mortality rates than lowland zone during growing (12.7% vs 20.3%) and laying (34.6% vs 47.1%) periods. Significant interaction ($p<0.05$) between agro-ecology and breed was observed on body weight and age at sexual maturity. In the highland zone, Sasso chickens were heavier and attained sexual maturity earlier than Kuroiler while in lowland areas the performance of Kuroiler was higher than that of Sasso.

With regard to management systems, the results show that management systems influenced significantly ($p<0.05$) all growth traits, egg production traits and survivability of chickens in favour of on-station birds. The final body weight and total egg yield (HDEP) under the on-station were 2510.9 g and 108.3 eggs, while for on-farm were 1870.5 g and 50.5 eggs in respective order. Mortality for on-station birds was lower than on-farm birds during growing (10.6% vs 22.1%) and laying (47.1%) 17.0%) periods. The results further showed that the mean values of egg weight, length, width, shape index, shell weight, shell thickness, yolk weight, albumen weight, albumen height and Haugh unit were also higher for on-station than on-farm while shell, yolk and albumen ratios were similar between the two management systems. Interactions between management

and breed were significant ($p<0.05$) on body weight, egg weight, shell ratio and all egg production traits except peak egg production rate and mortality rate. While Sasso performance was better than that of Kuroiler on body weight and age at first egg under the on-station management system, Kuroiler was better than Sasso on those traits under the on-farm condition.

For feed conversion ratio (FCR) and carcass traits, results showed that both FCR and carcass traits were influenced by breed. The FCR of Sasso was lower than that of Kuroiler. Carcass weight, dressing percentage and weight of different carcass parts were higher for Sasso than Kuroiler. Furthermore, correlations between carcass weight and carcass parts were high and positive.

Based on the results of these studies, the following conclusions can be made:-

i. The performance traits of the two breeds are dependent on agro-ecological zone and management systems. The chickens' performance in the highland zone appeared to be better than in the lowland in terms of growth and survivability. Similarly, on-station birds performed better than on-farm in growth performance, egg production and survival rate.

ii. The response of each breed differed in some traits when subjected to different environments. Kuroiler maintained its bodyweight regardless of agro-ecology, but it matured earlier and had a lower mortality rate than Sasso in lowland areas whereas Sasso appeared better in highland than in lowland areas in growth performance, survival rate and age at sexual maturity.

DECLARATION

I, Fadhili Said Guni, do hereby declare to the Senate of Sokoine University of Agriculture that this thesis is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

_____ _____

Fadhili Said Guni Date

(PhD Candidate)

The above declaration is confirmed by:

_____ _____

Prof. Said H. Mbaga Date

(Supervisor)

_____ _____

Prof. Andalwisye M. Katule Date

(Supervisor)

COPYRIGHT

ACKNOWLEDGEMENTS

First and foremost, I would like to thank Almighty Allah, the creator of the heavens and the earth and all that is between them, for giving me the strength and courage to go through all this work.

I would like to acknowledge and express my sincere appreciation to the African Chicken Genetic Gains Project (ACGG) in Tanzania for funding my studies. Special thanks also go to Dr. Goromela, E.H for allowing me to be one of the candidates under the ACGG of which he was a Project Leader in Tanzania.

I would like to express how grateful I am to my supervisors, Prof. Mbaga, S.H and Prof. Katule, A.M. for their remarkable role in giving constructive comments from the start of research work and guiding me throughout the study period. Their insightful comments and suggestions for the betterment of the whole work are appreciable. They were always available for me concerning this research work and beyond. My work would not be succeeded without their guidance and support. I pray and hope that Allah will reward them abundantly.

I also appreciate the useful comments and advice from my colleagues and members of academic staff in the Department of Animal, Aquaculture and Range Sciences (DAARS) particularly during seminar presentations that greatly improved this research work.

My father, Mr. Guni T. M and my sisters Aisha and Salma as well as my young brother Chongoe, have also been a great source of encouragement to me for which I would like to acknowledge. Thanks to Dr. Nguluma, A.S who have always been there for me in times of need. Finally, my deep appreciation goes to my lovely wife and our children for their great patience and understanding during the time I was away from home.

DEDICATIONS

This work is dedicated to my lovely wife (Grace); our daughters (Neema and Rehema); our sons (Baraka and Amani); my parents, my father Mr. Guni T. Mohamed and my mother, the late Mwajuma B. Sulle. All this is for you.

TABLE OF CONTENTS

LIST OF TABLES

TABLES IN PAPER I

TABLES IN PAPER II

TABLES IN PAPER III

TABLES IN PAPER IV

LIST OF ABBREVIATIONS

ACGG	African Chicken Genetic Gains
ADG	Average Daily Gain
AEZ	Agro-ecological zones
BFAP	Bureau of Food and Agricultural Policy
BPR	Barred Plymouth Rock
BW	Body weight
BWS	Body Weight at Slaughter
Ca	Calcium
CP	Crude Protein
CW	Carcass Weight
DP	Dressing Percentage
FAO	Food and Agriculture Organization of the United Nations
FCR	Feed Conversion Ratio
g	Gram
GLM	General Linear Model
HDEP	Hen-Day Egg Production
HHEP	Hen-Housed Egg Production
HU	Haugh Unit
ILRI	International Livestock Research Institute
Kcal	Kilocalories
Kg	Kilogram
Km	Kilometer
LSM	Least Square Mean
MANOVA	Multivariate Analysis of Variance
ME	Metabolizable Energy
MLFD	Ministry of Livestock and Fisheries Development
RIR	Rhode Island Red
SAS	Statistical Analysis System
SEM	Standard Error of the Mean
SUA	Sokoine University of Agriculture
TLMI	Tanzania Livestock Modernization Initiative
TLMP	Tanzania Livestock Master Plan
TWG	Total Weight Gain

CHAPTER ONE

1.0 GENERAL INTRODUCTION

1.1 Poultry Industry and its Importance

Poultry production is one of the key livestock subsectors in Tanzania as it plays important role in terms of generating employment opportunities, improving family nutrition, and empowering women. It is a suitable business for poor households due to the small area of the land needed and the low investment required to start up and run the operation. The role of poultry in poverty alleviation, food security and the promotion of gender equality in developing countries is well documented (Gueye, 2000). Poultry production represents an appropriate farming system that contributes to feeding the fast-growing human populations and providing income to poor small farmers (Gujit, 1994; Alders, 1996; Kitalyi and Mayer, 1998). Its products can be sold or bartered to meet essential family needs such as medicine, clothes and school fees. Several studies show that, among all the domesticated bird species, chicken is the largest constituent of the poultry population. Globally, more than 300 breeds of the domestic chicken species (*Gallus domesticus*) exist and are categorized into three main groups, namely pure commercial breeds, hybrids resulting from cross-breeding and indigenous/local breeds (Fulas *et al*., 2018). Among the three groups, indigenous chickens are predominant in most developing countries. It has been estimated that 80% of the poultry population in Africa are found in traditional scavenging systems (Dessalew, 2012), which makes substantial contributions to household food security.

1.2 Poultry Production Systems

In Tanzania, poultry production is categorized into three major production systems which are; commercially specialized, improved and traditional chicken production systems

(Da Silva *et al.,* 2017). The commercial specialized chicken system is an intensive system dealing with specialized breeds for egg production (layers) and meat production (broilers). This system is characterized by a higher level of productivity where poultry production is entirely market-oriented to meet the large poultry demand in major cities. According to BFAP and SUA (2018), the system contributes up to 80% of poultry meat and eggs consumed in urban areas and it requires reliable access to inputs, including commercial stock, feed, labour, health services as well as efficient marketing channels.

On the other hand, the improved family chicken sub-system is largely comprised of improved local of various crosses of chicken types or imported dual-purpose breeds raised under a semi-intensive/semi-scavenging system. In this system, birds are confined to a certain part with access to housing. This system is characterized by a medium level of feed, water and veterinary service inputs, and minimal to low bio-security and has moderate productivity i.e. an average of 150 eggs/year and 1.8 kg live weight bird at maturity (Da Silva *et al.,* 2017). Both commercial and improved family chicken systems are commonly found in urban and peri-urban areas.

The traditional/scavenging system is dominated by indigenous chickens, which are not classified into specific breeds, but they contribute to production of almost 100% and 20% of eggs consumed in rural and urban areas respectively (MLDF, 2011). This system is more common in rural areas and is an integral component of the livelihoods of most rural households. It can best be described as a low input-low output system, and in most cases, chickens are left to scavenge for their own feeds and water within a mixed farming system. Despite the indigenous chicken being dominant, several reports have shown that they have low production potential for growth and egg production. Egg production for most of these local chickens is around 40-60 eggs per hen per year while the average

mature body weight is 1500 g (Boki, 2000; Ringo and Mwenda, 2018). The low production may be attributed both to their inherent low genetic potential and the poor management under which they are kept.

1.3 Efforts to Improve Productivity

Globally, the demand for the animal source foods has grown exponentially, particularly in developing countries due to urbanization, income and population growth (FAO, 2002; FAO, 2010). In Tanzania, like in many other African countries, attempts have been made to increase chicken output (meat and eggs) through importations of high producing exotic breeds particularly in the commercial sector and through cross-breeding of indigenous chicken populations with exotic breeds (Olwande *et al.*, 2010). These efforts are yet to produce the expected outputs compared to high-producing exotic chicken lines which have been developed for high-input intensive production systems in temperate regions (Permin, 2008). Most of the genetic improvement programs of local chickens through cross-breeding or repeated back-crossing have not been successful in most developing countries owing to difficulties in retaining a separate population of parent birds, especially in rural settings (FAO, 2010). It appears that the survival of improved male birds retained for back-crossing was threatened by a lack of adaptation to the harsh production environment (i.e. in terms of climate, diseases and feed availability) and low complementary socio-economic. Such a harsh environment raised doubts about the sustainability of crossbreeding in some regions or for some breeding systems as most of the imported high yielding chickens didn't perform better in tropical countries. It has been argued by FAO (2010) that, when producing these poultry stocks for developing countries, large global breeding companies tend to promote the strains that are used in developed countries claiming that these strains are suitable for all environments. However, most of these strains have been selected for increased productivity under

relatively good management and nutrition conditions, generally without significant temperature stress; an environment that could be hardly met under tropical conditions.

1.4 Tropically Adaptable Chicken Breeds

The introduction of productive, yet tropically adapted chicken strains to increase meat yield and egg number is in agreement with Tanzania Livestock Modernization Initiative (TLMI) (MLFD, 2015), which among other key priority actions in poultry modernization is to research and select tropically adaptable semi-scavenging dual-purpose chicken breeds and introducing them into the family chicken production system (Da Silva *et al.,* 2017). Sasso and Kuroiler are among such breeds which are deemed to perform better in some countries including Ethiopia (Kidie, 2019; Biazen *et al.,* 2021), Nigeria (Bamidele *et al.,* 2019) and Uganda (Sharma *et al.,* 2011). Kuroiler is a dual-purpose breed, developed under humid conditions by Keggfarms in India to perform in low maintenance systems (Lozano-Jaramillo *et al*., 2019). The breed has been developed through crossing several pure genetic lines of chickens including White Leghorn, Rhode Island Red, Coloured broiler, and local Desi chickens, followed by selection for high production performance and ability to thrive in village environment under scavenging or semi-scavenging rearing systems (Sharma *et al*., 2015). On the other hand, Sasso is a commercial breed originating from warm and dry areas in Southern France where it was developed by the SASSO breeding company (Getachew *et al*., 2016; Lozano-Jaramillo *et al*., 2019). It has been developed through an intensive selection of traditional coloured lines of chickens from France (Sasso, 2014). The two breeds are known for many desirable features of indigenous birds, such as feather colours for camouflage, ability to escape from predators, resistance to diseases, adaptable to tropical and sub-tropical conditions (Ahuja *et al*., 2008; Mengsite *et al*., 2019). They also can scavenge, thus require low supplementation for maintenance yet grow about double the bodyweight of

their indigenous counterparts (Sharma, 2011), provided that they are protected against diseases. A mature Kuroiler bird weighs about 2.6 kg, and a hen can produce about 150-200 eggs per hen per year (Ahuja *et al*., 2008) while a mature Sasso bird weighs about 2.73-2.98 kg and can produce an average of 229 eggs per hen per year (Getiso *et al.*, 2017).

1.5 Problem Statement and Justification

Sasso and Kuroiler chickens have been recently introduced in Tanzania to support poverty reduction, productivity growth and increased household animal protein intake (Ringo and Mwenda, 2018). Sasso has been introduced in the country by Silverlands Tanzania Company located in Iringa, while Kuroiler has been introduced by African Chicken Genetic Gains project-Tanzania and two more companies; Nzua-Msigani Farms and AKM Glitters based in Dar es Salaam. The two breeds are now being popularized in the country and are distributed to farmers by poultry multiplication agencies in Tanzania. Though these breeds have been tested elsewhere in Africa, there is scientific and documented evidence of differences in the performance of different breeds in different environments and management conditions (Kemp *et al*., 2005; Berhe and Gous, 2008). An animal of good genetic potential may perform poorly when the production environment is not favourable due to the negative interaction between the animal's genes and its environment. This is because management practices may vary as a result of different production environments and constantly changing climatic conditions leading to variability in animal performance. Given the different agro-ecological conditions as well as different management systems of rearing chickens in Tanzania it is imperative to test the performance of these two breeds under the varying environmental conditions to ascertain their suitability. Agro-ecological zone as defined by rainfall, temperature, vegetation type, soil type and topography was found to be a significant source of variation

in growth and egg production performance in some studies (Assefa *et al*., 2018; Mulugeta *et al*., 2020). Similarly, the management condition as defined by level of nutrition, health care and housing also influenced the variation in animal performance (Bekele *et al*., 2009; Ali *et al*., 2010).

It is critical, then, to be aware of any interaction that affects performance and to develop an efficient strategy of genetic management accordingly. Therefore, the objective of this study was to evaluate the performance of the two breeds under different agro-ecologies and management systems to establish breed suitability under varying conditions and recommend the most suitable breed for a particular environment. Moreover, results from this study will assist in providing inputs in the designing of appropriate breeding programs for the improvement of chickens.

1.6 Objectives

1.6.1 Overall objective

To evaluate and compare the production performance of Kuroiler and Sasso chicken breeds under different agro-ecologies and management systems to establish breed suitability under varying conditions in Tanzania.

1.6.2 Specific objectives

i. To determine the effects of agro-ecological zones on growth performance, egg production and survival traits of Kuroiler and Sasso chickens.
ii. To determine the effects of management systems on growth performance, egg production and survival traits of Kuroiler and Sasso chickens.
iii. To evaluate the effects of management system on external and internal egg quality traits of Kuroiler and Sasso chickens.

iv. To evaluate the effects of breed on carcass and parts yields of Kuroiler and Sasso chickens.

1.7 Hypothesis

In this study, the following hypotheses were tested:

Hypothesis I: The two breeds would perform equally under different agro-ecological conditions

Hypothesis II: There is no significant difference between management systems on the performance of the two breeds.

Hypothesis III: Breed performance is not influenced by Genotype x Environment

1.8 Organisation of the Thesis

This thesis has been developed in published paper format according to Sokoine University of Agriculture. The thesis has six chapters; chapter 1 includes the general introduction which describes the importance and contribution of the livestock sector and poultry in particular to global protein consumption. The chapter also explains the poultry production in Tanzania and previous efforts which have been done to improve productivity in the country and their challenges. In addition, the chapter present the problem statement and justification, the overall objective and specific objectives and hypothesis. Chapter 2, 3, 4 and 5 includes the results of objectives I, II, III and IV presented in a published paper format i.e., Paper I, II, III and IV, respectively. Chapter 6 includes the general discussion of the overall study findings and conclusion, as well as the recommendations.

REFERENCES

Ahuja, V., Dhawan, M., Punjabi, M. and Maarse, L. (2008). PoultryBased Livelihoods of Rural Poor: Cast of Kuroiler in West Bengal. Research Report Document 012. South Asia Pro-Poor Livestock Policy Programme. [http: //www. drcsc.org/VET/ library/Animal/Bk– Poultry _Based _Livelihoods.pdf]. Site visited on 4/8/2018.

Alders, R. (1996). Facilitating women's participation in village poultry projects: experiences in Mozambique and Zambia. Proceedings of the 20th World's Poultry Congress, New Delhi, India, III: 441-447.

Alders, R., Cambaza, A.B. and Harun, M. (2003). Village chickens, food security and HIV/AIDS mitigation. Australia. AusAID Southern Africa Newcastle Disease Control Project, Maputo. 21pp.

Ali, K.O., Katule, A.M. and Syrstad, O. (2000). Genotype X Environment interaction for growing chickens: Comparison of four genetic groups on two rearing systems under tropical condition, Acta Agriculturae Scandinavica, *Section A-Animal Sciences* 50(2): 65 – 71.

Assefa, S., Melesse, A. and Banerjee, S. (2018). Egg production and linear body measurement traits of local and three exotic chicken genotypes reared under two agroecological zones. *International Journal of Ecology and Eco solution* 5(2): 18 – 23.

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* 52: 1541-1548.

Bekele, F., Gjøen, H.M., Kathle, J., Ådnøy, T. and Abebe, G. (2009). Genotype X environment interaction in two breeds of chickens kept under two management systems in Southern Ethiopia. *Tropical Animal Health and Production* 41: 1101–1114.

Berhe, E.T. and Gous, R.M. (2008). Effect of dietary protein content on growth, uniformity and mortality of two commercial broiler strains. *South African Journal of Animal Science* 38: 293-302.

BFAP and SUA. (2018). Structure and profitability of poultry value chains in Tanzania.

Biazen, A., Mengistu, U., Negassi, A., Getenet, A., Solomon, A. and Tadelle, D. (2021). Comparative Growth Performance, Carcass Characteristics and Meat Quality of Local Horro and Exotic Cockerels of Tropical Origin Fed Growers Diet. *Open Journal of Animal Sciences* 11: 62 - 83.

Boki, K.J. (2000). Poultry industry in Tanzania – with emphasis on small-scale rural poultry. In Possibilities for smallholder poultry projects in Eastern and Southern Africa. Proceedings of a workshop held on May 22–25, 2000 at Morogoro, Tanzania. pp. 15–22.

Da Silva, M., Desta, S. and Stapleton, J. (2017). Development of the chicken sector in the Tanzanian Livestock Master Plan. [https://core.ac.uk/download/ pdf/132697821. pdf]. Site visited on 14/4/2018.

Dessalew, T. (2012). Management practices, productive performances and egg quality traits of exotic chickens under village production system. MSc. Thesis, Addis Ababa University College of veterinary medicine and agriculture, Bishoftu, in east shewa, Ethiopia. pp. 1-2.

FAO (2002). Livestock a major threat to the environment. Remedies urgently needed. [http://www.fao.org/newsroom/en/news/2006/1000448/index.html]. Site visited on 2/10/2018.

FAO (2010). Poultry genetics and breeding in developing countries: Genetic approaches to improved performance in sub-optimal conditions. By R. Pym. FAO Poultry Development Review 67pp.

Fulas, H., Yohannis, H., Yobsan, T. and Abirham, K. (2018). Review on Challenges and Opportunities of Poultry Breeds. *Dairy and Veterinary Science Journal* 7(2): 555 – 706.

Getachew, F., Wondmeneh, E. and Dessie, T. (2016). Preliminary information on chicken strains to be tested in Ethiopia. Brief 2. March 2016. Box 30709, Nairobi 00100 Kenya. Box 5689, Addis Ababa, Ethiopia 3pp.

Getiso, A., Jimma, A., Asrat, M., Kebede, H.G., Zeleke, B. 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.

Guèye, E.F. (2000). The role of family poultry in poverty alleviation, food security and the promotion of gender equality in rural Africa. *Outlook on Agriculture* 29(2): 129 - 136.

Gujit, I. (1994). Making a difference: integrating gender analysis into PRA Training. Rapid Rural Appraisal Notes No. 19, Special Issue on Training, Sustainable Agriculture Programme, International Institute for Environment and Development. February 1994. pp. 49 – 55.

Kemp, C., Fisher, C. and Kenny, M. (2005). Genotype-nutrition interactions in broilers response to balanced protein in two commercial strains. Proceedings of the 15th European Symposium on Poultry Nutrition, Sept. 25-29, Balatonfured, Hungary. pp. 54 – 56.

Kidie, H.A. (2019). Characterization of chicken production system and on-farm evaluation of introduced exotic chicken breeds in Gondar Zuria and Kalu districts of Amhara region, Ethiopia. MSc. Thesis. Haramaya University, Haramaya, Ethiopia. 93pp.

Kitalyi, A.J. and Mayer, A. (1998). Village chicken production systems in rural Africa household food security and gender issues. The Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. 78pp.

Lozano-Jaramillo, M., Alemu, S. W., Dessie, T., Komen, H. and Bastiaansen, J. W. M. (2019). Using phenotypic distribution models to predict livestock performance. Scientific Reports 9: 15371.

Mengsite, F.W., Yitbarek, M.B. and Getachew, E. (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.

Ministry of Livestock and Fisheries Development (MLFD) (2011). Livestock Sector Development Programme [http://www.mifugo.go.tz/documentsstorage/ Livestock %20Programe.pdf]. Site visited on 2/11/2017.

Ministry of Livestock and Fisheries Development (MLFD) (2015). Tanzania livestock modernization initiative. [https://hdl.handle.net/10568/67749]. Site visited 20/2/2018.

Mulugeta, S., Goshu, G. and Esatu, W. (2020). Growth performance of DZ-white and Improved Horro chicken breeds under different agro-ecological zones of Ethiopia. *Journal of Livestock Science* 11: 45 – 53.

Olwande, P. O., Ogara, W. O., Okuthe, S. O., Muchemi, G., Okoth, E., Odindo, M. O. and Adhiambo, R. F. (2010). Assessing the productivity of indigenous chickens in an extensive management system in southern Nyanza, Kenya. *Tropical Animal Health and Production* 42: 283 – 288.

Permin, A. (2008). Good practices in small scale poultry production: A manual for trainers and producers in East Africa. A Consultancy Report to FAO, FAO ECTAD Regional Unit Eastern Africa, Nairobi, Addis Ababa, Ethiopia. 99pp.

Ringo, E. J. and Mwenda, V. (2018). Poultry subsector in Tanzania: A quick scan. Embassy of the Kingdom of the Netherlands. Dar es Salaam, Tanzania. 31pp.

SAS (2009). Statistical Analytical System. User Guide for Personal Computers, Statistical Programme. Windows Version 9.2, SAS Institute Inc. Cary, NC, USA.

SASSO (2014). Coloured chicken genetics. [http://www.sasso.fr/colouredchicken-genetics-for-organic-red-label-farmer-chickens.html]. Site visited on 12/11/2017.

Sharma, J. (2011). A new breed: Highly productive chickens help raise Ugandans from poverty researcher at the Center for Infectious Diseases and Vaccinology at ASU's Bio-design Institute. [https://asunews.asu.edu/node/21034]. Site visited on 12/11/2017.

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.

CHAPTER TWO

PAPER I

Performance evaluation of Kuroiler and Sasso chicken breeds reared under farmer management conditions in highland and lowland areas of Mvomero district, Eastern Tanzania.

Published in: Tropical Animal Health and Production (2021) 53:245

Available online at **https://doi.org/10.1007/s11250-021-02693-4**

Tropical Animal Health and Production (2021) 53:245
https://doi.org/10.1007/s11250-021-02693-4

REGULAR ARTICLES

Performance evaluation of Kuroiler and Sasso chicken breeds reared under farmer management conditions in highland and lowland areas of Mvomero district, Eastern Tanzania

F. S. Guni[1] · S. H. Mbaga[2] · A. M. Katule[2] · E. H. Goromela[3]

Received: 18 October 2020 / Accepted: 29 March 2021

Abstract
One thousand one hundred and fifty-two dual-purpose improved chickens (576 Kuroiler and 576 Sasso) of mixed sexes were reared in two diverse agro-ecological zones, i.e., highland and lowland in Mvomero district, Eastern Tanzania, to determine the effects of agro-ecological zones on growth performance, egg production, and survivability under farmer management conditions. Two villages per zone were purposively selected, and from each village, 16 farmers were included in the study; a particular farmer received 18 birds of mixed sexes of the same breed. Data on body weight, egg production trait, and mortality were taken at different ages from week 6 up to 52. General Linear Models fitting breed, agro-ecological zone, and interactions between breed and zone were used to analyze the data. Results show that breed had no significant effects on body weight and body weight gain. However, the effects of the agro-ecological zone and interaction between breed and zone on body weight and body weight gain were significant at the 16th and 20th week of age. The highland zone had heavier chickens than the lowland. While Sasso performed better than Kuroiler chickens in the highland zone, the opposite was observed in the lowland. Significant breed × agro-ecology interactions were observed only for age at first egg whereby Sasso matured earlier than Kuroiler in the highland zone but much later than Kuroiler in the lowland. Birds raised in the highland zone survived better than those chickens in the lowland during both growing and laying periods. Thus, knowledge of breed performance in relation to agro-ecological differences is critical when distributing improved chicken breeds to farmers.

Keywords Agro-ecology · Kuroiler chickens · Sasso chickens · Body weight · Egg production · Mortality

Introduction

Chicken production systems in Tanzania have been categorized into a traditional indigenous, improved family chicken, and commercial specialized chicken systems (Da Silva et al. 2017). The traditional system of poultry keeping is predominant and accounts for 96% of households which supplies 94% of poultry meat and eggs in rural areas (MLFD 2015). However, the traditional system is unable to meet the increasing demand for poultry meat and eggs owing to its low productivity in terms of both egg and meat production. An indigenous hen produces less than 50 eggs per year and has an average mature weight of 1.5 kg (Da Silva et al. 2017).

In Tanzania, like in many other African countries, attempts have been made to increase chicken output (meat and eggs) through importations of high producing exotic breeds particularly in the commercial sector and through crossbreeding of indigenous chicken populations with exotic breeds (Olwande et al. 2010). These efforts are yet to produce the expected output compared to high-producing exotic chicken lines which have been developed for high-input intensive production systems in temperate regions (Permin 2008). Alternatively, Da Silva et al. (2017) proposed identification, selection, and introduction of tropically adaptable semi-scavenging dual-purpose chicken breeds suitable for a family chicken production system as one of the key strategies to improve chicken productivity in the country. Currently,

✉ F. S. Guni
fadhili.guni@yahoo.com

[1] Tanzania Livestock Research Institute, Uyole, P.O. Box 6191, Mbeya, Tanzania

[2] Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture, P. O. Box 3004, Morogoro, Tanzania

[3] Tanzania Livestock Research Institute, Naliendele, P. O. Box 1425, Mtwara, Tanzania

Published online: 05 April 2021

efforts are being made to introduce those dual-purpose breeds which have a relatively higher genetic potential for growth and egg production and yet can survive under rural scavenging environment. One such breed is the Kuroiler, originating from India. According to Roysfarm (2018), the Kuroiler breed was developed by crossing several pure genetic lines of chickens including White Leghorn, Rhode Island Red, colored broiler, and local Desi chickens, followed by selection for high production performance and ability to thrive in village environment under scavenging or semi-scavenging rearing systems (Sharma 2015). The other breed is Sasso originating from France. It was developed for scavenging rearing systems through an intensive selection of traditional colored lines of chickens (Sasso 2014). The two breeds are now getting popularity in Tanzania and are known for more meat and egg production performance under rural scavenging or semi-scavenging rearing systems compared to the local chickens (Sharma 2011; Getiso et al. 2017).

Given the vast land expanse of Tanzania, coupled with the existence of diverse climatic and ecological zones, it is logical to test the performance of the two genotypes under the varying environmental conditions before recommending them for wider multiplication. Therefore, the objective of this study was to evaluate the performance of the two breeds under farmer management conditions in two diverse agro-ecological zones to establish breed suitability or otherwise, of each breed for a particular environment. Moreover, results from this study will assist in providing inputs in the designing of appropriate breeding and management programs for the improvement of chickens raised by rural households.

Materials and methods

Description of the study areas

This study was conducted in Mvomero district, Eastern Tanzania for a period of 52 weeks form December 2018 to December 2019. The district is located between latitudes 5–8° S and longitudes 37–39° E and lies on the foothills of Nguru Mountains to the north-west and the Uluguru Mountains to the south-east. The district is characterized by a bimodal rainfall pattern with long rains between March and May; the short rains are between November and January with a relatively short dry spell between June and September (Rumisha et al. 2019). This district is also dominated by various topography and ecological zones with different climatic conditions. Two diverse wards within the district, i.e., Nyandira and Dakawa, each representing highland and lowland zone respectively, were selected for the study. The selection of the study areas was based on their differences in temperature, altitude, vegetation type, and farming systems.

Nyandira ward (highland zone) is located about 60 km south-west of Morogoro municipality on the western slopes of the Uluguru Mountains in Tanzania. It lies between 1550 and 1750 m above sea level. The weather is fairly cool with temperatures ranging between 11 and 23 °C and an annual rainfall of about 1400 mm (Eik et al. 2008). The topography of this area is mountainous, with hills and valleys following the contours of two main rivers that provide a year-round source of water. The area is densely populated with smallholder farmers, 84% of whom practice both crop farming and livestock husbandry (Sonola 2015). The arable land on the hillsides is intensively cultivated with crops such as maize, beans, pigeon peas, vegetables, and fruits.

On the other hand, Dakawa ward (lowland zone) is located about 45 km north of Morogoro municipality along the main road to Dodoma, central Tanzania. The area lies between 293 and 379 m above sea level. Annual rainfall ranges between 580 mm and 1191 mm. The weather is slightly warm and dry; the mean maximum temperature is 31 °C whereas the mean minimum temperature is 19 °C. The major farming systems include maize-rice and agro-pastoralism (Mbaga et al. 2017)

Experimental design and sampling procedure

The experiment was arranged in a 2 × 2 factorial design involving two breeds (Kuroiler and Sasso) and two zones (highland and lowland). Selection of villages and households participating in the study was done in collaboration with District and Ward livestock officers. In each zone, two villages were purposively selected, and from each village, 16 farmers were involved in the study, i.e., 2 × 2 × 16 = 64 households. For each of the 16 farmers in a village, eight received Sasso, and the remaining eight received Kuroiler chickens, each with 18 birds of mixed sexes. Participating households were randomly selected from a list of farmers that had been keeping more than ten chickens for at least 5 years. Criteria for a household to be included in the study were based on willingness to participate in the research project and the ability to provide all necessary management for chickens including housing, supplementary feeding, health care, etc. Each participating farmer in the village was randomly allocated with one of the test breeds of chickens.

Management of experimental birds during brooding

A total of 1800 days old chicks, 900 of each breed were procured from Silverlands (Sasso) and AKM Glitters (Kuroiler) companies. Brooding of chicks was done from day-old up to 6 weeks of age at Poultry farm, Sokoine University of Agriculture (SUA), Morogoro. Upon arrival, chicks were wing tagged for identification. Commercial starter crumbles (2941 Kcal ME/kg, 21.2% CP) were fed *ad libitum* for the first 2 weeks of brooding. Thereafter, chick mash

(3049 Kcal ME/kg, 20.3% CP) was provided based on breeder's recommendations up to the 6th week of age. Water was provided *ad libitum* throughout the brooding period. Chicks were vaccinated against Newcastle, Gumboro, and Fowlpox following veterinary vaccination schedules. Medication was provided depending on the occurrence of specific disease symptoms. Sexing was done at the 6th week of age, and thereafter, birds were transferred to farmers for on-farm evaluations.

On-farm management of the birds

Upon arrival in the field, birds were firstly weighed individually to obtain the initial body weight. To mimic smallholder farmers' practices in rural areas, a semi-intensive system of management was adopted. A farmer was responsible for providing water and supplementary feeds to the birds depending on what was at his/her disposal. Kitchen leftovers, maize bran, and other crop by-products were the main feeds used to supplement the birds. Training on proper management of the birds and data recording was provided to participating farmers and four livestock field officers, two for each zone. Apart from data recording, field officers were also responsible for supervising and advising farmers on all management aspects of the birds under field conditions.

Data collection

Data on growth, egg production, and mortality were recorded at different ages, starting from the 6th to 20th week of age for males, while for female records were extended up to 52 weeks to capture egg production data. The following parameters were recorded/calculated.

1. Body weight (BW) at different ages; birds were weighed individually using a digital weighing scale at 6th week (to obtain initial body weight) and then at 8, 12, 16, and 20 weeks of age
2. Total weight gain (TWG) was calculated as the difference between initial body weight at week 6 and the final body weight at 20 weeks of age
3. Age at first egg was taken as the number of days between hatching date and date of the first egg (i.e., 5% flock egg production)
4. Similarly, age at peak egg production was taken as the age at maximum weekly % egg production
5. Hen Housed Egg Production (HHEP) was calculated by dividing the total number of eggs laid by the number of hens housed at the start of lay
6. Hen Day Egg Production (HDEP) was calculated by dividing the number of eggs by the number of hens surviving on that particular day (North 1984)
7. Egg production rate: the average for the whole egg-laying period of HDEP was calculated in percentage and termed as egg production rate
8. Mortality and disease occurrences were recorded as they occurred during both growing and laying periods

Statistical data analysis

All traits measured were subjected to analysis of variance using the General Linear Models (GLM) procedure of SAS (2009) by considering breeds and zone as fixed effects and their interaction. The effects of the zone were tested by using the differences between villages within the zone as the error term whereas, breed effects were tested by using the differences between farmer raising the *j*th breed within village and zone as the error term. Weight at week 6 was considered as the initial weight and taken as a covariate. Survival data were analyzed using the frequency procedure of SAS (2009) whereby breed and zone were tested for differences using a chi-square (χ^2) test.

The following statistical model was used to analyze the data for body weight (BWT) and total weight gain (TWG) measured on individual bird basis.

$$Y_{ijklm} = \mu + Z_i + B_j + (ZB)_{ij} + V(Z)_{ijk} + F(ZVB)_{ijkl} + b(x - \sum x/n)_{ijklm} + E_{ijklmn} \quad (1)$$

where Y_{ijklm} is the observation (body weight, total weight gain) on the *m*th bird kept by the *l*th farmer raising the *j*th breed within the *k*th village and *i*th zone, μ is the general means common to all observations in the study, Z_i is the effect of the *i*th zone (*i*: highland, lowland), B_j is the effect of the *j*th breed (*j*: Kuroiler, Sasso), $(ZB)_{ij}$ is the effect associated with the interaction between breeds and zones, $V(Z)_{ijk}$ is the effect of the *k*th villages within the *i*th zones, $F(VZB)_{ijkl}$ is the effect of *l*th household raising the *j*th breed within the *k*th village and *i*th zone, $b(x-\sum)_{ijklm}$ is the initial weight as a covariate, *x* is the initial weight of the bird, $\sum$ is the average initial weight, *b* is the regression coefficient, and E_{ijklm} is the random effects peculiar to each bird.

For egg production and other traits observed on a household basis (i.e., the household was the observation unit) were analyzed by using the statistical model 2.

$$Y_{ijkl} = \mu + Z_i + B_j + (ZB)_{ij} + V(Z)_{ik} + F(VZB)_{ijkl} + E_{ijkl} \quad (2)$$

where Y_{ijkl} is the observation (egg production traits) on the *l*th farmer raising the *j*th breed within the *k*th village and *j*th zone, μ is the general means common to all observations in the study, Z_i is the effect of the *i*th zone (*i*: highland, lowland), B_j

is the effect of the *j*th breed (*j*: Kuroiler, Sasso), $(ZB)_{ij}$ is the effect associated with the interaction between breeds and zones, $V(Z)_{jk}$ is the effect of the *k*th villages within the *i*th zones, $F(VZB)_{ijkl}$ is the random effect of *l*th household raising the *j*th breed within the *k*th village and *i*th zone, and E_{ijklm} is the random effects peculiar to each bird.

Results

Effects of breed and agro-ecological zone on body weight and body weight gain

Table 1 shows the least square means for body weight (BW) of chickens at different ages and total weight gain (TWG) summarized by breed and zone. The results show that breed had no significant ($P > 0.05$) effects on both BW and TWG. However, the agro-ecological zone was a significant ($P < 0.05$) source of variation for BW at weeks 16 and 20 as well as for TWG. Highland area recorded heavier birds than lowland at weeks 16 and 20. Similarly, the TWG in the highland area was higher than that of the lowland area. Significant interaction effects were observed for BW at 16 and 20 weeks of age, as well for TWG (Table 2). Kuroiler was heavier than Sasso chickens in the lowland area at 16 and 20 weeks of age, a phenomenon that was not observed in the highlands.

Effects of breed and agro-ecological zone on egg production performance

Table 3 shows the least square means on egg production traits summarized by breed and zone. The results show that there were no significant differences ($P > 0.05$) between breeds and between zones for all egg production traits studied. Significant breed × agro-ecological zone interaction was observed only for age at first egg ($P < 0.001$), where Sasso matured earlier than Kuroiler in the highland areas but much later than Kuroiler in the lowland areas (Table 4).

Effects of breed and agro-ecological zone on mortality rate

The percentage of bird's mortalities during the growing and laying phases summarized by breed, zone, and breeds within a zone is as indicated in Table 5. There were no significant differences ($P > 0.05$) between breeds with respect to the percentage of birds that died during both growing and laying phases. Nonetheless, the agro-ecological zone had significant effects on the mortality rate of the two breeds whereby birds in the highlands survived better than those in the lowland area during both phases. Moreover, there was a high percentage of mortality during the laying phase compared to the growing phase in both agro-ecologies. No significant differences were observed in mortality rates among the breeds within the zone except for the lowland area where Kuroiler survived better than Sasso chickens during the growing period.

Discussion

Performance or response in chickens is affected by two factors, i.e., genotype and environment. But also, differences between genotype can vary depending on the environment if there is an interaction between the two factors. In this study, the growth of chickens was mostly affected by the environment which reflects their differences in response to agro-ecological zone factors. The final body weight and weight gain during the growing phase were higher for chickens in the highland area than in the lowland. Such variation might have been caused by differences in feed availability and

Table 1 LSM ± SE values for body weight (BW in gram) at different ages (week) and total weight gain (TWG in gram) summarized by breed and zone

Fixed effects	Mean body weight (BW) at different ages (weeks)					Total weight gain (TWG)
	Week 6	Week 8	Week 12	Week 16	Week 20	
Breed						
Kuroiler	527.3 ± 3.0[b]	739.5 ± 4.7	1069.7 ± 8.3	1486.9 ± 12.3	1995.0 ± 14.3	1458.3 ± 14.3
Sasso	551.4 ± 3.0[a]	729.0 ± 4.7	1060.9 ± 8.6	1480.0 ± 12.8	1900.3 ± 14.9	1363.6 ± 14.8
P value	<.0001	0.6493	0.7993	0.7342	0.1981	0.1981
Zone						
Highland	542.8 ± 3.0	723.0 ± 4.6	1063.2 ± 8.3	1550.9 ± 12.2[a]	2021.7 ± 14.1[a]	1485.0 ± 14.1[a]
Lowland	535.9 ± 3.0	739.5 ± 4.7	1067.4 ± 8.5	1404.1 ± 12.7[b]	1873.6 ± 14.9[b]	1336.9 ± 14.0[b]
P value	0.3167	0.2212	0.8357	0.0065	0.0341	0.0341

LSM least square mean, *SEM* standard error of the mean

[a, b] Least square means with no superscript letters in common within a column and effect are significantly different

Table 2 LSM ± SEM values for the interaction effects of agro-ecological zones and breeds on body weights (BW in gram) at different ages (week) and total weight gain (TWG in gram)

Age (week)	Highland		Lowland		*P* value
	Kuroiler	Sasso	Kuroiler	Sasso	
BW 8	720.1 ± 6 ± .5^{b}	726.1 ± 6.6^{b}	747.1 ± 6.6^{a}	731.9 ± 6.7^{ab}	0.1062
BW 12	1067.0 ± 11.7	1059.5 ± 11.9	1072.1 ± 11.8	1062.4 ± 12.3	0.9163
BW 16	1532.3 ± 17.3^{a}	1569.4 ± 17.2^{a}	1441.5 ± 17.4^{b}	1366.7 ± 18.7^{c}	0.0015
BW 20	2004.1 ± 20.1^{a}	2039.3 ± 20.0^{a}	1985.8 ± 20.4^{a}	1761.3 ± 21.8^{b}	<.0001
TWG 20	1467.4 ± 20.1^{a}	1502.6 ± 20.0^{a}	1449.2 ± 20.4^{a}	1224.6 ± 21.8^{b}	<.0001

LSM least square mean, *SEM* standard error of the mean, *BW* bodyweight

$^{a, b}$ Least square means with no superscript letters in common within a row are significantly different

weather conditions of the two zones. This observation is supported by Goromela et al. (2006) who showed that agro-ecologies have a great influence on the availability of feed resources. Reports from other studies have shown better feed availability in highland than in lowland areas. For example, Pius and Mbaga (2018) reported better availability of feeds in the cool Southern highland than in the Central semi-arid zone, Tanzania. Also, Alem (2014) and Habte et al. (2013) reported relatively better performance of both local and exotic breeds in mid-highland than in the lowland ecologies of Ethiopia which were attributed to the availability of feeds and favorable environments. Mulugeta et al. (2020) also reported better growth performance of DZ-White and improved Horro chickens in the highland than in the lowland area in Ethiopia.

Significant breed × agro-ecology interaction effects were observed for body weight at 16 and 20 weeks of age. The body weight of Sasso birds in the lowland at week 20 was lighter by 13.6% than those Sasso in the highland area. The lower performance of Sasso in the lowland area depicts sensitivity of the breed to variation in environmental factors and may be attributed to heat stress, inadequate feeding, and limited scavengable feed resources which probably affected negatively the growth performance of the breed. This observation is proved with arguments put forward by Sanka et al. (2020) that Sasso breed has more broiler genes and is heavier, probably needs relatively more feeds to optimally express their genetic potential.

On the other hand, the final body weight of Kuroiler was similar in the two agro-ecologies which may imply that the breed was less sensitive to changes in the environmental conditions. According to Lozano-Jaramillo et al. (2019), variation in productivity among breeds can be attributed to the breeds' origin, which can influence the breed's intrinsic response to diverse environmental conditions. Kuroiler was developed in India under humid conditions (Lozano-Jaramillo et al. 2019), a factor that might play a role in its performance in the lowland area which had more or less similar conditions to those of its origin. Besides, this breed is said to have genes associated with homeostatic regulatory functions such as response to hypoxia, cold, and starvation (Fleming et al. 2016). Hence, these factors might have contributed to the Kuroiler breed maintaining its body weights regardless of the agro-ecologies under the present study.

In general, the observed final body weight attained by Sasso during the growing phase in the present study is below the range of 2.7 ± 0.53 kg and 2.98 ± 0.70 kg for the same breed reported by Getiso et al. (2017) in Ethiopia. Similarly, the final body weight of Kuroiler in the present study is lower than 2.6 kg reported by Sharma et al. (2015) at 25 weeks of age but higher than 1705.52 g at 20 weeks of age reported by

Table 3 LSM ± SE values for egg production performance summarized by breed and zone

Egg production trait	Breed		*P* value	Zone		*P* value
	Kuroiler	Sasso		Highland	Lowland	
Age at first egg (days)	181.6 ± 1.5	180.2 ± 1.5	0.5278	182.7 ± 1.5	179.1 ± 1.5	0.0911
Egg production rate (%)	45.7 ± 1.6	40.8 ± 1.6	0.2838	40.4 ± 1.7	46.2 ± 1.6	0.2410
Peak production rate (%)	65.6 ± 3.2	62.9 ± 3.2	0.5724	62.4 ± 3.3	66.1 ± 3.2	0.4326
Age at peak production (week)	36.5 ± 0.6	36.1 ± 0.6	0.9120	35.7 ± 0.6	37.2 ± 0.6	0.1052
Hen-day egg production (count)	82.6 ± 2.9	72.9 ± 2.9	0.2499	73.3 ± 2.9	82.2 ± 2.9	0.2732
Hen-housed egg production (count)	53.0 ± 2.0	52.9 ± 2.0	0.9510	60.6 ± 2.0	45.4 ± 2.0	0.1183

LSM least square mean, *SEM* standard error of the mean

Table 4 LSM ± SEM values for the interaction effects of agro-ecological zones and breeds on egg production performance

Egg production trait	Highland		Lowland		*P* value
	Kuroiler	Sasso	Kuroiler	Sasso	
Age at first egg (days)	189.3 ± 2.1[a]	176.0 ± 2.1[b]	173.8 ± 2.1[b]	184.4 ± 2.1[a]	<.0001
Egg production rate (%)	38.9 ± 2.4	41.8 ± 2.3	52.4 ± 2.3	39.9 ± 2.3	0.1872
Peak production rate (%)	64.7 ± 4.6	60.1 ± 4.6	66.4 ± 4.5	65.7 ± 4.6	0.6768
Age at peak production (week)	36.0 ± 0.9	35.5 ± 0.9	37.0 ± 0.9	37.5 ± 0.9	0.5766
Hen-day egg production (number)	73.6 ± 4.1	73.1 ± 4.1	91.7 ± 4.0	72.7 ± 4.0	0.2626
Hen-housed egg production (number)	61.8 ± 2.9	59.3 ± 2.9	44.1 ± 2.8	46.6 ± 2.8	0.5195

LSM least square mean, *SEM* standard error of the mean

[a, b] Least square means with no superscript letters in common within a row are significantly different

Islam et al. (2017) under scavenging conditions in Uganda and India, respectively. Availability of scavengable feed resources, age of recording, and frequency of supplementing the birds are the possible reasons for those differences between the results of the present study and that of other authors. For example, in the present study, supplementation was done infrequently depending on the available feeds given that most of the rural households are poor. On the contrary, the study of Getiso et al. (2017) was somewhat controlled whereby supplementation was done three times per day.

Concerning egg production traits, the results of the present study show that age at first egg is influenced by the interaction between breed and zone. In the highland area, Sasso chickens matured about 13 days earlier than Kurolier, while in the lowland the same breed matured about 11 days later than Kuroiler. This implies that the highland and lowland environments favored Sasso and Kuroiler breeds, respectively, in terms of age at first egg, as was the case for body weight explained earlier in this study. However, this finding is contrary to that of Assefa et al. (2019) who suggested that the Sasso breed is favored by the lowland environment in age at first egg. Such differences are possible since this trait is affected by several environmental factors including nutrition, temperature, diseases, and management practices (Zaman et al. 2004; Alem 2014; Kidie 2019). Generally, the average age at first egg of Sasso chickens observed in the present study is higher than 155 ± 24.6 days and 5.22 ± 0.43 months (156.6 days) reported by Assefa et al. (2019) and Kejela (2020), respectively, for Sasso chickens in Ethiopia. Conversely, the mean age at first egg of Kuroiler and Sasso chickens observed in the present study is comparable to the overall mean of 184 ± 1.6 and 176 ± 1.5 for Kuroiler and Sasso chickens, respectively, reported by Kidie (2019) in Amhara region, Ethiopia.

Egg production rate, peak production rate, and age at peak production were not affected by breed, agro-ecology, or breed × agro-ecology interaction. In comparison to the present findings, Kidie (2019) reported a much higher egg production rate of 67.7% and 69.2% for Kuroiler and Sasso chickens, respectively, under semi-scavenging management in Ethiopia. However, the egg production rate for Kuroiler and Sasso chickens in the present study is much higher than 28.8% and

Table 5 Mortality of birds (%) during the growing and laying phases summarized by breed, zone, and breeds within a zone

Parameter		Growing phase			Laying phase		
		Mortality	χ^2-test	*P* value	Mortality	χ^2-test	*P* value
Effects of breed and zone							
Breed	Kuroiler	15.5	0.9076	0.3408	29.2	0.5533	0.4570
	Sasso	17.5			42.2		
Agro-ecology	Highland	12.7[b]	12.2019	0.0005	34.6[b]	9.6128	0.0019
	Lowland	20.3[a]			47.1[a]		
Effects of breed within a zone							
Highland	Kuroiler	14.9	2.6511	0.1035	35.4	0.0896	0.7647
	Sasso	10.4			33.8		
Lowland	Kuroiler	16.0[b]	6.7035	0.0096	43.1	1.8581	0.1728
	Sasso	24.6[a]			51.0		

[a, b] Values with no superscript letters in common within a column and effect are significantly different

22.5% for Rhode Island Red (RIR) and Barred Plymouth Rock (BPR) dual-purpose chickens reported by Sazzad (1992) under rural management in Bangladesh. The age at peak production for Kuroiler and Sasso observed in the present study is comparable to the value of 36 weeks reported by Kidie (2019) for both breeds. Total egg yields (i.e., both hen-day egg production and hen-housed egg production) were also not affected by breed or by agro-ecologies. This may imply that the two breeds responded similarly to environmental conditions influencing egg yield in chickens. Total egg yields, both hen-day and hen-housed egg production for Kuroiler and Sasso reported in the present study, are higher than the overall mean of 25.1 ± 2.52 and 12.9 ± 1.39 for Fayoumi and 16.7 ± 3.15 and 6.6 ± 1.46 eggs for RIR reported by Bekele et al. (2009) under on-farm management in Southern Ethiopia. Also, the observed egg production (HHEP) for Kuroiler in this study is lower than 86.25 ± 25 and 69 eggs for Kuroiler and RIR reported by Islam et al. (2017) and Sazzad (1992) under backyard system in India and Bangladesh, respectively. The difference between results of the present study and those of other authors on egg production traits could be explained by differences in the type of breed used, the type of management such as feeding, and other agro-ecological factors in the respective areas.

Mortality constitutes a big loss to the farmer, as it reduces the number of birds and their products. In the present study, high mortality of chickens was observed in the lowland than in the highland area during both growing and laying phases. This could be attributed to poor management practices (inadequate feeding) of the birds observed in the lowlands than in the highland areas. This observation is in agreement with that of Alem (2014) and Mulugeta et al. (2020) who also reported high mortality of chickens in the lowland than in the highland and midland areas in Ethiopia. Moreover, high losses of chickens during the laying phase in this study might be attributed to higher stress due inadequate feeding which provides root for infections by suppressing the immune system and hence increase diseases. It has to be noted that the laying period in the present study coincided with the dry season which limits the amounts of scavengable feed resources in rural areas. This observation conforms to that of Kidie (2019) who argued that inadequate feeding, especially at the peak of production, may lead to high percentages of mortality as at that period birds require balanced rations for body maintenance and egg production. The dry season is also associated with the occurrence of several diseases affecting chickens under scavenging conditions in rural areas (Mwalusanya et al. 2002; Alem 2014).

The observed lower mortality of Kuroiler than Sasso chickens in lowland area (growing phase) reveals its ability to thrive well under the lowland environmental conditions, as was the case for body weight and age at first egg. Contrary, the observed high mortality for Sasso in the lowland area during both growing and laying phases may connote that the breed is likely to be less adapted to lowland scavenging environments compared to Kuroiler. This observation is in agreement with that of Kidie (2019) who reported high mortality for Sasso chickens than other introduced breeds under on-farm evaluation in Amhara region, Ethiopia.

Conclusion

The present study has revealed that the performance traits of the two breeds are dependent on agro-ecological zone factors. The highland zone appeared to better than the lowland in growth and survivability of chickens. Responses of the two breeds on egg production performance are similar regardless of agro-ecological zones. The study has further shown the existence of interaction between the breed and agro-ecology on bodyweight and age at first egg (age at sexual maturity). Kuroiler seemly to maintain its bodyweight regardless of agro-acology whereas Sasso appeared better in highland than in lowland areas. Thus, knowledge of breed performance in relation to agro-ecological differences is critical when distributing improved chicken breeds to farmers.

Acknowledgements The authors express their appreciation to the Department of Animal, Aquaculture and Range Sciences of Sokione University of Agriculture for providing necessary facilities during the brooding period. They are further grateful to the Mvomero District Council, in particular the Livestock and Fisheries Office and households for their cooperation during the course of data collection.

Code availability Not applicable.

Author's contribution All listed authors have made substantial contributions to the research design, or the acquisition, analysis, or interpretation of data, and drafting the manuscript or revising it critically. All authors have approved the submitted version.

Funding This research was carried out under the financial support of the African Chicken Genetic Gains (ACGG) project in Tanzania sponsored by the Bill and Melinda Gates Foundation (Grant Agreement OPP1112198).

Data availability Not applicable.

Declarations

Ethics approval National and institutional procedures for the care and use of animals were followed. The study was approved by International Livestock Research Institute Institutional Animal Care and Use Committee (ILRI IACUC) with reference number: IACUC-RC2016.26.

Conflict of interest The authors declare no competing interests.

References

Alem T (2014). Production and reproduction performance of rural poultry in lowland and midland agro-ecological zones of Central Tigray, Northern Ethiopia. *African Journal of Agricultural Research* 9(49):3531-3539. https://academicjournals.org/article/article1417520139_Alem.pdf

Assefa, S., Melesse, A. and Banerjee, S. 2019. Egg Production and Egg Quality Traits of Local and Exotic Chicken Breeds Reared in Two Agroecologies under Traditional Management System. *Research Journal of Food and Nutrition* 3 (1): 11-17. https://www.researchgate.net/publication/331684037

Bekele, F., Gjøen, H.M., Kathle, J., Ådnøy, T. and Abebe, G. 2009. Genotype X environment interaction in two breeds of chickens kept under two management systems in Southern Ethiopia. *Tropical Animal Health and Production* 41:1101–1114. https://www.researchgate.net/publication/23665839

Da Silva, M., Desta, S. and Stapleton, J. (2017) Development of the chicken sector in the Tanzanian Livestock Master Plan. https://core.ac.uk/download/pdf/132697821.pdf

Eik, L.O., Kifaro, G.C., Kiango, S.M., Nordhagen, Ø. M. Safari, J. and Mtenga, L.A. 2008. Productivity of goats and their contribution to household food security in high potential areas of East Africa: A case of Mgeta, Tanzania. *African Journal of Food Agriculture Nutrition and Development* 8(3).

Fleming, D. S., Koltes, J. E., Markey, A. D., Schmidt, C. J., Ashwell, C. M., Rothschild, M. F., Persia, M.E., Reecy, J.M. and Lamont, S.J. 2016. Genomic analysis of Ugandan and Rwandan chicken ecotypes using a 600 k genotyping array. BMC Genomics 17: 407. https://www.researchgate.net/publication/303555278

Getiso, A., Jimma, A., Asrat, M., Kebede, H.G., Zeleke, B. 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., Kwakkel, R. P., Verstegen, M. W. A. and Katule, A. 2006. Strategies to optimize the use of scavengeable feed resource base by smallholder poultry farmers. *African Journal of Agricultural Research* 1: 91-100. http://www.academicjournals.org/AJAR

Habte, M., Ameha, N. and Demeke S. 2013. Production performance of local and exotic breeds of chicken at rural household level in Nole Kabba Woreda, Western Wollega, Ethiopia. *African Journal of Agricultural Research* 8(11):1014- 1021.

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.

Kejela, Y. 2020. Production Performance of Chicken under Farmers' Management and Their Roles at Urban Household Economy in Southern Ethiopia. *Agricultural Sciences* 11: 178-190.

Kidie, H.A. 2019. Characterization of chicken production system and on-farm evaluation of introduced exotic chicken breeds in Gondar Zuria and Kalu districts of Amhara region, Ethiopia. MSc Thesis. Haramaya University, Haramaya, Ethiopia.

Lozano-Jaramillo, M., Alemu, S.W., Dessie, T., Komen, H. and Bastiaansen, J.W. M. 2019. Using phenotypic distribution models to predict livestock performance. Scientific Reports 9: 15371.

Mbaga, H.R., Msanya, B.M. and Mrema, J.P. 2017. Pedological Characterization of Typical Soil of Dakawa Irrigation Scheme, Mvomero District, Morogoro Region, Tanzania. *International Journal of Current Research in Biosciences and Plant Biology* 4(6): 77-86. https://doi.org/10.20546/ijcrbp.2017.406.009

MLFD 2015. Ministry of Livestock and Fisheries Development. Tanzania livestock modernization initiative. Dar es Salaam, Tanzania: Ministry of Livestock and Fisheries Development. https://livestocklivelihoodsandhealth.org/wpcontent/uploads/2015/07/Tanzania_Livestock_Modernization_Initiative_July_2015.pdf

Mulugeta, S., Goshu, G. and Esatu, W. 2020. Growth performance of DZ-white and Improved Horro chicken breeds under different agro-ecological zones of Ethiopia. *Journal of Livestock Science* 11: 45-53. https://cgspace.cgiar.org/rest/rest/bitstreams/187395/retrieve

Mwalusanya, N.A., Katule, A.M., Mutayoba, S.K. and Mtambo, M.M.A. 2002. Productivity of local chickens under village management conditions. *Tropical Animal Health and Production* 34: 405-416. https://link.springer.com/article/10.1023/A:1020048327158

North, M. O. 1984. Breeder Management. In Commercial Chicken Production Manual. The Avi. Publishing Company. Inc. Westport, Connecticut. 240-243, 298-321 pp.

Olwande, P.O., Ogara, W.O., Okuthe, S.O., Muchemi, G., Okoth, E., Odindo, M.O. and Adhiambo, R.F. 2010. Assessing the productivity of indigenous chickens in an extensive management system in southern Nyanza, Kenya. *Tropical Animal Health and Production* 42: 283–288.

Permin, A. 2008. Good practices in small scale poultry production: A manual for trainers and producers in East Africa. A Consultancy Report to FAO, FAO ECTAD Regional Unit Eastern Africa, Nairobi, Addis Ababa, Ethiopia.

Pius, L. O. and Mbaga, S. H. 2018. Variations in village chicken management packages in two agro-ecological zones of Tanzania. *International Journal of Livestock Production* 9(3): 42-49.

Roysfarm 2018. Kuroiler Chicken Breed Information. https://www.roysfarm.com/kuroiler-chicken

Rumisha, S.F., Shayo, E.H. and Mboera L.E.G. 2019. Spatio-temporal prevalence of malaria and anaemia in relation to agro-ecosystems in Mvomero district, Tanzania. *Malaria Journal* 18: 228.

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. *Tropical Animal Health and Production.*

SAS 2009. Statistical Analytical System. User Guide for Personal Computers, Statistical Programme. Windows Version 9.2, SAS Institute Inc. Cary, NC, USA.

SASSO 2014. Coloured chicken genetics. http://www.sasso.fr/coloured-chicken-genetics-for-organic-red-label-farmer-chickens.html

Sazzad, M. H. 1992. Comparative study on egg production and feed efficiency of different breeds of poultry under intensive and rural conditions in Bangladesh. *Livestock Research for Rural Development* 4(3): 65-69. http://www.fao.org/ag/aga/agap/frg/lrrd/lrrd4/3/bangla1.htm.

Sharma, J. 2011. A new breed: Highly productive chickens help raise Ugandans from poverty researcher at the Center for Infectious Diseases and Vaccinology at ASU's Bio-design Institute. https://asunews.asu.edu/node/21034

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.

Sonola, V.S. 2015. Evaluation of performance of Norwegian dairy goats in Mgeta Morogoro. MSc Thesis. Sokoine University of Agriculture, Morogoro, Tanzania.

Zaman, M.A., Sørensen, P. and Howlider, M.A.R., 2004. Egg production performance of a breed and three crossbreeds under semi-scavenging system of management. *Livestock Research for Rural Development* 16(8). http://www.lrrd.org/lrrd16/8/zama16060.htm

CHAPTER THREE

PAPER-II

Performance evaluation of Kuroiler and Sasso chicken breeds reared under on-farm and on-station management conditions in Tanzania

Published in: European Journal of Agriculture and Food Sciences 3(2): 53-59

Available online at https://doi.org/10.24018/ejfood.2021.3.2.254

RESEARCH ARTICLE

European Journal of Agriculture and Food Sciences
www.ejfood.org

Performance Evaluation of Kuroiler and Sasso Chicken Breeds Reared under On-farm and On-station Management Conditions in Tanzania

Fadhili S. Guni, Said H. Mbaga, and Andalwisye M. Katule

ABSTRACT

A study was conducted to evaluate the effect of management, breed, and their interaction on growth performance, egg production, and survivability under on-station and on-farm management conditions in Tanzania. A total of 1200 chicks, 600 for each breed, Kuroiler, and Sasso of mixed sexes were used. Birds under on-station management were confined and fed commercial ration throughout the experiment while those under on-farm management were allowed to semi-scavenge and supplemented with available feeds in the household. Brooding was carried out on-station for six weeks. Thereafter, birds were sub-divided for on-station and on-farm evaluation where data on body weight, egg production traits, and survival rate were taken at different ages from week 6 up to 52. The General Linear Models procedure fitting management, breed, and interaction between management and breed was used to analyze the data. Results show that management conditions had a significant influence on the performance of the breeds. Birds reared on-station performed better in all traits measured than those reared on-farm. The general effect of the breed was significant only for hen-day egg production (HDEP %) and hen-housed egg production (HHEP) in favour of Sasso chickens. Similarly, Sasso was more efficient at converting feed to live body weight. Interactions between management and breed were observed for all traits except peak egg production rate and mortality rate. While Sasso performance was better than that of Kuroiler on body weight, age at first egg, HDEP, age at peak egg production, and HHEP under the on-station management system, their performance in these traits were similar under the on-farm management except for body weight and age at first egg where Kuroiler was superior to Sasso. The survivability was also higher for Kuroiler than for Sasso under both management systems. It is concluded that genotype by environment (GxE) interaction had significant effects on the performance of the two breeds thus, a need to consider such effect when promoting them for either on-station or on-farm rearing.

Keywords: On-station, On-farm, Kuroiler, Sasso, Bodyweight, Egg production, Mortality.

Submitted : February 22, 2021
Published : March 31, 2021
ISSN: 2684-1827
DOI: 10.24018/ejfood.2021.3.2.254

F. S. Guni*
Tanzania Livestock Research Institute (TALIRI), Uyole, Mbeya, Tanzania.
(e-mail: fadhili.guni@yahoo.com)
S. H. Mbaga
Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture, Morogoro, Tanzania.
(e-mail: mbagash@yahoo.com)
A. M. Katule
Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture, Morogoro, Tanzania.
(e-mail: andalkat@yahoo.co.uk)

**Corresponding Author*

I. Introduction

Poultry production in most developing countries has an important economic, social, and cultural benefit and plays a significant role in family nutrition. About 85% of the rural populations in sub-Saharan Africa keep chickens which provide a reasonable proportion of animal protein and household cash income [1]. In Tanzania, like many other developing countries, household poultry production is practiced in rural and urban areas for the livelihood of the households i.e., as a source of income and food. Poultry, in particular chicken, production systems in Tanzania have been categorized as unimproved traditional indigenous, improved family, and commercial systems. The traditional system of poultry keeping is predominant, and accounts for 96% of household flocks and supplies 94% of poultry meat and eggs in rural areas [2]. However, this system is unable to meet the increasing demand for poultry meat and eggs owing to its low productivity in terms of both egg and meat.

Efforts have been made previously to improve meat and egg production through importations of high producing exotic breeds, particularly in the commercial sector. These efforts are yet to produce the expected output in the tropics, apparently due to a lack of adaptation to the tropical environment. Besides, the selection and breeding of exotic breeds were developed for high-input intensive production systems in temperate regions [3]. The failure of exotic stocks to meet expectations when raised under tropical conditions is often associated with the phenomenon termed 'genotype by environment interaction' [4].

Alternatively, the introduction of tropically adapted dual-purpose chicken breeds suitable for family chicken production has been proposed to be one of the key strategies to improve chicken productivity in the country [5]. Kuroiler and Sasso are among such breeds which have been introduced into the country. Kuroiler originates from India and has been developed through crossing several pure genetic lines of chickens including White Leghorn, Rhode Island Red, Coloured broiler, and local Desi chickens, followed by selection for high

RESEARCH ARTICLE

European Journal of Agriculture and Food Sciences
www.ejfood.org

production performance and ability to thrive in village environment under scavenging or semi-scavenging rearing systems [6]. The second breed is Sasso which originates from France. It has been developed through an intensive selection of traditional colored lines of chickens from France [7]. The two breeds are known for many desirable features of indigenous birds, such as the feather colors for camouflage, ability to escape from predators, resistance to diseases, adaptable to tropical and sub-tropical conditions [8], [9]. They have also the ability to scavenge, thus require low maintenance yet grow about double the bodyweight of their indigenous counterparts [10], provided that they receive supplementation and are protected against diseases. The two breeds are now being popularized in the country and distributed to farmers by two major poultry multiplication companies in Tanzania.

The multiplication and distribution of these breeds target smallholder farmers thus, they must be tested for performances under various management systems and be recommended accordingly. Therefore, this study intended to test the performance of Kuroiler and Sasso chickens to evaluate their genetic potential under a controlled environment (on-station) and farmer management (on-farm) conditions, and test for genotype x interactions for economic traits.

II. Material and Methods

A. Study Areas and Management of Chicks during Brooding

This study was conducted on-station and on-farm from December 2018 to December 2019. The on-station study was carried out at Sokoine University of Agriculture while the on-farm experiment was conducted in two villages (i.e., Wami-Sokoine and Wami-Luhindo) located about 45 km from the University. The university is located at the foothills of the Uluguru Mountains in Morogoro, Eastern Tanzania, about 550 m above sea level.

A total of 1200 day-old chicks, 600 for each Kuroiler and Sasso breed were procured from two different commercial companies in the country. Brooding of chicks was done from day-old up to 6 weeks of age at the University poultry farm. Upon arrival, chicks were wing-tagged for identification. Each breed was allocated to 2 brooding pens, each with 300 chicks. During the brooding period, chicks were fed a commercial starter diet in form of crumbles containing 2941 Kcal ME/kg and 21.2% CP from day old up to the 2nd week of age. A chick mash containing 3049 Kcal ME/kg and 20.3% CP was then fed from the 3rd up to the 6th week of age. Water was provided *ad libitum* throughout the brooding period. Birds were also routinely vaccinated against Newcastle, Gumboro, and Fowlpox diseases at specified age intervals. Treatment was provided in case of occurrence of specific disease symptoms. Sexing was done at the end of the brooding period i.e., at weeks 6 of age. The birds of each breed were then divided into two groups, of which 576 (288 Sasso and 288 Kuroiler) were transferred to farmers for on-farm evaluation, and 480 (240 Sasso and 240 Kuroiler) remained at the University poultry farm for on-station evaluation.

B. Management of Birds during Growing and Laying Phases Under On-station and On-farm Management Systems

1. On-station

The birds of each breed were randomly allocated to six deep litter pens of 40 birds each and reared under total confinement. They were provided with a commercial grower ration containing 15.5% CP and 2762 Kcal ME/kg, from the 6th to the 19th week of the age. Thereafter, a layer ration containing 18.5% CP and 2965 Kcal ME/kg was provided from the 20th week of age to the end of the experimental period. Routine vaccinations against Newcastle, as well as anthelmintic, were also given to the birds based on manufacturer instructions. Treatment was provided in case of occurrence of specific disease symptoms.

2. On-farm

The selection of villages and households participating in the study was done in collaboration with District and Ward livestock officers. Recruitment of a household (farmer) was based on individual willingness to participate in the research project and his/her ability to provide all necessary management for the chickens including housing, supplementary feeding, health care, etc. In each village 16 farmers (households) were randomly selected from a list of farmers that met the criteria to be included in the study. Out of the 16 farmers in a village, half of them received 18 pre-brooded Sasso and the remaining half received 18 Kuroiler chickens of mixed-sex.

A three days training on proper management of the birds and data recording was provided to participating farmers and two livestock field officers, one for each village. Apart from data recording, the field officers were also responsible for supervising and advising farmers on all management aspects of the birds under field conditions.

Upon arrival in the field, the birds were first weighed individually to obtain the initial body weight. A semi-intensive system of management was adopted whereby a simple enclosure was made around the homestead to restrict other birds from mixing with the experimental birds. The farmers were also responsible for providing housing, supplementary feeding, and basic health care. They were encouraged to make simple formulations to include energy, some protein sources, and minerals in addition to kitchen leftovers.

III. Data Collection

A. Growth Performance and Feed Conversion Ratio

The body weight (BW) of chickens was recorded at different ages from the 6th up to 20th weeks of age under both management systems. Birds were weighed individually using a digital weighing scale at the 6th week of age to obtain initial body weight, and then subsequently at 8, 12, 16, and 20 weeks of age. Total weight gain (TWG) was calculated as the difference between initial body weight at 6 weeks of age and final body weight at 20 weeks of age. Feed conversion ratio (FCR) was calculated as the amount of feed consumed per unit of body weight gain. This variable was calculated only for birds raised on-station.

B. Egg Production Traits

Age at first egg was taken as the number of days between hatching date and the date at first egg (i.e., 5% flock egg production rate). The peak production rate was taken as the maximum weekly % egg production. Similarly, age at peak egg production was taken as the age of birds at a maximum weekly egg production rate. Hen-housed egg production (HHEP) was

RESEARCH ARTICLE

European Journal of Agriculture and Food Sciences
www.ejfood.org

calculated by dividing the total number of eggs laid in a pen/per household by the number of hens housed at the start of lay. Hen-day egg production (HDEP%) was calculated by dividing the number of eggs laid in a pen/per household by the number of hens still alive up to that particular day of recoding [11].

C. *Mortality*

Mortality and its causes were recorded as they occurred during both the growing and the laying periods.

IV. Data Analysis

All traits measured were subjected to analysis of variance using the General Linear Models (GLM) procedure of SAS [12] by considering management conditions (i.e., on-station vs on-farm) and breeds as fixed effects, as well as breed x management interaction effects. Individual farmer or pen effect within a management condition was taken as a random effect. Weight at 6 weeks of age was considered to be a covariate during the analysis of data. Effects of management and breed on survival were tested by a chi-square (χ^2) test using the frequency procedure [12].

The following statistical model was used to analyze data for body weights (BWT) and total weight gains (TWG) measured on an individual bird basis:

$$Y_{ijkl} = \mu + M_i + B_j + (MB)_{ij} + FP(MB)_{ijk} + b(x_{ijkl} - \sum x_{ijkl}/n) + E_{ijkl} \quad (1)$$

where
Y_{ijkl} = observation (body weight, body weight gain) on the l^{th} bird from the k^{th} farmer or pen within the j^{th} breed and i^{th} management system;
μ = General means common to all observations in the study;
M_i = Effect of the i^{th} management system (i = on-station, on-farm);
B_j = Effect of the j^{th} breed (j= Kuroiler, Sasso);
$(MB)_{ij}$ = Effect associated with the interaction between the management system and breed;
$FP(MB)_{ijk}$= Random effect of the k^{th} farmer or pen within the i^{th} management system and j^{th} breed;
x_{ijkl} = initial bodyweight of the l^{th} bird from the k^{th} farmer or pen within the j^{th} breed and i^{th} management system;
$\sum x_{ijkl}/n$ = average initial body weight of all birds in the study;
b = Regression of body weight /body weight gain on initial body weight;
E_{ijkl}= Random effects peculiar to each bird.

For egg production and other traits observed on pen or household basis (i.e., the pen or household was the observation unit) were analyzed by using the following statistical model:

$$Y_{ijkl} = \mu + M_i + B_j + (MB)_{ij} + FP(MB)_{ijk} + E_{ijkl} \quad (2)$$

where:
Y_{ijk} = observation (Egg production variables) from the k^{th} farmer or pen within the j^{th} breed and i^{th} management system;
μ = General mean common to all observations in the study;
M_i = Effect of the i^{th} management system (i= on-station, on-farm);
B_j = Effect of the j^{th} breed (j= Kuroiler, Sasso);
$(MB)_{ij}$ = Effect associated with the interaction between the management system and breed;
$FP(MB)_{ijk}$= Random effect of the k^{th} farmer or pen within the i^{th} management system and j^{th} breed;
E_{ijkl}= Random effects peculiar to each bird.

Note: The effects of the management system and breed for body weight and egg production variables were tested using the farmer or pen variation within the management system and breed (i.e., FP(MB)ijk) as the error term.

For feed conversion ratio, Model 1 was modified to model 3 where the effects of the management system and interaction between the management system and breed were removed because FCR was measured under on-station experiment only.

$$Y_{ijk} = \mu + B_i + b(x - \sum x/n)_{ij} + E_{ijk} \quad (3)$$

All descriptions are similar to model 1 except:

Y_{ijk} = observation (Feed conversion ratio)

V. Results

A. *Effects of Management and Breed on Growth Performance of Kuroiler and Sasso Chickens*

The least-square means for body weight (BW), total weight gain (TWG), and average daily gain (ADG) of chickens summarized by management system and breed are presented in Table I. The overall results during the growing phase show that the management system significantly ($P<0.05$) influenced the body weight and weight gain of the two breeds. Chickens reared under on-station management were heavier and gained more weight than the chickens reared under on-farm management. Breed effects were insignificant ($P>0.05$) for body weight and body weight gain. The results further show that FCR differed significantly ($P<0.05$) between the two breeds whereby, Sasso had a lower feed conversion ratio compared to Kuroiler. Significant interaction effects ($P<0.05$) between the management system and breed were observed on BW, TWG, and ADG (Table II).

B. *Effects of Management System and Breed on Egg Production of Kuroiler and Sasso Chickens*

The least-square means for egg production traits summarized by management systems and breeds are presented in Table III. The results show that there were significant differences ($P<0.05$) between management systems on all egg production traits studied in favor of the on-station management system. The general effects of the breed were significant ($P<0.05$) only for HDEP and HHEP where Sasso outperformed Kuroiler. No significant differences ($P>0.05$) were observed between the two breeds for age at first egg, peak egg production rate, and age at peak egg production. Significant interaction effects ($P<0.05$) between the management system and breed were observed for all egg production traits except for peak egg production rate which was not significant (Table IV).

RESEARCH ARTICLE

European Journal of Agriculture and Food Sciences
www.ejfood.org

TABLE I: LSM±SEM VALUES FOR GROWTH PERFORMANCE TRAITS OF CHICKENS SUMMARIZED BY MANAGEMENT SYSTEMS AND BREEDS

Fixed effects	Variables			
	BW at week 6 (g)	BW at week 20 (g)	Total weight gain (g)	Average daily gain(g)
Management system				
On-station	541.4±3.3	2510.9±16.4^{a}	1977.3±16.4^{a}	20.2±0.2^{a}
On-farm	536.0±3.0	1870.5±16.1^{b}	1336.9±16.1^{b}	13.6±0.2^{b}
Breed				
Kuroiler	527.0±3.2^{b}	2154.1±15.8	1620.5±15.9	16.5±0.2
Sasso	550.4±3.2^{a}	2227.3±16.9	1693.7±16.9	17.3±0.2

$^{a-b}$ Means with different superscripts within a column and effect are significantly different (P<0.05), LSM = least-squares mean, SEM = Standard error of the mean, BW = Bodyweight.

TABLE II: LSM±SEM VALUES FOR THE INTERACTION EFFECTS OF MANAGEMENT SYSTEMS AND BREEDS ON GROWTH PERFORMANCE TRAITS OF CHICKENS

Fixed effects		Variables				
Management system	Breed	BW at week 6 (g)	BW at week 20 (g)	Total Weight Gain (g)	Average Daily Gain (g)	FCR
On-station	Kuroiler	529.3±4.7^{b}	2313.1±22.7^{b}	1779.4±22.7^{b}	18.2±0.2^{b}	5.8±0.1^{a}
	Sasso	553.5±4.7^{a}	2708.8±23.8^{a}	2175.2±23.8^{a}	22.2±0.2^{a}	4.8±0.1^{b}
On-farm	Kuroiler	524.6±4.3^{b}	1995.2±22.1^{c}	1461.6±22.1^{c}	14.9±0.2^{c}	-
	Sasso	547.3±4.3^{a}	1745.9±23.7^{d}	1212.3±23.7^{d}	12.4±0.2^{c}	-

$^{a-d}$ Means with different superscripts between breeds within management system are significantly different (P<0.05), LSM = least-squares mean, SEM = Standard error of the mean, BW = Bodyweight, FCR = Feed conversion ratio.

TABLE III: LSM±SEM VALUES FOR EGG PRODUCTION TRAITS OF CHICKENS SUMMARIZED BY MANAGEMENT SYSTEMS AND BREEDS

Fixed effects	Variables				
	Age at first egg (days)	Hen-housed egg production (%)	Peak egg production rate (%)	Age at peak production (week)	Hen-day egg production (count)
Management					
On-station	153.4±1.7^{b}	56.4±2.6^{a}	81.1±3.3^{a}	34.5±0.2^{b}	108.3±4.3^{a}
On-farm	179.1±1.2^{a}	34.9±0.7^{b}	66.0±2.6^{b}	37.3±0.3^{a}	50.5±1.2^{b}
Breed					
Kuroiler	166.5±1.5	41.9±2.5^{b}	74.7±3.0	36.2±0.3	71.3±4.1^{b}
Sasso	166.1±1.5	49.5±1.1^{a}	72.3±3.0	35.6±0.3	87.5±1.8^{a}

$^{a-b}$ Means with different superscripts within a column and effect are significantly different (P<0.05), LSM = least-squares mean, SEM = Standard error of the mean.

TABLE IV: LSM±SEM VALUES FOR THE INTERACTION EFFECTS OF MANAGEMENT SYSTEMS AND BREEDS ON EGG PRODUCTION TRAITS OF CHICKENS

Fixed effects		Variables				
Management system	Breed	Age at first egg (days)	Hen-housed egg production (%)	Peak egg production rate (%)	Age at peak production (week)	Hen-day egg production (count)
On-station	Kuroiler	159.2±2.5^{c}	49.1±4.9^{b}	83.2±4.7^{a}	35.3±0.3^{b}	91.4±8.0^{b}
	Sasso	147.7±2.5^{d}	63.7±1.9^{a}	78.9±4.7^{a}	33.7±0.3^{c}	125.2±3.1^{a}
On-farm	Kuroiler	173.8±1.7^{b}	34.5±1.0^{c}	66.2±3.6^{b}	37.0±0.4^{a}	51.3±1.6^{c}
	Sasso	184.5±1.7^{a}	35.2±1.0^{c}	65.7±3.7^{b}	37.5±0.4^{a}	49.8±1.7^{c}

$^{a-d}$ Means with different superscripts between breeds within management system are significantly different (P<0.05), LSM = least-squares mean, SEM = Standard error of the mean.

TABLE V: MORTALITY RATES OF BIRDS (%) DURING THE GROWING AND LAYING PHASES SUMMARIZED BY MANAGEMENT SYSTEMS, BREEDS, AND BREEDS WITHIN A MANAGEMENT SYSTEM

Fixed effects		Growing phase			Laying phase		
		Mortality	χ^2-test	P-value	Mortality	χ^2-test	P-value
Management	On-station	10.6	24.3792	***	17.0	53.7141	***
	On-farm	22.1			47.1		
Breed	Kuroiler	12.5	14.2977	***	30.9	1.5680	ns
	Sasso	21.2			36.1		
On-station	Kuroiler	7.5	4.9362	*	16.5	0.0402	ns
	Sasso	13.7			17.5		
On-farm	Kuroiler	16.7	9.7072	**	43.1	1.8581	ns
	Sasso	27.4			51.0		

*(P < 0.05); ** (P <0.01 *** (P < 0.001); ns (P > 0.05).

C. Effect of Management System and Breed on the Survivability of Kuroiler and Sasso Chickens

The mortality rates of the birds during the growing and laying phases are summarized by management systems, breeds, and breeds within management systems (Table V). There were significant differences (P<0.05) between the two management systems for the survivability of chickens. Birds reared under on-station management had lower mortality rates (growing 10.6% and laying 17.0%) than birds reared under on-farm management (growing 22.1% and laying 47.1%). The general effect of the breed was significant (P<0.05) only during the growing period where Sasso had a higher percentage of deaths (21.2%) than Kuroiler (12.5%). Breed effects within the management system were significant only during the growing period, where Kuroiler had lower mortality rates than Sasso under both management systems i.e. (on-station 7.5% vs. on-farm 16.7%) and (on-station 13.7% vs. on-farm 27.4%) for

RESEARCH ARTICLE

European Journal of Agriculture and Food Sciences
www.ejfood.org

Kuroiler and Sasso respectively. No significant difference (P>0.05) was observed for mortality rates of the two breeds within the management system during the laying period. In general, a higher percentage of mortality of chickens had occurred during the laying than during the growing period, where the on-farm management system encountered more deaths.

VI. Discussion

Performance traits are mostly affected by genotype (breed, strain, lines, ecotype, etc.) and environment (management system, nutrition, diseases, etc.). In this study, most of the traits studied were affected by both genotype and environment depending on the stage of growth. The mean body weight and body weight gain of chickens reared on-station were higher than of those chickens reared on-farm, implying a higher growth rate under on-station than on-farm conditions. The most likely explanation for the higher growth performance of on-station birds could be the provision of formulated rations throughout the experimental period. The on-farm birds were only supplemented with any available feeds at the household mainly maize bran and kitchen leftovers, which may not supply the sufficient nutrients required for growth. This suggests that the on-farm management conditions were less favorable for the two breeds unless higher levels of supplementation are adopted. This observation is supported by the results reported previously [13]-[15]. Besides, Bekele et al [16] and Kayitesi [17] argued that chickens reared under semi-scavenging spend most of their time searching for feed. This results in much loss of energy that could otherwise be used for production including weight gain and egg production.

In general, the two breeds did not differ significantly in respect of body weight and body weight gain. However, important interactions were observed between breeds and management systems on these variables. It was found that, whereas Sasso birds reared under an on-station management system were heavier and grew faster than Kuroiler birds, they performed poorer than Kuroiler birds under an on-farm management system. The higher growth performance of Sasso than Kuroiler chickens under on-station management conditions could be explained by its lower feed conversion ratio. This may suggest that the breed is more efficient at converting feed to live bodyweight. A similar observation has been also reported by Sanka et al [18] when comparing Kuroiler and Sasso chickens fed different diets. On the other hand, the lower performance of Sasso than Kuroiler chickens under on-farm management conditions has also been reported by Kidie [19] under similar management systems in Ethiopia. This probably suggests that the Sasso breed needs relatively better management conditions to express its full genetic potential. It is also likely that the Sasso breed has less scavenging ability than that of Kuroiler, hence failed to efficiently utilize the available scavenging feed resources under the on-farm conditions.

The bodyweight of Sasso chickens observed in the present study at 20 weeks of age under on-station management is within the range of 2343.7 to 2962.1 g reported by Bamidele et al [20] for the similar breed, age, and management system in Nigeria. Similarly, the observed body weight of Kuroiler chickens at 20 weeks of age in the present study falls within the range of 1728±8.2 to 1909±4.0 g reported by Kidie [19]. However, Assefa et al [21] reported that the mean body weight of Sasso chickens ranged from 3.01 to 3.23 kg under on-farm management conditions, which was much higher than what was observed in the present study. The genetic differences between lines, variation in supplementary feeds, and availability of scavengable feed resources in the respective areas could explain the observed difference between the current result and those reported by Assefa et al [21].

The on-station management system also outperformed the on-farm management system in all egg production characters, as was the case for body weight and other characters. Birds under the on-station management system laid their first egg about 25 days earlier and reached peak production earlier than those under the on-farm management system. It was further observed that the hen-housed egg production (HHEP) under on-station management was twice as much that of the on-farm management birds. Also, the on-farm birds had 21.5% and 15.1% lower hen-day egg production and peak egg production respectively, than the on-station birds. Studies elsewhere in the tropics have also reported better performance of on-station birds over those under on-farm management [22], [16]. The lower performance of on-farm birds might have been due to the prevalence of diseases and infrequent feed supplementation to birds which in most cases depended on seasons and household practices. A similar notion has been expressed by Goromela et al [23] and Knueppel et al [24].

The observed significant interactions between the management system and breed on hen-housed egg production, hen day egg production, and age at peak egg production rate in the present study imply that the two breeds differed in their response to management systems. It was observed that while the two breeds performed similarly in respect of hen-day egg production, age at peak production, and hen-housed egg production under the on-farm management system, Sasso chickens outperformed Kuroiler for these characters under the on-station management system. This observation may imply that the Sasso breed needs relatively better management than the Kuroiler for them to express its full genetic potential. Nevertheless, this observation is contradictory to that of Bamidele et al [20] who observed that Kuroiler chickens outperformed Sasso chickens in HHEP under on-station management. Such contradiction is not surprising since this character depends also on factors such as temperature, disease, and the ability of the birds to tolerate these effects. For example, [25] and [16] reported contradictory results on HHEP where Rhode Island Red breed (RIR) was superior to Fayoumi in an earlier study whereas the reverse was observed in a latter study. This was attributed to the slow recovery of RIR against Fowlpox disease. On the other hand, the HHEP for Kuroiler and Sasso chickens observed in the present study under on-farm management are lower than 77.60±1.74 eggs of the Vanaraja dual-purpose breed reported by Singh et al [26] under backyard management in India.

The age at first egg is deemed to be the age of attainment of sexual maturity of the chickens and is an important economic egg production character. In this study, Sasso chickens matured earlier than Kuroilers under the on-station management system, while the reverse was observed under the on-farm management system. The Sasso also attained a peak egg production rate earlier than the Kuroiler under the on-station management

RESEARCH ARTICLE

European Journal of Agriculture and Food Sciences
www.ejfood.org

system. The better performance of Sasso than Kuroiler in respect of age at sexual maturity and age at peak egg production under on-station conditions might be attributed to its higher live body weight at the onset of egg production. According to Olawumi [27], body weight is among the factors that determine the age at first egg, age at egg peak production, and overall performance. It is to be noted that the Sasso breed was also heavier than the Kuroiler under on-station management as has been explained earlier. A similar observation was reported by [27] for Bovan Nera chickens when they were compared with other genotypes under an on-station management system in Nigeria. In comparison to the present findings on age at first egg under on-farm management conditions, [28], [19], [29] reported lower age at the first egg for Sasso i.e., 157.2, 176, and 177 days respectively. Likewise, Bamidele et al [20] reported the age at first egg of 120±1.3 and 133±0.6 days for Kuroiler and Sasso, respectively under on-station management, values which were also lower than those of the present study. However, Islam et al [30] and Kidie [19] reported the mean age at first egg of 184 days for Kuroiler under an on-farm management system, which was higher than that of the present study for the similar breed and management conditions. Differences in nutritional level, availability of scavengable feed resources, and other environmental factors might be the reasons for the differences between the results obtained in the present study and those from other authors.

Concerning survivability of chickens, higher mortality rates were observed for the birds raised under the on-farm than under the on-station management conditions. The high mortality rates under on-farm management were mainly due to diseases and other unknown reasons. Probably poor management practices including inadequate feeding, poor housing, and health care might be the predisposing factors for mortality. This observation is similar to the report of several authors [15], [13], [17], [31]. The on-station mortality rates in the present study were mainly due to diseases and cannibalism (cloaca pecking) during the growing and laying periods, respectively. It has been suggested that the exposure of the cloacal mucous membranes soon after the actual expulsion of an egg may attract other hens which start vent pecking [32]. This probably attracted the chickens to develop such behavior, although the actual cause of cannibalism was not considered for analysis. The on-station mortality rates observed in this study are within the range of 5.5 to 13.0% and 16.0 to 28.3% during the growing and laying periods, respectively reported by Bamidele et al [20] for similar breeds and similar management conditions in Nigeria.

The present study also revealed that a higher percentage of mortality occurred during the laying than during the growing period. This could partially be explained by the fact that the laying period in this study coincided with the dry season, which is associated with insufficient feed sources and the occurrence of several diseases affecting chickens in rural areas [33], [34]. This observation agrees with the argument put forward by Kidie [19] that inadequate feeding and imbalanced nutrition, especially at the peak of production, may lead to high percentages of mortality as at that period birds require balanced rations for body maintenance and egg production. Higher mortality rates during the laying period than during the growing period were also reported by Bekele et al [16] in Ethiopia. Generally, Kuroiler had a comparatively higher survival rate than the Sasso under both management systems. Bamidele et al [20] reported similar observations under on-station management conditions in Nigeria. The genetic differences and the ability of the breed to tolerate environmental stress in a particular environment might have been the reasons for such variation. Kuroiler chickens are said to be resistant to infectious diseases as reported from other studies [7], [35], [36]. This observation is also supported by the findings from the study by Mpenda et al [37] who reported higher antibody titers in Kuroiler chickens than in other breeds.

VII. Conclusion

Based on the results of the present study, it is concluded that there is a large difference between the on-station and the on-farm management systems for all chicken performance traits studied. Also, a bird's performance depends on the interaction between the breed and the management system. The Kuroiler seemly to cope comparatively better than Sasso under sub-optimal management conditions while the Sasso excelled under improved management. Thus, the introduction of improved chicken genotypes to farmers should go hand in hand with the provision of knowledge on the overall management of the birds for improved productivity. However, cost-benefit studies are recommended for these introduced breeds to understand their economic viability under the on-station and on-farm management conditions.

Acknowledgment

This research was carried out under the financial support of the African Chicken Genetic Gains (ACGG) project in Tanzania sponsored by the Bill and Melinda Gates Foundation (Grant Agreement OPP1112198). The authors express their appreciation to the Department of Animal, Aquaculture, and Range Sciences of Sokoine University of Agriculture for providing necessary facilities for on-station study. We are further grateful to households and field officers who participated in the project for their cooperation during data collection under the on-farm study.

Ethical Statement

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

Statement of animal rights: National and institutional procedures for the care and use of animals were followed. 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

[1] Aklilu, H., Almekinders, C.J.M., Udo, H.M.J and Van der Zijpp, A.J. (2007). Village poultry consumption and marketing in relation to gender, religious festivals and market access. *Tropical Animal Health and Production 39*, 165-168.

[2] MLFD (2015). Ministry of Livestock and Fisheries Development. Tanzania livestock modernization initiative. Dar es Salaam, Tanzania: Ministry of Livestock and Fisheries Development. Available: https://livestocklivelihoodsandhealth.org/wpcontent/uploads /2015/07/Tanzania_Livestock_Modernization_Initiative_July_2015.pdf.

RESEARCH ARTICLE

European Journal of Agriculture and Food Sciences
www.ejfood.org

[3] Permin, A. (2008). Good practices in small-scale poultry production: A manual for trainers and producers in East Africa. A Consultancy Report to FAO, FAO ECTAD Regional Unit Eastern Africa, Nairobi, Addis Ababa, Ethiopia.
[4] Ali, K.O., Katule, A.M. and Syrstad, O. (2000). Genotype X Environment interaction for growing chickens: Comparison of four genetic groups on two rearing systems under tropical condition, *Acta Agriculturae Scandinavica*, Section A-Animal Sciences, 50(2), 65–71.
[5] Da Silva, M., Desta, S. and Stapleton, J. (2017) Development of the chicken sector in the Tanzanian Livestock Master Plan. Available: https://core.ac.uk/download/pdf/132697821.pdf.
[6] 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).
[7] SASSO (2014). Coloured chicken genetics. Available: http://www.sasso.fr/coloured-chicken-genetics-for-organic-red-label-farmer-chickens.html.
[8] Ahuja, V., Dhawan, M., Punjabi, M. and Maarse, L. (2008). Poultry-based livelihoods of rural poor: Cast of Kuroiler in West Bengal. Research report document 012. South Asia Pro-Poor Livestock Policy Programme. Available: http: //www. drcsc.org/VET/ library/Animal/Bk–Poultry _Based _Livelihoods.pdf.
[9] Mengsite, F.W., Yitbarek, M.B. and Getachew, E. (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.
[10] Sharma, J. (2011). A new breed: Highly productive chickens help raise Ugandans from poverty researcher at the Center for Infectious Diseases and Vaccinology at ASU's Bio-design Institute. Available: https://asunews.asu.edu/ node/21034.
[11] North, M.O. (1984). Breeder Management. In Commercial Chicken Production Manual. The Avi. Publishing Company. Inc. Westport, Connecticut. 240-243, 298-321 pp.
[12] SAS (2009). Statistical Analytical System. User Guide for Personal Computers, Statistical Programme. Windows Version 9.2, SAS Institute Inc. Cary, NC, USA.
[13] Lwelamira, J., Kifaro, G.C. and Gwakisa, P.S. (2008). On station and on-farm evaluation of two Tanzania chicken ecotypes for body weights at different ages and for egg production. *African Journal of Agricultural Research*, 3(12), 843-851.
[14] Magala, H., Kugonza, D.R., Kwizera, H. and Kyarisiima, C.C. (2012). Influence of management system on growth and carcass characteristics of Ugandan local chickens. *Journal of Animal Science Advances* 2(6), 558–567.
[15] Wondmeneh, E., Van der Waaij, E.H., Udo, H.M.J., Tadelle, D. and Van Arendonk, J.A.M. (2016). Comparison of different poultry breeds under station and on-farm conditions in Ethiopia. *Livestock Science* 183 (2016) 72–77. Available: http://dx.doi.org/10.1016/j.livsci.2015.11.019.
[16] Bekele, F., Gjøen, H.M., Kathle, J., Ådnøy, T. and Abebe, G. (2009). Genotype X environment interaction in two breeds of chickens kept under two management systems in Southern Ethiopia. *Tropical Animal Health and Production* 41:1101–1114. Available: https://www.researchgate.net/publication/23665839.
[17] Kayitesi, A. (2015). Management systems and location effects on growth and carcass traits of Kuroiler and Local chickens. MSc Thesis. Makerere University, Uganda.
[18] 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. *Tropical Animal Health and Production* 52(6), 3315-3322
[19] Kidie, H.A. (2019). Characterization of chicken production system and on-farm evaluation of introduced exotic chicken breeds in Gondar Zuria and Kalu districts of Amhara region, Ethiopia. MSc Thesis. Haramaya University, Haramaya, Ethiopia.
[20] 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*. Available: https://doi.org/10.1007/s11250-019-02158-9.
[21] Assefa, S., Melesse, A. and Banerjee, S. (2018). Egg production and linear body measurement traits of local and three exotic chicken genotypes reared under two agroecological zones. *International Journal of Ecology and Ecosolution* 5(2), 18-23.
[22] Sazzad, M.H. (1992). Comparative study on egg production and feed efficiency of different breeds of poultry under intensive and rural conditions in Bangladesh. *Livestock Research for Rural Development* 4(3): 65-69. Available: http://www.fao.org/ag/aga/agap/frg/lrrd/lrrd4/3/bangla1.htm.
[23] Goromela, E. H., Kwakkel, R. P., Verstegen, M. W. A. and Katule, A. (2006). Strategies to optimize the use of scavengeable feed resource base by smallholder poultry farmers. *African Journal of Agricultural Research* 1: 91-100. Available: http://www.academicjournals.org/AJAR.
[24] Knueppel, D., Peter, C., Ayubu, O.M., Peter, M., David, M. and Carol, C. (2009). Improving Poultry Production for Sustainability in the Ruaha Landscape, Tanzania. Wildlife Conservation Society, 24.
[25] Akhtar, N., Mahmood, S., Hassan, M. and Yasmeen, F. (2007). Comparative study of production potential and egg characteristics of Lyallpur Silver Black, Fayoumi and Rhode Island Red breeds of poultry, *Pakistan Veterinary Journal*, 27(4), 184–188.
[26] Singh, P., Kachroo, D., Thakur, N.P., Khajuria, V., Kumar, P., Kumar, M., and Kour, G. (2018). Comparative Performance of Vanaraja, Gramapriya, and Indigenous Desi Bird under Backyard System of Rearing in Jammu Province, India. *International Journal of Current Microbiology and Applied Sciences* 7(02), 101-105. Available: https://doi.org/10.20546/ijcmas.2018.702.013.
[27] Olawumi, S.O. (2011). Study on pre-laying characteristics of three breeds of commercial layers in the Derived Savannah Zone of Nigeria. *Pakistan Journal of Biological Sciences* 14(23), 1061–1065.
[28] Kejela, Y. (2020). Production Performance of Chicken under Farmers' Management and Their Roles at Urban Household Economy in Southern Ethiopia. *Agricultural Sciences* 11: 178-190.
[29] Getiso, A., Jimma, A., Asrat, M., Kebede, H.G., Zeleke, B. 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.
[30] 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.
[31] Abalaka G.O., Mkpado M. and Ugwu S.O.C. (2013). Rearing methods, seasons of the year, and survivability of rural poultry enterprise in Nigeria. *Journal of Agriculture and Sustainability*, 3(1), 27–55.
[32] Savory, C.J. (1995) Feather pecking and cannibalism. *World's Poultry Science Journal*, 51: 215–219.
[33] Mwalusanya, N.A., Katule, A.M., Mutayoba, S.K. and Mtambo, M.M.A. (2002). Productivity of local chickens under village management conditions. *Tropical Animal Health and Production* 34: 405-416.
[34] Alem T (2014). Production and reproduction performance of rural poultry in lowland and midland agro-ecological zones of Central Tigray, Northern Ethiopia. *African Journal of Agricultural Research* 9(49):3531-3539.
[35] Fleming, D.S., Koltes, J. E., Markey, A.D., Schmidt, C.J., Ashwell, C.M., Rothschild, M.F., Persia, M.E., Reecy, J.M. and Lamont, S.J. (2016). Genomic analysis of Ugandan and Rwandan chicken ecotypes using a 600 k genotyping array. BMC Genomics 17: 407.
[36] Okumu, N.O. (2016). Genetic diversity and viral disease resistance of the indigenous chickens from selected areas in Kenya. MSc Thesis, Kenyatta University, Kenya.
[37] Mpenda, F.N., Lyantagaye, S.L. and Buza, J. (2020). Immune response following Newcastle disease immunization and growth performance of Kuroiler, broiler, and local Tanzanian chickens. *International Journal of Livestock Production*, 11(1), 1-7.

CHAPTER FOUR

PAPER III

Effects of breed and management system on egg quality traits of two improved dual-purpose chicken breeds

Submitted in: Livestock Research for Rural Development

Effects of breed and management system on egg quality traits of two improved dual-purposes chicken breeds

F S Guni, S H Mbaga[*], A M Katule[*] and E H Goromela[**]

Tanzania Livestock Research Institute - Uyole, P.O.Box 6191 Mbeya, Tanzania.
fadhili.guni@yahoo.com

[*]Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture, P.O. Box 3004, Morogoro, Tanzania.

[**]Tanzania Livestock Research Institute - Naliendele, P. O. Box 1425, Mtwara, Tanzania.

Abstract

This study was conducted to evaluate egg quality traits of Sasso and Kuroiler chickens under semi-scavenging (on-farm) and deep litter (on-station) management conditions, as well as the phenotypic correlations between the traits. A total of 666 fresh eggs (246 from on-farm and 420 from on-station) were used to evaluate the external and internal egg quality traits. The eggs were collected from 240 hens raised on-station and 320 hens raised on-farm. The external egg quality traits evaluated were egg weight, length, width, shape index, shell weight, shell thickness and shell ratio while the internal egg quality traits evaluated were the yolk weight, albumen weight, yolk ratio, albumen ratio, albumen height and Haugh unit were. The collected data were analyzed using the General Linear Models (GLM) procedure of SAS software (SAS 2009). The results show that the mean values of all egg quality traits studied were higher for on-station than on-farm except shell, yolk and albumen ratios which did not differ between the two management systems. With regards to breed effects, Kuroiler chickens had higher values for egg weight, egg length, yolk weight, albumen height and Haugh unit than Sasso chickens. Significant interaction effect of management system and breed was observed on egg weight and

eggshell ratio. The Pearson's correlation coefficients showed that egg weight was positively correlated with all external and internal egg quality traits of both Sasso and Kuroiler chickens, except with shape index and yolk ratio for external and internal egg quality respectively. The results suggest that an appropriate management system for these improved chickens should be considered for maximum egg quality traits.

Keywords: Egg quality, Kuroiler, On-farm, On-station, Sasso

Introduction

Poultry eggs have been traditionally considered as an important source of nutrients for humans, and nutritionally are a complete food that is used throughout the world regardless of religious and ethnic groups (Stadelman and Cotterill 2001; Kraus and Zita 2019). Nowadays, it is widely recognized that eggs are more than a source of nutrients, but also play important roles in most pharmaceutical, food-processing and cosmetic industries (Mine and Kovacs-Nolan 2004; Abeyrathne et al 2013). In the egg processing industries, the shell, albumen and the yolk that form the egg, as well as their proportions, affect the amount and price of the product (Altan et al 1998).

Egg quality is the general term that refers to general standards which define both internal and external quality. It has also been defined by Stadelman (1977) as the characteristics of eggs that affect its acceptability to the consumers and is a more important price contributing factor in table and hatching eggs. External egg quality traits include size and shell qualities, while the internal egg quality traits include yolk and albumen qualities. The eggshell is an economically important trait as it determines the ability of eggs to withstand transportation shocks from producers to consumers (Mertens et al 2006). It has been reported by Bobbo et al (2013) that approximately 7-8 % of the total amount of eggs get broken through the transfer from the production to the consumer leading to serious

economic losses both to the producers, dealers and consumers (Hamilton 1982). The eggshell is also necessary to impede pathogenic challenges from the external environment of eggs and so to reduce food poisoning risks (Coutts et al 2006; Mertens et al 2006). On the other hand, albumen and the yolk in eggs have several proteins with functional properties such as nutrition, health, and antimicrobial effects (Kovacs-Nolan et al 2005; Ko and Ahn 2008; Abeyrathne et al 2013). There are some propositions that eggs with the heaviest yolks and the largest yolk to albumen (Y: A) ratios may contain the highest amounts of cholesterol (Hussein et al 1993; Campo 1995). Given that possibility, eggs containing a small proportion of yolk and a large proportion of albumen would appear to be suitable for consumers of table eggs, whereas eggs containing a large proportion of yolk should be more appropriate for processed foods such as mayonnaise, baking goods, creams and omelette, which use the yolk as a major ingredient. So, the knowledge of these traits and influencing factors is important. Previous studies have shown that the egg quality traits are influenced by several factors; among which are genotype and management system (Matt et al 2009; Tang et al 2015).

Sasso and Kuroiler chickens are dual-purpose breeds that have been introduced in Tanzania as a way of improving the productivity of the poultry industry and improve people's livelihoods. The productive performance in terms of growth, egg production and survivability of these breeds has been recently evaluated under different management systems and environments, and the breeds have shown promising performance in Tanzania (Sanka et al 2020; Guni et al 2021a; Guni et al 2021b), Ethiopia (Kidie 2019; Biazen et al 2021) and Nigeria (Bamidele et al 2019). However, little research has been done on the egg quality traits of these breeds under different management systems in Tanzania. Therefore, this study intended to evaluate the egg quality traits of Sasso and

Kuroiler chickens under semi-scavenging (on-farm) and deep litter (on-station) management systems to establish if there are significant breed and management system effects on egg quality characteristics. Understanding the phenotypic correlations that exist between egg quality traits is also important for breed selection and trait improvement.

Materials and methods

Location of the study area

The study was conducted for a period of 52 weeks from December 2018 to December 2019 using Sasso and Kuroiler chickens under on-station and on-farm conditions. The on-station study was conducted at Sokoine University of Agriculture (SUA). The University is located at the foothills of the Uluguru Mountains in Morogoro municipality, Eastern Tanzania, about 550 m above sea level. The on-farm study was conducted in two villages i.e. Wami-Sokoine and Wami-Luhindo about 45 Km from the University.

Management of chicks during brooding

A total of 1200 (600 Kuroiler and 600 Sasso) day-old chicks were purchased from AKM Glitters in Dar es Salaam and Silverlands Tanzania in Iringa regions respectively to be used in this study. Brooding was done for six weeks at the Poultry farm of the Sokoine University of Agriculture. On arrival these chicks were weighed, wing tagged and thereafter placed into the deep litter brooding pens, where four brooder guards with five feet diameter circle each were made using ceiling boards and each had capacity of holding 300 chicks. Commercial feeds purchased from Silverland Tanzania Company were used for both breeds throughout the brooding period and the on-station experiment. During the brooding period, chicks were fed a starter diet in form of crumbles containing 2941 Kcal ME/kg and 21.2% CP from day old up to the end of 2nd week and chick mash containing 3049 Kcal ME/kg and 20.3% CP from the 3rd up to end of the 6th week. Clean water was

provided in ad-libitum. Chicks were vaccinated against Newcastle disease, Gumboro, and Fowlpox in accordance to the vaccination schedules. Chick sexing was done at the end of the brooding period.

On-farm management of the experimental birds

At the end of brooding, three hundred and twenty (320) pullets were distributed to selected farmers in the two villages. The selection of villages and farmers participating in the study was done in collaboration with District and Ward livestock officers. The selection of villages was done purposively so that both on-farm and on-station evaluation could be done in a similar environment in terms of altitude, rainfall pattern, humidity and temperature. On the other hand, the selection of farmers was done randomly from a list of farmers who had been keeping chickens for at least five years. In each village, 16 farmers were involved in the study. Each farmer was allocated with 10 pullets of a single breed. The allocation of the breed was done randomly by writing breed names in separate 16 pieces of paper (8 for Kuroiler and 8 for Sasso) and each farmer was required to select only one piece of the unfolded paper. Lastly, half of the farmers in each village received Sasso pullets and the remaining eight farmers received Kuroiler pullets. The pullets were reared under a semi-scavenging system of management. These experimental birds were kept in shelters where simple enclosures were made around the shelters which allowed restriction of non-experimental birds and predators from entering the shelters. Cereal grains, cereal by-products and kitchen leftovers were the main feeds supplemented to the experimental birds.

On-station management of the experimental birds

Under the on-station experiment, a total of two hundred and forty (240) pullets were randomly allocated to 6 deep litter pens (3 for Kuroiler and 3 for Sasso) of 40 birds each

and reared under total confinement. The birds were provided with a commercial grower ration containing 15.5% CP and 2762 Kcal ME/kg, from the 7th week to the end of the 19th week of age. Thereafter, the birds were provided with layer rations containing 18.5% CP and 2965 Kcal ME/kg from the 20th week up to 52nd week.

Measurement of the external egg quality traits

Samples of eggs were collected at four weeks intervals beginning at 28th to 52nd week of age. A total of 666 fresh eggs (246 eggs from on-farm and 420 eggs from on-station) were used to evaluate the external egg quality traits. External egg quality traits evaluated include egg weight, length, width, shape index, shell weight, shell thickness and shell ratio. Egg weights were obtained by weighing individual eggs using a digital weighing balance whereas the length and width of the eggs were measured using a digital vernier calliper. The egg shape index (%) was calculated as the ratio of egg width to egg length times 100. The eggshells with their membranes were dried on open-air and weighed using a digital weighing balance. The shell weight was divided by egg weight to get the shell ratio. The thickness of shells was measured using a digital vernier calliper.

Measurement of the internal egg quality traits

The eggs used for external egg quality measurements were also used to measure the internal egg quality traits. The internal egg quality traits evaluated include yolk weight, albumen weight, yolk ratio, albumen ratio, albumen height and Haugh unit. The internal egg quality measurements were obtained by carefully breaking the egg followed by separation of the albumen and the yolk contents. The weight of albumen was obtained by taking total internal egg weight (i.e., yolk weight + albumen weight) minus yolk weight. The albumen weight and yolk weight were determined using a digital weighing balance. Albumen and yolk ratios were calculated by taking their weights as the percentage of total

egg weight. Haugh Unit (HU) was calculated according to Haugh (1937) by fitting the average albumen height and egg weight into the following equation: $HU=100 \log (H + 7.57 – 1.7W^{0.37})$, where H = Albumen height and W = Egg weight.

Statistical data analysis

The General Linear Models (GLM) procedure of SAS software (SAS 2009) was used to analyze all traits measured with the MANOVA option for calculating partial correlation coefficients among the egg quality variables. Management system and the breed were considered as fixed effects while individual farmer or pen effect within a management system was taken as a random effect.

The following statistical model was used to analyze the external and internal egg quality traits observed on a pen or individual farmer (i.e., the pen or individual farmer was the observation unit):

$Y_{ijklm} = \mu + M_i + B_j + (MB)_{ijk} + FP(MB)_{ijkl +} E_{ijklm}$

Where:

Y_{ijk} = observation (Egg quality traits) from the k^{th} farmer/pen within the j^{th} breed and i^{th} management system;

μ = General mean common to all observations in the study;

M_i = Effect of the i^{th} management system (i= on-station, on-farm);

B_j = Effect of the j^{th} breed (j= Kuroiler, Sasso);

$(MB)_{ijk}$ = Effect associated with the interaction between management system and breed;

FP $(MB)_{ijkl}$ = Random effect of the k^{th} farmer/pen within the j^{th} breed and i^{th} management system;

E_{ijklm} = Random effects peculiar to each bird;

Note: Effects of the management system and breed for egg quality variables were tested using the farmer/pen variation within the management system and breed (i.e. $FP(MB)_{ijk}$) as the error term.

Results and discussions

Effects of management system and breed on external egg quality traits

The least-square means for the effects of management system and breed on external egg quality traits of chickens are presented in Table 1. Management system significantly ($P<0.05$) affected all external egg quality traits except shell ratio, while breed of chicken significantly ($P<0.05$) affected egg weight and egg length.

Table 1. Least square means (±se) for the effects of management system and breed on external egg quality traits of chickens

Variable	Management		P-value	Breed		P-value
	On-farm	On-station		Kuroiler	Sasso	
Egg weight (g)	53.20±0.37[b]	59.73±0.24[a]	<.0001	57.13±0.33[a]	55.80±0.29[b]	0.0365
Egg length (mm)	55.94±0.19[b]	57.05±0.12[a]	<.0001	56.89±0.17[a]	56.10±0.15[b]	0.0060
Egg-width (mm)	41.28±0.11[b]	43.00±0.07[a]	<.0001	42.28±0.09	41.99±0.08	0.1069
Egg Shape index (%)	73.92±0.27[b]	75.48±0.18[a]	<.0001	74.73±0.24	74.97±0.22	0.1062
Shell weight (g)	6.08±0.06[b]	6.94±0.04[a]	<.0001	6.58±0.05	6.44±0.05	0.1131
Shell ratio (%)	11.47±0.10	11.67±0.06	0.1499	11.56±0.09	11.59±0.08	0.9683
Shell thickness (mm)	0.53±0.00[b]	0.56±0.00[a]	0.0008	0.55±0.00	0.54±0.00	0.9921

[a-b] *Means with different superscripts within a row and effect differed significantly (P<0.05).*

Egg weight differed ($P<0.05$) between the two management systems with on-station birds laying heavier eggs (59.73±0.24 g) than on-farm (53.20±0.37 g). The observed difference between the two management systems on egg weight might be due to insufficient feeding prevailing under on-farm that does not support the birds with adequate levels of nutrition needed to express their genetic potential. Similarly, Champati et al (2020) reported heavier eggs for intensively reared chickens than for semi-intensive while Dong et al (2017) and Küçükyılmaz et al (2012) also observed variation in egg weight for different rearing systems. In contrast to the present findings, Patel et al (2018) and Sokołowicz et al

(2018) did not find significant differences in egg weight between deep litter and other rearing systems. Conflicting reports from these authors could be due to the effect of a variety of factors such as genotype used, nutrition, and environment (Rakonjac et al 2014). The shape index is the ratio between the width and length of the egg, which is a good indicator of uniformity in the size of the eggs. In the present study, the egg shape index was higher for on-station (75.48±0.18) than for on-farm (73.92±0.27) which could be explained by the size and weight of an egg. Normally egg length and width are the determinants of the shape of an egg. In the present study egg length and width were higher for on-station eggs (57.05±0.12 and 43.00±0.07 mm) than for on-farm eggs (55.94±0.19 and 41.28±0.11 mm). Sokołowicz et al (2018) had a comparable observation where the egg shape index was found to be higher for birds under deep litter than those from free-range and organic systems. Similarly, using Red Island Red (RIR) and Fayoumi chicken breeds, Bekele et al (2009), found a higher egg shape index for eggs from the on-station than from on-farm. On the contrary, Sekeroglu et al (2010), Oke et al (2014), and Champati et al (2020) reported the effect of rearing system on egg shape indices not to be significant. The shape index in the present study varied from 73.92±0.27 to 75.48±0.18 %. This value falls within the range of 72 to76% reported by Altuntas and Sekeroglu (2008) as the standard/normal shape. Therefore, both Sasso and Kuroiler chickens had eggs of standard size that fit properly in normal egg trays. It has been suggested that the eggs with a shape index below 72% are sharp and those above 76% are roundish (Altuntas and Sekeroglu 2008) which increase the possibility of breakages during transportation.

Eggshell quality is also associated with levels of resistance to breakages during transportation. In this study, the management system significantly ($P<0.05$) affected shell weight, and shell thickness in favour of on-station. The lower values for on-farm eggs for shell quality traits are most likely to be associated with poor feeding coupled with

inadequate intake of Calcium (Ca) and other trace minerals. It has been reported by Roberts (2010) that Calcium supplementation is a key for eggshell quality, each eggshell contains up to 3 g of Ca, and so the diet of hens must contain an adequate amount of Ca in utilizable form. Since the on-station birds were provided with a commercial diet, it is anticipated that they had well-balanced minerals required for eggshell formation. Nevertheless, several authors have reported varying results on the effect of the management system on shell weight and shell thickness. For example, Ogunshola et al (2018) reported heavier eggshells in the deep litter system than in the cage system but there was no significant difference in shell thickness between these systems. On the other hand, Dahloum et al (2018) did not find differences in shell weight of eggs from different rearing systems. Kühn et al (2014) also did not find differences in shell weight and thickness of eggs from the litter-floor and free-range systems. Likewise, Patel et al (2018) observed no differences in shell thickness of eggs from deep litter, semi-scavenging and backyard management. These inconsistent results might be associated with the interaction of the management system with several factors affecting these traits including genotype used, age, oviposition time, and nutrition (Ketta and Tumova 2016).

With regard to breed effects on external egg quality, results show that only egg weight and egg length differed ($P<0.05$) between the two breeds. Kuroiler chickens had heavier eggs (57.13±0.33 g) than Sasso (55.80±0.29 g). Similarly Kuroiler chickens had longer eggs (56.89±0.17 mm) eggs than Sasso chickens (56.10±0.15 mm). This difference might be due to variations in genetic make-up between the breeds. However, using similar breeds, Sanka et al (2021) did not find significant differences in egg weight, which might be due to differences in the management of the birds, specifically on feeding practices. The overall egg weight for Sasso chickens in the present study is within the range of 45.7 – 59.9g reported by Sanka et al (2021) and Kidie (2019) for the same breed. Likewise, the

egg weight for Kuroiler in this study is within the range of 46.25 – 59.0 g reported by the same authors. In contrast, Bamidele et al (2019) reported that the overall egg weight for Kuroiler and Sasso was 54.0 and 54.9 g respectively, which was lower than the egg weight observed in the present study. This difference may be attributed to variation in feeding, hen's age and other environmental factors affecting egg weight in chickens.

Effects of management system and breed on internal egg quality traits

The least-square means for the effects of management system and breed on internal egg quality traits of chickens are presented in Table 2. Management system significantly (P<0.05) affected all internal egg quality traits except yolk ratio and albumen ratio. On the other hand, yolk weight, albumen height and Haugh unit were influenced (P<0.05) by the breed of chickens.

Table 2. Least square means (±se) for the effects of management system and breed on internal egg quality traits of chickens.

Variable	Management		P-value	Breed		P-value
	On-farm	On-station		Kuroiler	Sasso	
Yolk weight (g)	17.12±0.14[b]	19.47±0.09[a]	<.0001	18.61±0.13[a]	17.98±0.11[b]	0.0029
Yolk ratio (%)	32.30±0.25	32.66±0.16	0.3047	32.62±0.22	32.35±0.20	0.3481
Albumen weight(g)	29.89±0.29[b]	33.12±0.19[a]	<.0001	31.87±0.25	31.14±0.23	0.1456
Albumen ratio (%)	56.11±0.29	55.39±0.19	0.0892	55.76±0.26	55.74±0.23	0.9565
Albumen height (mm)	6.80±0.05[b]	7.58±0.03[a]	<.0001	7.29±0.45[a]	7.09±0.41[b]	0.0080
Haugh unit	84.12±0.27[b]	86.98±0.17[a]	<.0001	85.98±0.24[a]	85.12±0.21[b]	0.0243

[a-b] *Means with different superscripts within a row and effect differed significantly (P<0.05).*

It was observed that yolk weight and albumen weight differed (P<0.05) between the two management systems with on-station eggs showing higher values than on-farm. The higher mean values for yolk weight and albumen weight from on-station eggs might be related to the size of an egg as these traits have a significant association with egg weight (Suk and Park 2001). It has to be noted that eggs from on-station were also heavier than those of on-farm, as described earlier in this study. This observation conforms to the

arguments put forward by Zhang et al (2005) and Aygun and Yetisir (2010) that egg weight influences the weight of components of eggs especially albumen and yolk. In agreement with the results of the present study Sokolowicz et al (2018) and Dong et al (2017) also observed variation in rearing systems on yolk weight.

The Haugh unit (HU) which is calculated from the height of the inner thick albumen and the weight of an egg is considered to be a typical measure of albumen quality. It is generally accepted that the higher the Haugh unit value, the better the quality of the egg. In this study, the albumen height and Haugh unit were also affected by the management system with on-station eggs showing higher values of albumen height (7.58±0.03 mm) and Haugh unit (86.98±0.17) than those of on-farm (6.80±0.05 mm) and (84.1±0.27). The higher score in albumen height and Haugh unit for eggs from on-station than on-farm could be associated with better management and nutrition of the birds; which have a significant influence on internal egg quality traits (Gerber 2012). This observation concurs with that of Bekele et al (2009) who also found higher values for eggs from on-station than on-farm. Sokolowicz et al (2018) also found a significant rearing system effect where eggs from the deep litter system outperformed free-range in Haugh unit value. However, the current finding disagreed with Dong et al (2017) who did not find any differences between rearing systems on those traits.

With regard to breed effects on internal egg quality, it was observed that the albumen height and Haugh unit differed ($P<0.05$) between the two breeds. Kuroiler had higher mean values for albumen height (7.29±0.45 mm) and Haugh unit (85.98±0.24) than Sasso (7.09±0.41 mm, albumen height and 85.12±0.21, Haugh unit). Differences between breeds/strains for albumen height and Haugh unit have been reported by several authors (Bekele et al 2009; Kucukyılmaz et al 2012). In addition to albumen height and Haugh

unit, the yolk weight was also heavier (18.61 g) for Kuroiler than for Sasso (17.98 g). Yolk weight and egg weight are positively correlated traits; probably this might be a reason for heavier yolk for Kuroiler, as the breed had also heavier eggs than Sasso. It was further observed in this study that, neither the management system nor the breed affected the yolk ratio and albumen ratio. This may imply that the share of these traits to the total egg weight of the two breeds is similar regardless of breed or management system. In agreement, Sanka et al (2021) also observed similarity in yolk and albumen ratio for Kuroiler and Sasso eggs under semi-scavenging management. Moreover, Patel et al (2018) reported similar observations on the yolk ratio but they reported contrasting results on the albumen ratio.

Effect of interaction between management system and breed on egg quality traits

Interaction effects between management system and breed on egg quality traits are presented in Table 3. The results show that there were significant interaction effects between management system and breed on egg weight and eggshell ratio. This may imply that with exception of egg weight and shell ratio, the response of the two breeds on other evaluated egg quality traits was similar when subjected to different management systems. It was observed that, while the two breeds had comparable egg weight and shell ratio on-farm, these traits differed on-station where Kuroiler outperformed Sasso on egg weight but had a lower shell ratio than Kuroiler. The probable reason for this variation might be due to differences in strength of correlation coefficients for egg weight and shell ratio between the two breeds; the correlation between egg weight and shell ratio was higher for Sasso than for Kuroiler (Table 4); therefore for every increase in egg weight, the per cent share of the shell became higher for Sasso than for Kuroiler. Similar to the present findings, Bekele et al (2009) and Kucukyılmaz et al (2012) also found significant interaction effects on egg weight when two breeds were compared under two different

rearing systems, but in contrast, Sokolowicz et al (2018) did not find significant interactions between the rearing system and breed on egg weight.

Table 3. Least square means (±se) for the interaction effect between management system and breed on egg quality traits of chickens

Variable	On-farm		On-station		P-value
	Kuroiler	Sasso	Kuroiler	Sasso	
Egg weight (g)	53.51±0.61^{c}	53.05±0.50^{c}	60.74±0.38^{a}	58.55±0.38^{b}	0.0458
Shell ratio (%)	11.60±0.15^{ab}	11.32±0.12^{b}	11.49±0.09^{b}	11.89±0.09^{a}	0.0046

$^{a-c}$ Means with different superscripts within a row differed significantly (P<0.05).

Phenotypic correlation coefficients for external egg quality traits

The phenotypic correlation coefficients for external egg quality traits are shown in Table 4. Significant and positive correlations were observed between egg weight and egg length, egg width, shell weight, shell ratio as well as shell thickness of both Sasso and Kuroiler chickens. The highest correlations were observed between egg weight and egg width for Sasso and Kuroiler chickens (0.80 and 0.66, respectively), while the lowest significant and positive correlation (0.15) was observed between egg weight and shell thickness for both Sasso and Kuroiler chickens.

Table 4. Phenotypic correlation coefficients for external egg quality traits of Sasso and Kuroiler chickens

BREED	TRAIT	Egg weight	Egg length	Egg width	Shape index	Shell weight	Shell ratio	Shell thickness
Sasso	Egg weight	1	0.68***	0.80***	-0.12*	0.40***	0.29***	0.15**
Kuroiler		1	0.59***	0.66***	-0.01^{ns}	0.50***	0.18**	0.15*
Sasso	Egg length		1	0.33***	-0.76***	0.32***	-0.14*	0.07^{ns}
Kuroiler			1	0.33***	-0.66***	0.22***	-0.18**	0.06^{ns}
Sasso	Egg width			1	0.33***	0.26***	-0.29***	0.11*
Kuroiler				1	0.47***	0.33***	-0.11^{ns}	0.33***
Sasso	Shape index				1	-0.13*	-0.06^{ns}	0.00^{ns}
Kuroiler					1	0.05^{ns}	0.08^{ns}	0.09^{ns}
Sasso	Shell weight					1	0.74***	0.27***
Kuroiler						1	0.61***	0.15*
Sasso	Shell ratio						1	0.17**
Kuroiler							1	0.06^{ns}
Sasso	Shell							1
Kuroiler	thickness							1

*** (P < 0.0001); ** (P < 0.001); *(P < 0.05); ^{ns}(P > 0.05).

This observation indicates that egg weight has a direct relation with egg width, egg length, shell weight, and shell thickness, thus may suggest that it is possible to use egg weight in determining the egg width, egg length, shell weight, and shell thickness on both Sasso and Kuroiler chickens. This observation supports the suggestion put forward by Ozcelic (2002) that the egg weight values are more appropriate in determining the shell quality since shell weight and shell thickness are mainly measured after breaking the egg. In agreement with the present results, Oluwami and Ogunlade (2008) also observed a significant correlation between egg weight and other external egg quality, with the correlation between egg weight and egg width also being the highest (0.88), following the same trend as observed in this study. Positive correlation between egg weight and shell weight was also reported by Farooq et al (2001). On the contrary, a significant but negative correlation (-0.12) was observed between egg weight and shape index for Sasso chickens, while for Kuroiler the relationship was non-significant but also negative (-0.01). In agreement with the present findings, Kul and Seker (2004) and Oluwami and Ogunlade (2008) also found negative correlation coefficients between egg weight and shape index.

Phenotypic correlation coefficients for external and internal egg quality traits

The phenotypic correlation coefficients for external and internal egg quality traits are shown in Table 5. Significant and positive correlations were observed between egg weight and yolk weight, albumen weight, albumen ratio and albumen height. In addition, the correlation between egg weight and Haugh unit was also significant and positive for Kuroiler while for Sasso chickens the relationship was not significant but positive. The highest correlations in both breeds were observed between egg weight and albumen weight (0.83 and 0.85, respectively) for Sasso and Kuroiler chickens. These results may imply that egg weight can be used to estimate internal egg contents (yolk and albumen weight) as well as the albumen ratio without breaking the egg.

Table 5. Phenotypic correlation coefficients for external and internal egg quality traits of Sasso and Kuroiler chickens

BREED	TRAIT	Yolk weight	Yolk ratio	Albumen weight	Albumen Ratio	Albumen height	Haugh unit
Sasso	Egg weight	0.39***	-0.42***	0.83***	0.23***	0.39***	0.02ns
Kuroiler		0.55***	-0.27***	0.85***	0.23***	0.55***	0.23***
Sasso	Egg length	0.27***	-0.27***	0.57***	0.16**	0.28***	0.02ns
Kuroiler		0.32**	-0.15**	0.44***	0.00ns	0.33***	0.13*
Sasso	Egg width	0.35***	-0.29**	0.70***	0.25***	0.36***	0.07ns
Kuroiler		0.42***	-0.11*	0.56***	0.13*	0.41***	0.21***
Sasso	Shape index	-0.02ns	0.07ns	-0.08ns	0.00ns	-0.02ns	0.03ns
Kuroiler		0.02ns	0.05ns	0.04ns	0.11*	0.02ns	0.04ns
Sasso	Shell weight	0.20***	-0.12*	0.27***	-0.00ns	0.19***	0.04ns
Kuroiler		0.28***	-0.13*	0.43***	0.12*	0.28***	0.12*
Sasso	Shell ratio	-0.07ns	0.17**	-0.30***	-0.17**	-0.07ns	0.04ns
Kuroiler		-0.10ns	0.05ns	-0.15**	-0.04ns	-0.09ns	-0.03ns
Sasso	Shell thickness	0.16**	0.03ns	0.06ns	-0.06ns	0.16**	0.11ns
Kuroiler		0.06ns	-0.07ns	0.12*	0.02ns	0.07ns	0.02ns

*** *(P < 0.0001);* ** *(P < 0.001);* * *(P < 0.05);* ns *(P > 0.05).*

This observation is supported by the report of Moula et al (2010) who also observed a strong and positive correlation between egg weight and albumen weight (0.972) and between egg weight and yolk weight (0.552). Several studies have shown that egg weight is genetically linked to the weight of all three of the major components of an egg i.e. shell, albumen and yolk. Washburn (1990) showed that the link between egg weight and albumen weight is higher than those between egg weight and shell or yolk weight. On the other hand, the correlations between egg weight and yolk ratio for Sasso (-0.42) and Kuroiler (-0.27) were significant but negative, indicating that heavier eggs in the present study had a lower yolk ratio. This is in agreement with the report of Padhi et al (2013) in Vanaraja chickens.

Phenotypic correlation coefficients for internal egg quality traits

The phenotypic correlation coefficients for internal egg quality traits are shown in Table 6. Significant and positive correlations were observed between yolk weight and yolk ratio, albumen height and Haugh unit in both Sasso and Kuroiler eggs. The correlation between yolk weight and albumen weight was significant and positive for Kuroiler whereas for

Sasso that relationship was not significant. The highest positive correlations of 0.91 and 0.93 for Sasso and Kuroiler respectively, were observed between albumen height and Haugh unit while the highest negative correlations of -0.61 were observed between yolk ratio and albumen ratio for Sasso and Kuroiler eggs.

Table 6. Phenotypic correlation coefficients for internal egg quality traits of Sasso and Kuroiler chickens

BREED	TRAIT	Yolk weight	Yolk ratio	Albumen weight	Albumen Ratio	Albumen height	Haugh unit
Sasso	Yolk weight	1	0.65^{***}	0.02^{ns}	-0.43^{***}	0.60^{***}	0.40^{***}
Kuroiler		1	0.63^{***}	0.21^{***}	-0.34^{***}	0.60^{***}	0.43^{***}
Sasso	Yolk ratio		1	-0.60^{***}	-0.61^{***}	0.64^{***}	0.88^{***}
Kuroiler			1	-0.53^{***}	-0.61^{***}	0.64^{***}	0.86^{***}
Sasso	Albumen			1	0.72^{***}	0.03^{ns}	-0.29^{***}
Kuroiler	weight			1	0.69^{***}	0.21^{***}	-0.09^{ns}
Sasso	Albumen ratio				1	-0.42^{***}	-0.53^{***}
Kuroiler					1	-0.34^{***}	-0.48^{***}
Sasso	Albumen					1	0.91^{***}
Kuroiler	height					1	0.93^{***}
Sasso	Haugh unit						1
Kuroiler							1

*** ($P < 0.0001$); **($P < 0.001$); *($P < 0.05$); ^{ns}($P > 0.05$).

The significant positive correlations between albumen height and Haugh units obtained in the present study supports the findings of Oluwami and Ogunlade (2008), Kul and Sekar (2004), Akbas et al (1996) and Ozcelik (2002) who reported positive correlation values as 0.98, 0.95, 0.97 and 0.97 respectively. This may imply that as the albumen height is improved, also does the Haugh unit. Since the Haugh unit measures the freshness of an egg (Moula et al 2010) it is reasonable to use the albumen height to determine the Haugh unit. The highest negative correlations observed in this study may imply that when the yolk ratio is high, the albumen ratio is reduced at the same magnitude for both Sasso and Kuroiler chickens. Such information is important especially in pharmaceutical and food processing industries where the yolk and albumen ratio is necessary. For example, egg albumen contains many functionally important proteins among those are ovalbumin (54%), ovotransferrin (12%), ovomucoid (11%), ovomucin (3.5%), and lysozyme (3.5%)

and have high potentials for industrial applications if separated (Abeyrathne et al 2013). Therefore, by understanding the variation that exists between breeds for internal egg quality traits (albumen vs. yolk), one could select certain breeds for their peculiarity in the intended qualities.

Conclusions

Based on the results of the present study, it is concluded that both the external and internal quality of eggs were influenced by the management system. Eggs from on-station appeared to be better in quality than those of on-farm. Breed had significant effects on weight, egg length, yolk weight, albumen height and Haugh unit. Kuroiler laid heavier eggs with higher yolk weight, albumen height and Haugh unit score than Kuroiler. Egg weight as an important egg quality parameter has positive correlations with all traits except shape index for external and yolk ratio for internal egg quality traits.

Acknowledgements

The authors express their appreciation to the Department of Animal, Aquaculture and Range Sciences of the Sokoine University of Agriculture for providing necessary facilities for the on-station experiment. They are further grateful to both livestock officers and households for their cooperation during on-farm data collection.

Funding

This research was carried out under the financial support of the African Chicken Genetic Gains (ACGG) project in Tanzania sponsored by the Bill and Melinda Gates Foundation (Grant Agreement OPP1112198).

Conflict of interest

The authors declare no competing interests

References

Abeyrathne E D N S, Lee H Y and Ahn D U 2013 Egg white proteins and their potential use in food processing or as nutraceutical and pharmaceutical agents - A review. *Poultry Science* 92(12): 3292- 3299. PMid: 24235241.

Akbas Y, Altan O and Kocak C 1996 Effects of hens age on external and internal egg quality characteristics. *Turkey Journal of Veterinary Animal Science* 20: 455-460.

Altan O, Oguz O and Abas Y 1998 Effects of selection for high body weight and age of hen on egg characteristics in Japanese Quail (Cortunix cortunix japonica). *Turkey Journal of Veterinary Anima Science* 22: 67-73.

Altuntas E and Sekeroglu A 2008 Effect of egg shape index on mechanical properties of chicken eggs. *Journal of Food Engineering* 85(4): 606-612. https://doi.org/10.1016/j.jfoodeng.2007.08.022.

Aygun A and Yetisir R 2010 The relationships among egg quality characteristics in different hybrid layers to forced molting programs with and without feed withdrawal. *Journal of Animal and Veterinary Advances* 9(4): 710-715. DOI:10.3923/javaa.2010.710.715.

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* 52: 1541-1548. https://doi.org/10.1007/s11250-019-02158-9.

Bekele F, Gjøen H M, Kathle J, Ådnøy T and Abebe G 2009 Genotype X environment interaction in two breeds of chickens kept under two management systems in Southern Ethiopia. *Tropical Animal Health and Production* 41: 1101- 1114. https://www.researchgate.net/publication/23665839.

Biazen A, Mengistu U, Negassi A, Getenet A, Solomon A and Tadelle D 2021 Comparative Growth Performance, Carcass Characteristics and Meat Quality of Local Horro and Exotic Cockerels of Tropical Origin Fed Growers Diet. *Open Journal of Animal Sciences* 11: 62-83. https://doi.org/10.4236/ojas.2021.111006.

Bobbo A G, Baba S S and Yahaya M S 2013 Egg quality characteristics of three phenotypes of local chicken in Adamawa state. *Journal of Agriculture and Veterinary Science* 4 (2):13-21. http://www.iosrjournals.org/iosr-javs/papers/vol4-issue2/C0421321.pdf.

Campo J L 1995 Comparative yolk cholesterol content in four Spanish breeds of hens, an F2 cross, and a White Leghorn population. *Poultry Science* 74: 1061-66.

Champati A, Samal L, Behura N C, Pati P K, Muduli S and Popalghat H K 2020 Laying performance and egg quality traits of Hansli x CSML birds under different rearing systems. *Journal of Entomology and Zoology Studies* 8(4):37-39.

Coutts J A, Wilson G C, Fernandez S, Rasales E, Weber G and Hernandez J M 2006 Optimum Egg Quality -A Practical Approach. 5M Publishing: Shefield UK. pp. 63.

Dahloum L, Yakubu A and Halbouche M 2018 Effects of housing system and plumage colour on egg quality characteristics of indigenous naked-neck chickens. *Livestock Research for Rural Development* 30:206 http://www.lrrd.org/lrrd30/12/abdul30206.html.

Dong X Y, Yin Z Z, Ma Y Z, Cao, H Y and Dong D J 2017 Effects of rearing systems on laying performance, egg quality, and serum biochemistry of Xianju chickens in summer. *Poultry Science* 96(5): 1485-1491.
Farooq M, Mian M A, Ali M, Durrani F R, Asghar A, Muqarrab A K 2001 Egg traits of Fayoumi birds under subtropical conditions. *Sarhad Journal of Agriculture* 17:141–145.

Gerber N 2012 Factors affecting egg quality in the commercial laying hen. A review. http://eggfarmers.org.nz/eggfarmers/wp-content/uploads/2012/04/factors_ affecting_egg_quality.pdf.

Guni F S, Mbaga S H and Katule A M 2021a Performance Evaluation of Kuroiler and Sasso Chicken Breeds Reared under On-farm and On-station Management Conditions in Tanzania. *European Journal of Agriculture and Food Sciences* 3(2): 53-59. https://doi.org/10.24018/ejfood.2021.3.2.254.

Guni F S, Mbaga S H, Katule A M. and Goromela E H 2021b Performance evaluation of Kuroiler and Sasso chicken breeds reared under farmer management conditions in highland and lowland areas of Mvomero district, Eastern Tanzania. *Tropical Animal Health and Production* 53: 245. https://doi.org/10.1007/s11250-021-02693-4.

Hamilton R M G 1982 Methods and Factors that affects the measurement of egg shell quality. *Poultry Science* 61: 2022-2039.

Haugh R 1937 The Haugh unit for measuring egg quality. The US Egg & Poultry Magazine 43: 552 –573.
Hussein S M, Harms R H and Janky D M 1993 Effect of age on the yolk to albumen ratio in chicken eggs. *Poultry Science* 72:594–597.

Ketta M and Tůmová E 2016 Relationship between eggshell thickness and other eggshell measurements in eggs from litter and cages. *Italian Journal of Animal Science* 17(1): 234-239. https://doi.org/10.1080/1828051X.2017.1344935.

Kidie H A 2019 Characterization of chicken production system and on-farm evaluation of introduced exotic chicken breeds in Gondar Zuria and Kalu districts of Amhara region, Ethiopia. MSc. Thesis. Haramaya University, Haramaya, Ethiopia.

Ko K Y and Ahn D U 2008 An economic and simple purification procedure for the large scale production of ovotransferrin from egg white. *Poultry Science* 87(7): 1441-1450. PMid:18577628. http:// dx.doi.org/10.3382/ps.2007-00434.

Kovacs-Nolan J K N, Phillips M and Mine Y 2005 Advances in the value of eggs and egg components for human health. *Journal of Agricultural and Food Chemistry* 53(22): 8421-8431. PMid:16248532. http://dx.doi.org/10. 1021/jf050964f.

Kraus A and Zita L 2019 The Effect of Age and Genotype on Quality of Eggs in Brown Egg-Laying Hybrids. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 67(2): 407–414.

Küçükyılmaz K, Bozkurt M, Nur Herken E and Çınar M 2012 Effects of rearing systems on performance, egg characteristics and immune response in two layer hen genotype. *Asian-Australasian Journal of Animal Sciences* 25(4): 559-568.
Kühn J, Schutkowski A, Kluge H, Hirche F and Stangl G 2014 Free-range farming: A natural alternative to produce vitamin D-enriched eggs. Nutrition 30: 481-484. https://doi.org/10.1016/j.nut.2013.10.002.

Kul S and Seker I 2004 Phenotypic correlations between some external and internal egg quality traits in the Japaneese quail (Cortunix cortunix Japanica). *Internatonal Journal of Poultry Science* 3: 400 – 405.

Matt D, Veromann E and Luik A 2009 Effect of housing systems on biochemical composition of chicken eggs. *Agronomy Research* 7(2): 662–667.

Mertens K, Bamelis F, Kemps B, Kamers B, Verhoelst E, De Ketelaere B, Bain M, Decuypere E and De Baerdemaeker J 2006 Monitoring of eggshell breakage and eggshell strength in different production chains of consumption eggs. *Poultry Science* 85(9):1670-1677.

Mine Y and Kovacs-Nolan J 2004 Biologically active hen egg components in human health and disease. *Journal of Poultry Science* 41: 1-29.

Moula N, Antoine-Moussiaux N, Decuypere E, Farnir F, Mertens K, De Baerdemaeker J and Leroy P 2010 Comparative study of egg quality traits in two Belgian local breeds and two commercial lines of chickens, *Archiv Fuer Gefluegelkunde* 2010; 74: 164–171.

Ogunshola O J, Bankole O A, Baki O I, Morenikeji O B and Chineke C A 2018 Effects of Age and Management System on Egg Quality Traits of Fulani Ecotype Hens. Proceedings of the 43rd Annual Conference of the Nigerian Society for Animal Production, 2018.

Olawumi S O and Ogunlade J T 2008. Phenotype correlations between some External and Internal egg Quality traits in Exotic Isa Brown Layer Breeder. *Asian Journal of Poultry Science* 2: 30 – 35.

Oke O E, Ladokun A O and Onagbesan O M 2014 Quality parameters of eggs from chickens reared in deep litter system with or without access to grass or legume pasture. *Livestock Research for Rural Development* 26(11): 1-10.

Ozcelik M 2002 The phenotypic correlations among some external and internal quality characteristics in Japanese quail eggs. *Veterinary Journal of Ankara University* 49: 67-72.

Padhi M K, Chatterjee R N, Haunshi S and Rajkumar U 2013 Effect of age on egg quality in chicken. *Indian Journal of Poultry Science* 48(1):122-125.

Patel N, Sundi B, Prasad S, Kumar R and Mandal B 2018 Reproductive and Egg Quality Traits of Vanaraja Birds under Different System of Management. *International Journal of Current Microbiology and Applied Sciences* 7: 696-699.

Rakonjac S, Bogosavljević-Bošković S, Pavlovski Z, Škrbić Z, Dosković V, Petrović M and Petričević V 2014 Laying hen rearing systems: A review of major production results and egg quality traits. *World's Poultry Science Journal* 70(1): 93-104. doi:10.1017/S0043933914000087.

Roberts J R 2010 Factors affecting eggshell and internal egg quality. In: Proc. 18th Annual ASAIM SE Asian Feed Technology and Nutrition Workshop. Le Meridien Siem Reap, Cambodia, 1–9.

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. *Tropical Animal Health and Production* 52: 3315–3322.

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. *Animal Production Science* https://doi.org/10.1071/AN20453.

SAS 2009 Statistical Analytical System. User Guide for Personal Computers, Statistical Programme. Windows Version 9.2, SAS Institute Inc. Cary, NC, USA.

Sekeroglu A, Musa S, Ergun D, Zafer U, Muammer T, Mustafa S and Hussain O 2010 Effects of Different Housing Systems on Some Performance Traits and Egg Qualities of Laying Hens. *Journal of Animal Veterinary Advances* 9: 1739-1744.

Sokołowicz Z, Krawczyk J and Dykiel M 2018 Effect of alternative housing system and genotype on egg quality characteristics. *Emirates Journal of Food and Agriculture* 30(8): 695 - 703.

Stadelman W J 1977 Quality identification of shell eggs in egg science and technology. 2nd ed. Westport, Connecticut: AVI Publishing Company Inc., 33pp.

Stadelman W J and Cotterill O J 2001 Egg Science and Technology. 4th ed. Avi Publ. Co., Westport, CT.

Suk Y O and Park C 2001 Effect of breed and age of hen on the yolk to albumen ratio in two different genetic stocks. *Poultry Science* 80: 855-58.

Tang S G H, Sieo C C and Kalavathy R 2015 Chemical Compositions of Egg Yolks and Egg Quality of Laying Hens Fed Prebiotic, Probiotic, and Synbiotic Diets. *Journal of Food Science* 80(8): 1686–1695.

Washburn K W 1990 Genetic variation in egg composition. In R. D. Crawford, ed. Poultry Breeding and Genetics. New York: Elsevier Scientific Publishers, pp. 781–798.

Zhang L C, Ning Z H, Xu GY, Hou Z C and Yang N 2005 Heritabilities and genetic and phenotypic correlations of egg quality traits in brown-egg dwarf layers. *Poultry Science* 84(8):1209-13. doi: 10.1093/ps/84.8.1209.

CHAPTER FIVE

PAPER IV

Carcass and parts yield of two improved chicken breeds reared under intensive management system in Tanzania

Submitted in: Tanzania Journal of Agricultural Sciences (TAJAS)

Carcass and parts yield of two improved chicken breeds reared under intensive management system in Tanzania

***F.S. Guni[1], S. H. Mbaga[2] and A. M. Katule[2]**

[1]Tanzania Livestock Research Institute - Uyole, P.O. Box 6191 Mbeya, Tanzania.

[2]Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture,

P. O. Box 3004, Morogoro, Tanzania.

*Corresponding author e-mail: fadhili.guni@yahoo.com

Abstract

The effect of breed on the carcass characteristic of two dual-purpose chicken breeds reared under the intensive management system was investigated. A total of 40 birds from Sasso and Kuroiler breeds (20 chickens per breed) were randomly taken as a representative sample and were slaughtered and carcass dissected manually. The

parameters for all breeds included bodyweight at slaughter (BWS), carcass weight (CW), dressing percentage (DP %), parts yield including breast, drumsticks, thighs, wings, back and neck. With regard to all parameters collected, the two breeds were found to be significantly ($P<0.05$) different for all carcass characteristics. The BWS, CW and all carcass parts weight were significantly ($P<0.05$) higher for Sasso than Kuroiler. In addition, Sasso had higher proportions of breast, back and wings than Kuroiler but the two breeds were comparable on thighs, drumsticks and neck. There were significant and positive phenotypic correlations between BWS and all carcass traits studied.

Keywords: Kuroiler, Sasso, carcass traits, correlation, intensive management

Introduction

The poultry meat industry has experienced rapid expansion, particularly in the last 30 years which has been accompanied by the genetic development of genotypes that allow for greater meat yield (OECD, 2018). Similarly, the demand for poultry and livestock products has increased significantly which prompted most poultry-related development agencies to promote the intensification of improved poultry systems. When considering the improvements in the poultry industry in terms of new genotypes, it is imperative to provide information that helps producers and consumers to make informed decisions about the genetic potential of those genotypes in different production systems and environments. Sasso and Kuroiler are genetically improved dual-purpose breeds which have been introduced in Tanzania to support poverty reduction, productivity growth and increased household's animal protein intake (Ringo and Mwenda, 2018). The advantage of these breeds and other dual-purpose birds over the commercial egg or meat-type

chickens is their duality where males are used for meat production and females for egg production (Mueller *et al.,* 2018). Performance test in terms of growth, egg production and survivability of these breeds has been evaluated, and the results have been documented (Sanka *et al.,* 2020; Guni *et al.*, 2021a; Guni *et al.,* 2021b).

In the poultry production chain, carcass and parts yield provide valuable information to guide producers on which breed to keep or when to slaughter the birds. Some studies have shown carcass yield and proportions of carcass parts in chickens to be affected by several factors among which is the genotype. While investigating the slaughter characteristics of male dual-purpose chickens under the intensive management system, Biazen *et al.* (2021) showed that Kuroiler chickens had heavier slaughter weight, dressed carcass weight, eviscerated carcass weight, breast weight, thigh weight, and drumstick weight than Sasso, Koekoek and Horro chickens. Similarly, studies by Ibrahim *et al.* (2019) and Mueller *et al.* (2018) have shown differences among different dual-purpose chicken breeds on carcass yields as well as proportions of carcass parts. In more recent carcass evaluations, Sanka *et al.* (2021) did not find significant differences between Sasso and Kuroiler on carcass weight and carcass parts when chickens were subjected to varying levels of feed supplementation under semi-scavenging conditions. Thus, the knowledge of carcass parameters between and among different chicken genetic groups is important in the formulation of breeding programs targeting different management systems. Therefore, this study intended to evaluate the carcass traits of male chickens of Sasso and Kuroiler breeds under the intensive management system.

Materials and methods

Location of the study area

The study was conducted at the Poultry farm of Sokoine University of Agriculture (SUA). The University is located at the foothills of the Uluguru Mountains in Morogoro, Eastern Tanzania, about 550 m above sea level. The monthly mean and maximum temperatures are 18.7 and 30.1 ^{o}C, respectively.

Management of the birds

A total of 240 (120 Kuroiler and 120 Sasso) male chickens, were raised under the intensive management system. They were randomly assigned to six deep litter pens (3 pens per breed), each having 40 birds. The birds were offered commercial diets produced by the Silverland Tanzania Company located in Iringa region. During the brooding, birds were provided with a starter crumbles containing 2941 Kcal ME/kg and 21.2% CP (0 - 2 weeks) and chick mash containing 3049 Kcal ME/kg and 20.3% CP (3 - 6 weeks). A grower ration containing 15.5% CP and 2762 Kcal ME/kg was provided from the 7th to the end of the 16th week. Clean water was provided in ad-libitum throughout the experimental period.

Carcass traits measurements

At the end of the 16 weeks, a sample of 40 birds (20 birds/breed) were randomly selected and slaughtered to determine carcass weight as well as carcass parts yield. Sampled birds were starved for 12 hours but had free access to drinking water until slaughter. The birds were slaughtered by cutting the jugular vein, bled for 2 minutes and then scalded at about 55 – 60 ^{o}C for 1 minute and manually de-feathered. The carcass weight was taken after de-feathering and removal of feet, head and the viscera (gizzard, heart, spleen, liver and intestine). The eviscerated carcass, breast, thighs, drumsticks, wings, back and neck were weighed using a digital balance. Carcass weight data were used to calculate the dressing percentage and carcass part composition (%) by taking the weight of the individual parts as the percentage of the body weight at slaughter (BWS) of the chicken.

Statistical data analysis

The General Linear Models (GLM) procedure of SAS software (SAS, 2009) was used to analyze the data for body weight at slaughter, carcass weight, and parts yield with the MANOVA option for calculating partial correlation coefficients among the carcass trait variables. The breed was considered as the fixed effects while individual bird was taken as a random effect. The following Model was used

$Y_{ij} = \mu + B_i + E_{ij}$

Where:

Y_{ij} = observation (Bodyweight at slaughter, carcass weight, and carcass parts yield) from the i^{th} breed.

μ = General mean common to all observations in the study;

B_i = Effect of the i^{th} breed (i= Kuroiler, Sasso);

E_{ijk}= Random effect peculiar to each bird.

Results and discussions

Carcass characteristics of Sasso and Kuroiler male chickens slaughtered at 16 weeks are presented in Table 2. Significant ($p < 0.05$) differences were observed between the two breeds on body weight at slaughter, carcass weight and carcass parts weight. Sasso chickens presented heavier body weight at slaughter (2340.8 g) than Kuroiler (2000.8 g). Likewise, Sasso had significant ($p < 0.05$) higher carcass weight and Dressing percentage (DP %) than Kuroiler which implies existence of genetic differences between the two breeds in growth rate and muscle deposition.

Table 1: Least square mean values for the effects of breed on carcass yield of dual-purpose male chickens slaughtered at 16^{th} **week of age.**

Variable	Breed	SEM	P-value

	Kuroiler	Sasso		
BW at slaughter (g)	2000.80[b]	2340.80[a]	57.52	0.0001
Carcass weight (g)	1346.60[b]	1622.50[a]	39.90	<.0001
Dressing %	67.56[b]	69.20[a]	0.51	0.0299
Breast weight (g)	335.10[b]	419.00[a]	12.42	<.0001
Thigh weight (g)	247.70[b]	271.90[a]	7.34	0.0252
Drumstick weight (g)	221.40[b]	252.50[a]	6.96	0.0031
Back weight (g)	257.20[b]	335.40[a]	9.25	<.0001
Wing weight (g)	188.00$_b$	212.30[a]	5.09	0.0017
Neck weight (g)	87.60[b]	115.70[a]	3.35	<.0001

[a-b] Means with different superscripts within a row differed significantly (P<0.05), SEM = Standard error of the mean; BW= Bodyweight

This observation agrees with the reports of Mueller *et al.* (2018), Ibrahim *et al.* (2019), and Biazen *et al.* (2021) who also revealed the existence of breed/genotype differences in the slaughter weight of chickens. As expected, birds with higher growth potentials (i.e., higher BWS) will present a higher meat production capacity (carcass yield). In the present study, the Sasso breed also had a heavier ($p < 0.05$) carcass weight than Kuroiler breed. The carcass weight (1622.50 g) of Sasso chickens observed in the present study was higher than 1400.6 g for Koekoek chickens and 1415.4 g for Lohman Dual reported by Ibrahim *et al.* (2019) but comparable to 1677 g and 1684.4 g for Sasso and Novo Brown chickens reported by Mueller *et al.* (2018) and Ibrahim *et al.* (2019) respectively. Similarly, the carcass weight for Kuroiler chickens observed in the present study (1346.60 g) was comparable to 1400.6 g for Koekoek chickens reported by Ibrahim *et al.* (2019) but lower than 1677 g for Sasso chickens reported by Mueller *et al.* (2018). Generally, the BWS and CW observed in the present study for both Sasso and Kuroiler at 16 weeks are comparable to the market weight i.e. 2kg for fast-growing chickens kept for less than 8 weeks. This supports the suggestion by Biazen *et al.* (2021) that despite the longer growing period required for dual-purpose chicken breeds than the fast-growing broiler, males of the two breeds can still be utilized as alternative meat-type chicken in places where specialized broilers are not accessible or where the local types are considered to be un-economical given their slow growth and lower body weight at slaughter.

The dressing percentage (DP %) was higher for Sasso (70.63%) than Kuroiler (68.54%) which might be due to the observed higher bodyweight of Sasso chickens in the present study. The observed dressing percentages for Sasso and Kuroiler in the present study were higher than (66.75%) for Kuroiler chickens reported by Aline (2015) in Uganda. This difference might be due the variation in type of feed given to the birds and other environmental factors.

The carcass parts including the breast, thighs, drumsticks, back, wings and neck were also heavier for Sasso than Kuroiler. The breast, thighs, drumsticks are considered the most valuable carcass parts in broiler and dual-purpose male chickens kept for meat production while the back, wings and neck are regarded as less valuable carcass parts (Biazen *et al.,* 2021). The higher performance of Sasso in these traits might be directly related to the carcass weight, whereby Sasso had higher proportions than Kuroiler. This observation is supported by the reports of Katekhaye (2017), Rezaei *et al.* (2018), Biazen *et al.* (2021) and several authors who have also indicated higher carcass parts weight for heavier birds.

The data for carcass parts expressed as a percentage of the BWS are presented in Table 2. The proportions of breast, back and neck were higher ($p < 0.05$) for Sasso chickens than for Kuroiler chickens. The proportions of thighs, drumsticks and the wings did not differ ($p > 0.05$) between the two breeds, suggesting that although the two breeds differed in body weight at slaughter and carcass weights, yet the share of thighs, drumsticks and wings to the total weight were similar. This observation is in agreement with that of Lichovníkova *et al.* (2009) who also found insignificant differences for the proportion of leg muscle (thigh and drumstick) between fast-growing chickens and layer male chickens. The highest carcass part observed was the breast (17.86 and 16.77 % for Sasso and Kuroiler respectively), while the lowest was the neck (4.93 and 4.38% for Sasso and Kuroiler respectively). The higher proportion of breast to the total BWS might

be related to the effect of selection for meat production where more attention is placed on the breast proportion (Marapana, 2016). Though the breeds used are not pure meat birds, by being dual-purpose birds, they thus carry genes from meat breeds. Thus, the higher carcass weight and breast proportion of the Sasso males is an indication that the breed is relatively better for meat production under intensive management than Kuroiler.

Table 2: Least square mean values for the effects of breed on carcass yield of dual-purpose male chickens slaughtered at 16th week of age (carcass parts expressed as a percentage of the BWS).

Variable	Breed		SEM	P-value
	Kuroiler	Sasso		
Breast weight	16.77[b]	17.86[a]	0.28	0.0096
Thigh weight	12.38	11.83	0.13	0.0562
Drumstick weight	11.12	10.75	0.14	0.0806
Back weight	12.92[b]	14.28[a]	0.22	0.0001
Wing weight	9.48	9.06	0.16	0.0788
Neck weight	4.38[b]	4.93[a]	0.08	<.0001

[a-b] Means with different superscripts within a row differed significantly (P<0.05), SEM = Standard error of the mean, BWS = Body weight at slaughter.

However, the choice of breed type for meat production is influenced not only by bird growth but also by the cost of production. Indeed, it would be useful and practical to undertake a study aimed at comparing carcass and parts yield for these breeds when slaughtered at different ages under different management systems to determine their cost-effectiveness and the ultimate quality of the final product i.e. meat. For example, local chickens have lower carcass weight as well as low yield of carcass parts, moreover, in terms of consumer preference, such meat scored better compared to broiler (Kyarisiima *et al.,* 2011). This may imply a tradeoff between time to slaughter and final product quality based on the market preference.

Correlation between body weight at slaughter, carcass weight and parts yield

Correlation coefficients (r) between BWS and CW and parts yield of Sasso and Kuroiler chickens are shown in Table 3. Significant positive correlations were obtained between BWS, CW and other carcass traits of the two breeds except for the relationship between

wing and neck weight for Sasso, which was positive but not significant (0.36). The highest correlation was observed between body weight at slaughter (BWS) and carcass weight (0.99) in both breeds, while the lowest was between wing weight and neck weight (0.36 and 0.68 for Sasso and Kuroiler respectively). With regard to the correlation between BWS and carcass parts, the breast had the highest correlation (0.98) and (0.95) for Sasso and Kuroiler respectively, while the neck had the lowest (0.73) and (0.80) for Sasso and Kuroiler respectively.

Table 3: Correlation coefficients (r) between body weight at slaughter, carcass weight **and carcass traits of Sasso and Kuroiler chickens**

Breed	Trait	Slaughter weight	Carcass	Breast	Thigh	Drumstick	Back	Wing	Neck
Sasso	Slaughter weight	1	0.99***	0.98***	0.88***	0.92***	0.90***	0.85**	0.73*
Kuroiler		1	0.99***	0.95***	0.82**	0.93***	0.92***	0.90***	0.80**
Sasso	Carcass		1	0.98***	0.90***	0.92***	0.91***	0.85**	0.74*
Kuroiler			1	0.95***	0.83**	0.92***	0.93***	0.91***	0.82**
Sasso	Breast			1	0.93***	0.96***	0.91***	0.84**	0.73**
Kuroiler				1	0.91***	0.92***	0.96***	0.88***	0.91***
Sasso	Thigh				1	0.85**	0.86**	0.67*	0.75*
Kuroiler					1	0.72*	0.87***	0.65*	0.94***
Sasso	Drumstick					1	0.84**	0.87***	0.60*
Kuroiler						1	0.86**	0.90***	0.76**
Sasso	Back						1	0.62*	0.89***
Kuroiler							1	0.86**	0.87**
Sasso	Wing							1	0.36ns
Kuroiler								1	0.68*
Sasso	Neck								1
Kuroiler									1

*** (P < 0.0001); ** (P < 0.001); * (P < 0.05); ns (P > 0.05).

The positive correlation values recorded in this study for all carcass traits and BWS of the two breeds suggest that there are genetic relationships between and among carcass traits and hence, the BWS of chicken can be used to predict the carcass weight as well as parts

yield from live body weight before slaughter. This observation is in agreement with the findings of Olawumi (2013) on Arbor and Acre chickens in Nigeria.

Conclusion

Based on the results of the present study, it is concluded that Sasso males showed higher body weight at slaughter, higher carcass weight and higher parts weight than Kuroiler. The correlation between body weight at slaughter with carcass weight and carcass parts were high and positive.

Acknowledgements

The authors express their appreciation to the Department of Animal, Aquaculture and Range Sciences of the Sokoine University of Agriculture for providing necessary facilities used in this study.

References

Aline, K. (2015). Management Systems and Location Effects on Growth and Carcass Traits of Kuroiler and Local Chickens. MSc. Thesis, Makerere University, Kampala.

Biazen, A., Mengistu, U., Negassi, A., Getenet, A., Solomon, A. and Tadelle, D. (2021). Comparative Growth Performance, Carcass Characteristics and Meat Quality of Local Horro and Exotic Cockerels of Tropical Origin Fed Growers Diet. *Open Journal of Animal Sciences* 11: 62-83. https://doi.org/10.4236/ojas.2021.111006.

Guni, F. S., Mbaga, S. H. and Katule, A. M. (2021). Performance Evaluation of Kuroiler and Sasso Chicken Breeds Reared under On-farm and On-station Management Conditions in Tanzania. *European Journal of Agriculture and Food Sciences 3*(2): 53-59. https://doi.org/10.24018/ejfood.2021.3.2.254

Guni, F.S., Mbaga, S.H., Katule, A.M. and Goromela, E.H. (2021). Performance evaluation of Kuroiler and Sasso chicken breeds reared under farmer management conditions in highland and lowland areas of Mvomero district, Eastern Tanzania. *Tropical Animal Health and Production* 53: 245. https://doi.org/10.1007/s11250-021-02693-4.

Ibrahim, D., Goshu, G., Esatu, W. and Cahaner, A. (2019). Dual-purpose production of genetically different chicken crossbreeds in Ethiopia. 2. Egg and meat production of the final crossbreed females and males. *Poultry Science* 98: 3405–3417. https://doi.org/10.1007/s13165-020-00328-w.

Katekhaye, A.F. (2017). Comparative Study on Carcass Characteristics of Shrinidhi and Vanaraja Chicken Varieties. Ph.D. Dissertation, P.V. Narsimha Rao Telangana Veterinary University, Rajendranagar, Hyderabad.

Kyarisiima, C. C., Nagujja, F.A., Magala, H., Kwizera, H., Kugonza, D.R. and Bonabana-Wabbi, J. (2011). Perceived Tastes and Preferences of Chicken Meat in Uganda. *Livestock Research for Rural Development* 23 (11). www.Irrd.org/Irrd23/11/kyar23242.htm.

Lichovníková, M., Jandásek, J., Jůzl, M. and Dračková, E. (2009). The meat quality of layer males from free range in comparison with fast growing chickens. *Czech Journal of Animal Science* 54: 490-497. https://doi.org/10.17221/3/2009-CJAS.

Marapana R.A.U.J. (2016). Effect of Different Dress Weight Categories on Yield Part Percentage and Relationship of Live and Dress Weight of Broiler Carcasses Slaughter at Different Condition. *Journal of Food Science and Technology Nepal* 9 (31-38): DOI:10.3126/jfstn.v9i0.14760.

Mueller, S., Kreuzer, M., Siegrist, M., Mannale, K., Messikommer, R.E. and Gangnat, I. D. M. (2018). Carcass and meat quality of dual-purpose chickens (Lohmann Dual, Belgian Malines, Schweizerhuhn) in comparison to broiler and layer chicken types. *Poultry Science* 97: 3325-3336.

OECD (2018). Market examinations in Mexico: Case study of the chicken meat market.

Olawumi, S. O. (2013). Phenotypic correlations between live body weight and Carcass traits in arbor acre breed of broiler chicken. *International Journal of Science and Nature* 4(1): 145-149.

Rezaei, M., Yngvesson, J., Gunnarsson, S., Jönsson, L. and Wallenbeck, A. (2018). Feed Efficiency, Growth Performance, and Carcass Characteristics of a Fast- and a Slower-Growing Broiler Hybrid Fed Low- or High-Protein Organic Diets. *Organic Agriculture* 8: 121-128. https://doi.org/10.1007/s13165-017-0178-6.

Ringo, E. J. and Mwenda, V. (2018). Poultry subsector in Tanzania: A quick scan. Embassy of the Kingdom of the Netherlands. Dar es Salaam, Tanzania. 31 pages

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. *Tropical Animal Health and Production* 52: 3315–3322.

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. *Asian Journal of Poultry Science* 15: 1-12. https://scialert.net/abstract/?doi=ajpsaj.2021.1.12.

SAS (2009). Statistical Analytical System. User Guide for Personal Computers, Statistical Programme. Windows Version 9.2, SAS Institute Inc. Cary, NC, USA.

CHAPTER SIX

6.0 General Discussion, Conclusions and Recommendations

6.1 General Discussion

Previous attempts to increase chicken output (meat and eggs) in Tanzania have involved importations of high producing exotic breeds particularly in the commercial sub-sector and through cross-breeding of indigenous chicken populations with exotic breeds. Increased productivity of the poultry subsector by using specialized exotic breeds (broilers and layers) in Tanzania have failed to become a sustainable option mainly because this strategy recurrently faced the problem of birds not being adopted widely by the rural farmers due to several socioeconomic and environmental challenges. The exotic breeds of chicken introduced in Tanzania were from temperate countries where they were developed through intensive selection for meat and egg production in high input production system. Such production system can hardly be achieved in a developing

country like Tanzania where chicken production is mainly carried out in extensive production systems characterized by low input and low output. Furthermore, lack of adaptability of the exotic chicken breeds to environmental stressors of the tropical climate limit their ability to reach desired production levels. In the tropics the easiest way to overcome the Genotype by environment (GxE) interaction without managerial intervention is simply to use breeds that are adapted to the environmental stressors of the particular environment (Olori, 2008). In this study, two genetically improved chicken genotypes i.e. Kuroiler and Sasso that are tropically adapted were introduced in Tanzania and were evaluated for growth, egg production, egg quality, carcass yield and survivability under two agro-ecological zones (highland and lowland) and two management systems (on-station and on-farm).

The two agro-ecologies selected in this study are used for comparison purposes, but where possible the results may be used as references in other regions with similar conditions.

6.2.1 Effects of Agro-ecology on the production performance of chickens

Agro-ecological zones are geographical areas exhibiting similar climatic conditions that determine their ability to support agriculture including livestock production. Agro-ecological zones (AEZ) are characterized by several factors including altitude, temperature, humidity, seasonality, rainfall amounts and distribution. Agro-ecology has shown to be a significant source of variation in the growth performance and survivability of the two breeds studied. Chickens raised in the highland zone had better growth and survival rate than those chickens raised in the lowland zone (Chapter 2). Good performance and survivability in the highlands could be due to availability of feedstuffs as a result of high rainfall which attracted more people in farming activities such as

cultivation of various crops; which ultimately formed the basis of high availability of scavengeable feed resources and house leftovers compared to lowland.

In addition, highland areas have good climatic conditions for poultry production especially its moderate temperature, which probably enabled the birds to express their genetic potential better than in lowland areas. On the other hand, the lowland area had a slightly higher temperature range (19 - 31^{0}C) than the highland areas (11 - 23^{0}C). It has been suggested that the optimum ambient temperature range for poultry is 12–26 ^{0}C. As temperature rises, the bird has to maintain the balance between heat production and heat loss and so will reduce its feed consumption to reduce heat from metabolism (Moreki, 2008). A decrease in feed consumption depresses the growth performance as the bird utilizes the minimal feeds only to maintain body activities. It is likely that such heat stress as well decreases in feed intake coupled with sub-optimal management suppressed the immune system of the birds, and hence making them more prone to diseases resulting in high mortality rate in lowland areas as observed in the present study (Chapter 2). Thus, knowledge of breed performance in relation to agro-ecological differences is important when distributing improved chicken breeds to farmers.

6.1.2 Effects of management system on production performance of chickens

Management involves all practices employed by the farmer including level of supplementary feeding, health care and rearing system. The findings in Chapter 3 show that management system had significant effect on growth performance, egg production and survival rates. Management system also had significant effects on external and internal egg quality traits (Chapter 4). It shows that birds raised on-station were heavier, laid more eggs and survived better than birds raised on-farm. The quality of eggs from on-station was also better than those of on-farm. The poor performance under on-farm

management could be due to poor feed quality and quantity provided as supplementary feeds which are dependent on farmers' ability. In addition, the scavenged feed resource available sometimes are not highly concentrated to supply sufficient nutrients (energy, protein and minerals) required to support growth and egg production. Furthermore, birds under on-farm management conditions are also exposed to harsh conditions such as extreme weather (rain, hot and cold), diseases and predation (Ondwasy *et al.,* 2006; Bebora *et al.,* 2005). The current study findings have revealed that such factors lead to poor growth, low egg production and high mortality rates (chapter 3). Although the studied breeds (Kuroiler and Sasso) are promoted as high meat and egg producers under village conditions, the results from the present study indicate that good performance will not be realized unless there is high adoption of good management in terms of feeding, housing and disease control.

Feed conversion ratio (FCR) and carcass traits were evaluated under the on-station management (Chapter 3 and 5). As feed costs represent 60-70% of the total cost of production, efficient conversion of feed into live weight is essential for profitability, and small changes in FCR at any given feed price can have a substantial impact on financial returns. The findings in this study show that Sasso had a lower FCR and higher carcass weight than Kuroiler indicating variation in the genetic potential of the two breeds in growth rate and muscle deposition. The higher carcass weight of Sasso than Kuroiler was expected due to heavier bodyweight of the former at slaughter as well the lower FCR which imply that Sasso is more efficient at converting feeds to live body weight, and hence carcass weight. Based on the present findings, if poultry meat is sold on a weight basis, then Sasso could be more profitable than Kuroiler due to its lower feed conversion ratio. Nevertheless, compared to most local chickens, these breeds seemed to be higher in body weight regardless of agro-ecology and management systems, and hence can be more

useful in increasing chicken meat production under smallholder poultry farming. For example, at the 16th week of age, both Kuroiler and Sasso males had already attained a body weight of 2kg; which is above the marketable weight of 1.5 kg for dual-purpose chickens (Chapter 5). This is to say, the males of both Kuroiler and Sasso breeds can replace broilers for meat production in places with limited access to broiler chickens. However, considering that the two breeds have been introduced in recent years in Tanzania, the management cost needs to be established in order to understand the profitability of production.

6.1.3 Genotype by environment (GxE) interaction

In chapter 1, the concept and definition of GxE interactions due to differences between two environments were presented. The interaction effect between breed and environment were evaluated in order to see the response of each breed when subjected to different environment. The findings show that growth, age at sexual maturity and survivability of these improved breeds are influenced by the interaction between breed and agro-ecologies. In chapter 3, the findings show that that, while Sasso had lower growth performance than Kuroiler in highland areas, the two breeds had similar growth in highland areas. Also, while Sasso matured earlier than Kuroiler in highland areas, it matured at later age than Kuroiler in highland areas. Moreover, more deaths in lowland areas were encountered for Sasso than for Kuroiler, while there was no such difference in the highland areas between the two breeds. This implies that Sasso is more sensitive to high temperature which probably suppressed its growth and survivability, and hence less suitable breed for areas with high temperature. On the other hand, Kuroiler breed maintained its bodyweight and had lower mortality regardless of agro-ecology, and hence the breed is suitable in either of the two agro-ecologies.

The interaction effect was also observed between breed and management systems. The findings in chapter 4 show that Sasso performance was better than Kuroiler under the on-station management while Kuroiler outperformed Sasso under the on-farm condition. These findings may suggest that Kuroiler chickens can cope with hash environment more than Sasso. This can be clearly shown by its relatively better growth and survival rates than Sasso under sub-optimum management conditions. Thus, knowledge of breed performance in different management systems is important for commercial companies when distributing improved chicken breeds to farmers.

6.2 General conclusions

i. Sasso chickens are more sensitive to high temperature which suppresses their growth and survivability, and hence less suitable breed for areas with high temperature. On the other hand, Kuroiler breed maintained its bodyweight and had lower mortality regardless of agro-ecology, therefore the breed is suitable in either of the two agro-ecologies.

ii. In addition, Sasso breed needs relatively better management (feeding and disease control) to perform to the optimum level; hence the breed is suitable to farmer who at least can afford providing some kind of good management. Kuroiler chickens seem to be hard, can grow and survive better under sub optimal management conditions. This implies that small holder farmers in rural areas can manage to raise Kuroiler with modest supplementation.

6.3 Recommendations

Based on the findings of this study, the following areas are suggested for future research:

i. Suitable package of management practices for improved poultry farming addressing important issues like feeding and health management of the birds are suggested.

ii. Cost-benefit analysis studies are suggested for the two breeds in different management systems to appraise the profitability or otherwise, of the improved breeds so that farmers can be advised accordingly.

iii. Testing of these breeds in the country should be done in other areas with different management/agro-ecologies to come up with a clear understating of the overall performance of these breeds under different environments. This will allow more informed decision making for the design of breeding, introduction and dissemination programs to a particular environment.

References

Bebora, L.C., Mbuthia, P.G., Macharia, J.N., Mwaniki, G., Njagi, L.W. and Nyaga, P.N. (2005). Appraisal of Village Chicken's Potential in Egg Production. Kenya. *Veterinarian* 29: 10–13.

Minga, U. M., Katule, A., Maeda, T. and Musasa, J. (l989). Potential and problems of the traditional chicken industry in Tanzania. In: Proceedings of the 7th Tanzania. *Veterinary Association Scientific Conference* 7: 207 – 215.

Morêki, J.C. (2008). Feeding Strategies in Poultry in Hot Climate. Non-Ruminants Division. Department of Animal Production: Gaborone, Botswana. 102pp.

Olori, V.E. (2008). Breeding broilers for production systems in Africa. *Nigerian Poultry Science Journal* 5 (4): 173 – 180.

Ondwasy, H., Wesonga, H. and Okitoi, L.O. (2006). Indigenous Chicken Production Manual. (Kenya Agricultural Research Institute technical note no. 18, February 2006, Nairobi). 13pp.