EVALUATION OF SELECTED PERFORMANCE PARAMETERS IN AN ONGOING INDIGENOUS CHICKEN IMPROVEMENT PROGRAMME IN KENYA

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DECLARATION

DECLARATION BY THE CANDIDATE

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DEDICATION

This work is dedicated to my parents Mr. and Mrs. Richard Gathuri, siblings; Grace Wangechi, Simon Mureithi, Faith Wambui, Hope Wanjiku, Mirriam Waithera and Aaron Ndung'u.

ABSTRACT

A genetic improvement programme to increase productivity of indigenous chicken (IC) in Kenya was implemented by Kenya Agricultural and Livestock Research Organization (KALRO) in Naivasha, Kenya. In this work, increased productivity was achieved through crossbreeding, distribution and replacement of IC exotic breeds. This study was conducted in an effort to ascertain the traits of the exotic breeds and their progeny as proceeding from the breeding programme, their egg quality traits and production performance. A sample of 120 exotic parent hens (E_f), 120 1st filial generation of E_f (F1) progeny hens, 12 exotic parent cocks (E_m) and 12 F1 progeny cocks were randomly selected for phenotypic characterization by qualitative and quantitative measurements. Data on $E_{f,}$ F1 progeny and IC hen egg production was obtained from daily performances of up to the 64th week of laying and evaluated. Structured questionnaires were administered to a random sample of 60 farmers to evaluate reproductive performance of F1 progeny hens in Lurambi Sub County, Kakamega County. In addition, eggs were collected and evaluated for egg quality traits from the parent stock (E_f), F1 progeny hens and IC housed at the Naivasha Poultry Research Centre. F1 progeny hens had a body weight of 2.159 ± 0.221 kg, chest circumference of 33.275 ± 2.553 cm and wingspan of 46.137 ± 5.753 cm that was lower than E_f that had 2.283 ± 0.249 kg, 35.133 ± 1.710 cm and 47.425 ± 1.836 cm for the above-mentioned traits respectively. F1 progeny had egg production performance of first egg layed at 128 days, reached peak lay at 186 days and attaining a peak lay of 90%, this was a higher performance when compared to IC which layed the first egg at 158 days, attained a peak lay at 194 days and had a peak lay of 55%. On egg quality based Haugh Unit (HU), E_f had 86.226 ± 5.376 while F1 had 83.020 ± 5.710 and IC had 72.780 ± 15.150. The 2nd filial generation (F2); a crossbreed of F1 and IC, generation had lower egg weights (56.814 ± 7.812 g) and HU values (79.499 ± 8.177) than F1. On crossbreeding F2 with IC to produce the 3rd filial generation (F3), the egg weight and HU reduced to 47.308 ± 4.580 g and 73.373 ± 7.769 respectively. F1 progeny outperformed the IC in body size, egg quality and egg productivity. The study concludes that the resultant F1 had a good production performance in the research station, but hybrid vigour was lost when crossbred with IC. In this regard, farmers should replenish their flocks with F1 progeny to reap the full benefits of heterosis.

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LIST OF ABBREVIATIONS

Abbreviation	Description
ADC	Agricultural Development Corporation
BPR	Barred Plymouth Rock
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistic
GDP	Gross Domestic Product
HHEP	Hen Housed Egg Production
HU	Haugh Unit
IC	Indigenous Chicken
ICVC	Indigenous Chicken Value Chain
KALRO	Kenya Agriculture and Livestock Research Organization
KAPAP	Kenya Agricultural Productivity and Agribusiness Programme
MoLD	Ministry of Livestock Development
NAHRS	National Animal Husbandry Research Station
NPDP	National Poultry Development Program
RIR	Rhode Island Red

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CHAPTER ONE

INTRODUCTION

1.1. Background information

The poultry sub-sector contributes 4% of Kenya's Agricultural Gross Domestic Product (GDP) (Olwande et al., 2013a), with the indigenous chicken (IC) constituting 80% of the national poultry population. It also produces 40% and 60% of marketed poultry eggs and meat respectively (Sabuni et al., 2010; MOLD, 2010; Ochieng et al., 2013). The IC are mainly reared in rural areas making them an important component in provision of food, income, employment and a pathway out of poverty (Ampaire & Rothschild, 2010; Ayieko et al., 2014). Poultry production has been increasing in peri-urban areas; driven mainly by the high demand for poultry products in the cities (Okeno et al., 2013a).

Productivity of the national IC flock has remained low at 40 to 100 eggs per year with slow growth rate and late maturity (Kingori et al., 2010). Various constraints have been identified and have been associated with the low IC productivity and profitability. The key among them include high disease incidences, parasitic infestation, poor genetic potential, uncontrolled breeding, predation, poor quality and inadequate feeds (Okitoi et al., 2009a; Olwande et al., 2013b). The unplanned breeding has been recognized as a possible explanation to the poor performance of IC due to high levels of inbreeding (Okeno et al., 2013a). Failure to address these problems has hindered the commercialization of IC production, although the meat and eggs from IC are preferred and fetch premium prices in the Kenyan market (Ochieng et al., 2013).

The Kenya Agricultural and Livestock Research Organization (KALRO), which is mandated with research in agriculture and livestock in Kenya, has been involved in attempts to improve the IC productivity by multiplication and distribution of improved genetic material to farmers. This was initiated with the objective of increasing the agricultural productivity and incomes of smallholder farmers (KALRO, 2014). Use of exotic breeds in crossbreeding system has been the strategy used by KALRO in achieving increased IC productivity. This is similar to such previous attempts which were mainly donor driven such as the National Poultry Development Programme (NPDP) (1976-1995) which used the exotic cockerel exchange strategy for IC improvement.

Various IC improvement programmes are also on-going in different parts of Kenya. They are aimed at improving farmers’ livelihood as well as improving rural household food and nutrition security through breed improvement. The programmes have mainly focused on within breed selection, crossbreeding, and entire breed replacement in some regions in Kenya. Combining within breed selection and crossbreeding has potential for increased IC production and profitability especially where there are opportunities for genetic evaluation (Okeno et al., 2013a).

The current KALRO IC improvement initiative has set up a crossbreeding programme that provides smallholder farmers with F1 cockerels. The programme has simultaneously been running an IC selection and multiplication programme and smallholder farmers are therefore able to purchase both the improved cockerels as well as better performing IC breeding stock. The farmers are also provided with the necessary extension services to enhance the productivity and profitability of the F1 and IC at household level. However, both the production and reproduction performance of the crossbreeds and their subsequent generations at farm level needs to be established as it is anticipated that there is bound to be genotype and environment interaction. This might even be more so in crossbred systems in the tropics that utilize genetic material selected for performance in the temperate regions where the cockerels breeds have been sourced. Besides, there has also been concerns on the potential adverse effects of the exotic breeds on IC genetic diversity.

The KALRO programme has been running for a few decades and has generated a large pool of data that requires evaluation. Mobilization of substantial resources would however be needed to undertake regular evaluation of the various production and reproduction parameters of the breeding flocks and their subsequent progeny on station and in the field. The lack of continuous evaluation leaves a gap which if addressed would help in the crucial assessment of the programme performance against its overall objectives. In light of the above background, the current study was designed to address part of the gaps alluded to by evaluating a section of data generated for some of the poultry performance parameters to help indicate the trends and scope. The study specifically aimed to assess the phenotypic characteristics of the breeding flocks, the egg production performance and the egg quality characteristics of the IC and of the crossbred progenies on-station and on-farm. The findings of this study are expected to partially help to establish both the production and genetic efficiency of the KALRO crossbreeding programme.

1.2. Statement of the problem

The KALRO crossbreeding programme targeted to increase the productivity of IC by introduction of crossbred exotic breeds with better production potential. The programme performance has not been determined against its short and long term targets. However, data has been collected for the entire period of the project and can be used to evaluate the suitability of the programme implementation against the objective.

Unplanned livestock breeding can be detrimental to a livestock population production and reproduction efficiency which subsequently affects its productivity and profitability. It is possible to determine the impact of different breeding strategies through data collection and analysis. In poultry, growth and egg production performance data has been used to determine efficiency of alternative breed improvement programmes. Besides the available data at the KALRO Naivasha Centre, there is need to collect the improved IC performance data at field level. This is to ensure that the benefits of selection generated and multiplied at the centre level are transmitted to the farming environment. Previous researches have shown a mismatch between livestock performance results obtained on-station and farm environment and more so in programmes where the genetic superiority sent to the farm is not accompanied by effective corresponding production information (extension services).

The current study aimed at evaluating the existing data at KALRO Naivasha as well as assessing on-farm production performance of improved IC in Kenya.

1.3.Justification

Phenotypic characterization is the first step towards animal genetic resources conservation and utilization (FAO, 2007b). Information on phenotypic characteristics of the F1 generation sold directly to the farmers from KALRO will guide in decision making on the optimal utilization of the crossbreeding system while at the same time guiding against the negative impact on the IC genetic resources. A breed improvement programme should consider consumer interests (Kahi et al., 2003).

Various breeding programmes have failed because of ignoring consumer interests and preferences. The information on production performance will guide producers on the potential productivity of the crossbreed in smallholder production systems in Kenya. Normally, the genotype-environment interaction results to a decrease in performance in tropical environment; hence a continuous evaluation of breeds and their crosses is paramount (Ibrahim et al., 2014). In most cases, however, the loss is compensated for by the heterosis. The findings of this study will provide valuable information on performance of the flocks disseminated by KALRO. In turn, the research organization will make necessary adjustments in the course of implementing its mandate. Disseminating the findings will also help farmers, extension staff and other stakeholders to make informed decisions on production and marketing of the products.

1.4. Objectives

1.4.1. General Objective

To characterise the exotic parent stock and evaluate selected production and reproduction performance parameters in an on-going indigenous chicken improvement programme in Kenya.

1.4.2. Specific objectives

1. To phenotypically characterize the current exotic parent stock ($E_{f,}$ E_m) used in the KALRO breeding programme and its F1 progeny
2. To evaluate on station egg production and quality traits of the exotic parent stock ($E_{f,}$ E_m), the F1 progeny and the indigenous chicken (IC) flock.

3. To evaluate on farm egg production and quality traits of F1, F2, F3 and IC flocks.

1.5. Hypotheses

H_a1: The phenotypic characteristics of the current parent stock ($E_{f,}$ E_m) used in the KALRO breeding programme and its F1 progeny are different.

H_a2: The on station egg production and quality traits of the exotic parent stock ($E_{f,}$ E_m), the F1 progeny and the indigenous chicken (IC) flock are different.

H_a3: The on farm egg production and quality traits of F1, F2, F3 and IC flocks are different.

CHAPTER TWO

LITERATURE REVIEW

2.1. The poultry industry in Kenya

2.1.1. Indigenous chicken production in Kenya

Poultry farming in Kenya contributes approximately 4% of the national agricultural GDP at an estimated population of 28.5 million chicken as at the year 2013 as shown in Figure 1 (Olwande et al., 2013a; FAOSTAT, 2014). Chicken constitute higher livestock population amongst the major animal species reared in Kenya as evidenced by the numbers presented in Figure 1. This implies that poultry production is considered important in supplying human food in Kenya. The indigenous chicken accounts for about 80% of the poultry population and provides food, income and employment opportunities to the rural and peri-urban populations in Kenya (King'ori et al., 2010; Ngaira et al., 2013).

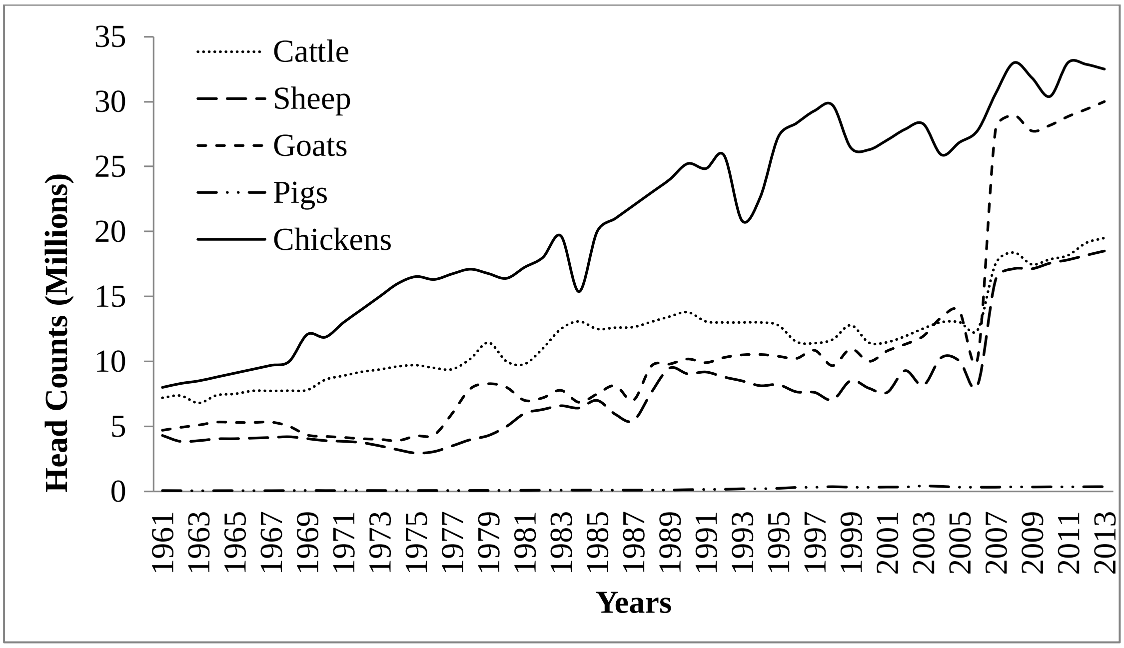

Figure 1: Annual Livestock Production Trends in Kenya between 1961 and 2013 (FAOSTAT, 2014)

The IC in Kenya are mainly kept in extensive farming system characterized by low inputs in terms of capital, skills, housing and nutrition (Ochieng et al., 2011; Okeno et al., 2011). The eggs and meat productivity is low due to among other factors; their genotype and poor feed conversion efficiency (Ochieng et al., 2013). However, IC adapts to low input management system by scavenging and foraging around homesteads (Addis & Aschalew, 2014; Ngeno et al., 2014). This is an important characteristic to be retained in the IC populations even in scenarios where crossbreeding is used as is the case with the Kenya KALRO crossbreeding programme.

2.1.2. The role of indigenous chicken

Despite the challenges encountered in the low input extensive system, the IC production provides tangible and intangible benefits to resource poor rural households (Ngaira et al., 2013). A study by Ochieng et al. (2011) noted that the system plays crucial roles in poverty alleviation in rural household mostly to women and youths, considering that the venture requires low capital investment, land resource and have faster returns to investment. Besides, the IC eggs forms an important source of protein for the rural households (Okeno et al., 2013b). Poultry eggs are of high biological value and contribute substantially to food security to the resource poor (Sola-Ojo & Ayorinde, 2009; Hussain et al., 2013). In most cases, the IC are kept for eggs and meat and are therefore characterized as dual purpose birds. The main market for eggs and live birds from the smallholder IC producer is mainly concentrated in the production locality and in many instances the egg is sold as a unit, making them affordable to rural and sub-urban resource poor dwellers (King'ori et al., 2010;

Ayieko et al., 2014). A small proportion of the products are sold to the big cities mostly through middlemen (Okeno et al., 2013b).

Provision of employment and poverty alleviation are tangible benefits. However, some of the intangible benefits played by the IC includes; use in traditional medicine and various cultural rites (King'ori et al., 2010; Bobbo et al., 2013). Indigenous chicken make a great contribution towards achieving Millenium Development Goal 1 by creating gender equity, since women are involved in the day to day management of the enterprise and promotion of rural livelihoods by provision of food (Hassen et al., 2007; FAO, 2014b).

2.2. Characteristics of indigenous chicken

Over many years of natural selection, IC has been able to adapt and multiply in diverse environments (Keambou et al., 2014) and are thus found wherever there is human settlement (Desta & Wakeyo, 2011; Ngeno et al., 2013). Under the extensive management, they have a capacity of per annum egg production of 138 to 160 eggs with an egg weight of 43g to 47g. The eggs hatchability was estimated at 83% to 84% (Kingori, 2004)

The IC are considered as local birds that thrive in extensive management system and self-propagate by uncontrolled breeding with subsequent natural incubation and brooding of the offspring. There is little input from the farmers in terms of vaccination for disease prevention and thus over decades they have developed natural resistance to bacterial and protozoan disease and tolerance to parasitic infestation (Msoffe et al., 2004; Niraj et al., 2014). They survive predation by their agility that allows them to run fast, fly and roost on trees or hide in bushes (Pym, 2009; FAO, 2014a). Easy propagation by incubation of eggs and brooding the chicks without need for investment on expensive technologies makes them adorable by the rural poor (FAO, 2008; Nigussie et al., 2010; Olwande et al., 2013b).

The quest to improve indigenous poultry production has been met with tremendous challenges that have led to poor performance (Ochieng et al., 2012; Okeno et al., 2012). For instance, uncontrolled and unorganized breeding has led to high inbreeding rate of about 8.3% per generation against the recommended rate of between 1-2% (Okeno et al., 2013a). Without intense selection and breeding programs focused on improvement of economic traits, the IC have evolved for adaptation traits rather than performance (Desta & Wakeyo, 2011).

Studies have shown that the IC have potential for fast growth, they grow slower than exotic breeds mainly due to among other factors lack of organized genetic selection and insufficient nutrients (Okitoi et al., 2009b). However, even where IC is raised in optimal management conditions, they exhibit considerable variation in growth and productivity which is as a result of differences in genetic makeup. The hens exhibit recurrent broodiness and have lower egg mass when compared to the exotic chicken.

2.3. Attributes and quality traits of IC products

Meat obtained from IC is preferred at the rural community level as well as in urban centres due to their leanness, myofibril arrangement, flavour and the assumption that they are organically produced (King'ori et al., 2004; Halima et al., 2009; Feleciano et al., 2012). The same applies to the eggs, since they are considered more nutritious than commercially produced ones. Additionally, due to the foraging ability on green matter around homesteads the IC lay eggs that have a deep yellowed yolk colour that is preffered by the consumers. For the above reasons, the IC products fetch a higher market price than the commercially produced meat and eggs.

In human nutrition, food is intended to not only satisfy hunger but to supply essential body nutrients for preventing nutritional related diseases and support healthy lifestyle. IC eggs meet the above description appropriately since they are a rich source of low cost protein, 18 vitamins and minerals (Jose et al., 2015). Additionally, eating of eggs is not affected by traditional restrictions in most of the Kenyan communities and has a high biological value. For this reason, eggs are considered as an ideal diet for children and convalescents.

The quality of eggs is dependent on the external and internal characteristics which in turn acts as price determinant for table eggs. For instance, preference to large eggs has been indicated as the consumer's value for money (Liu & Winston, 2010 ; Obike & Azu, 2012). Preference for a certain shell colour creates confidence for the product and varies according to the consumer's culture. Consumers have a mind set that brown eggs are from organic production system hence are healthier to consume although there is no existing literature that correlates shell colour to egg quality despite (Grobbelaar et al., 2010; Hussain et al., 2013). Besides the egg shell strength, the shell colour is considered imporatnt as it influences consumer preference. The coluor is a qualitative trait that varies depending on the genetic makeup of the birds.

Eggs are fragile food products which require careful handling, besides, the shell strength is a characteristic that is of economic importance to the egg handlers. The strength of the egg shell which is determined by the shell thickness is important as it results to less losses being incurred during handling. Shell weakness is a major contributor to eggs loss during laying, collection, packaging and transportation of eggs and accounts for between 13% to 20% of post-harvest loss (Sultana et al., 2007; Rayan et al., 2010).

The internal egg qualities that include; yolk width and height, albumen width and height are measures of egg freshness (Mudhar, 2011). These tend to be affected by age and genotype of the birds (Monira et al., 2003). The set standards of egg quality evaluation include; shape index, yolk index, shell thickness, and the Haugh unit (Ihsan, 2012). These are also of importance in embryonic development (Niraj et al., 2014). In embryo development, the shell colour affects hatchability since it offers protection against thermal and harmful solar radiation (Liu & Winston, 2010).

2.4. Factors to consider when undertaking a poultry breeding programme

Breeding initiative is usually undertaken to improve on traits that are considered economical to the farmer while also considering the acceptability of the final product by the end users. The primary objective of any poultry production enterprise being to maximize on profitability which has a correlation with productivity. A highly profitable flock would be expected to be highly productive. Data collected in diverse studies shows that IC in Kenya and in other regions too have lower production in terms of egg and meat (growth rate) than their exotic breed counterparts. The low production has dictated that poultry breeders focus more in IC breed improvement (Addis & Aschalew, 2014). However, the breeders have to work closely with the poultry farmers in order to cater for their breeding objective which include selecting for high egg number, large body sizes, high hatchability and fast growth rate (Okeno et al., 2012). In most instances, the consumer preferences are captured in farmers breeding goal as they purchase the eggs and/or meat from them. It is important to consider poultry producers' and consumer concerns in the breeding programme in order for the breeding plan to succeed (Nigussie et al., 2010).

High production would be desirable to the farmer since it translate to better returns for the investment. The only possible limitation is that production traits are antagonistic to survival traits. For instance, chicken breeds that are selected for high production are less resistance to diseases and tend to have high feed intake which increases the overall enterprise costs resulting from the birds consuming more feeds which account for up to 70% of poultry enterprise. Furthermore, with reduced resistance such flock tends to be vulnerable to diseases epidemics. However, where optimal management is practised such flocks tend to compansate for the increased production cost with proportinate increase in profitability. Care should be taken to ensure the response to selection for better perfomance does not increase to levels that can threaten the survival of the smallholder producers enterprises. The new technologies involved in feeding, housing, vaccination and disease control must be economically worthy to the farmer and be marketable at the farmer level.

The IC possess inherent factors that should be preserved in their utilisation in a breeding programme as they have been aquired over generations in response to the prevailing stressful production conditions in the tropics (Okeno et al., 2012). Nigussie et al (2010) documented that local poultry adaptability to the local environment characterized with poor nutrition, high parasitic burden is of great significance to the rural farmers. The IC possess unique genes that have played part in their persistence even in the harsh environments. This can be maintained through designing of breeding programmes that place emphasis on preservation of the unique qualities in IC while at the same time promoting productivity. One way of achieving this is through the use of genetic improvement strategy that focuses on selection within a genotype or ecotype (Bett et al., 2011; Okeno et al., 2013b).

Table 1: Mean ranks of characteristics considered by farmers when selecting breeding hens and cocks in Kenya

Traits	Counties in Kenya						
	Siaya	**Kakamega**	**Bomet**	**Narok**	**W. Pokot**	**Turkana**	**Mean**
Breeding hens							
Egg number	2.32	2.34	1.60	2.10	1.84	1.21	2.00
Body size	2.71	2.59	1.83	2.11	3.01	1.44	2.21
Growth rate	2.74	2.52	2.01	2.71	2.73	1.91	2.44
Hatchability	2.23	2.61	2.64	3.34	2.04	1.90	2.39
Mothering ability	2.11	2.12	2.61	2.72	2.32	2.32	2.34
Broodiness	2.91	2.41	2.84	2.80	2.81	2.11	2.71
Disease resistance	2.20	2.32	3.11	2.71	2.14	2.42	2.28
Egg size	3.91	3.47	2.17	2.64	4.00	1.89	2.69
Plumage colour	2.71	3.76	2.80	3.81	3.01	2.68	3.34
Breeding cocks							
Body size	1.94	1.72	1.81	1.63	1.31	1.50	1.71
Growth rate	2.22	1.73	1.62	2.11	2.00	2.00	1.92
Disease resistance	2.40	2.41	2.40	2.62	2.13	2.21	2.42
Plumage colour	2.91	2.90	2.44	3.41	3.11	2.81	3.21
Fighting ability	3.24	3.21	3.01	3.42	3.74	3.64	3.14

1 is for most important while 4 is for least important

Source: Okeno et al. (2012)

The IC farming is progressively shifting from the free range system to intensive farming system, though economically unjustifiable due to the poor feed conversion efficiency (Gondwe & Wollny, 2005; Ngeno et al., 2012). With the idea of commercialization of the IC farming, it is worthwhile to consider the feed conversion efficiency; since some farmers who are located in the peri-urban areas with limited space for scavenging have adapted the semi-intensive system where they supplement the birds with feeds (King'ori et al., 2010). It is therefore prudent to consider promoting genes of high feed conversion efficiency. The F1 progeny considered in this study offers such an opportunity but only after considering the genetic and economic implications of using them in different production systems.

Considering the extensive production system and the constraints noted earlier, there is need to improve the IC ecotypes which can effectively produce under the same conditions. This is in the light that replacement by the commercial breeds which are more productive than the IC may not be a viable alternative since they cannot attain their potential productivity under the extensive production system (Besbes, 2009). There is therefore a need to consider the designing of a breeding programme whose improved chicken can fit well in the smallholder production system which is predominat in Kenya (Ngeno et al., 2012).

Genetic selection focuses on the needs and preferences of the communities involved in poultry rearing (Okeno et al., 2012). In this regard, it was found that there is a farmer preference for high growth rate, high disease resistance, large egg number, small body size, high chick fertility, large egg size and egg shell colour in order of worth (Okeno et al., 2011)

2.5. Previous breeding programmes for improving indigenous chicken in Kenya

In the history of agriculture in East Africa, the European settlers made attempts to improve IC in Tanzania and later in Uganda by crossbreeding the local chicken types with Rhode Island Red, White Leghorns, Light Sussex and Black Australorp (Trail, 1962).

In Kenya, the National Poultry Development Programme (NPDP) spearheaded interventions on poultry improvement by crossbreeding the IC with Rhode Island Red cocks from 1976 to 1994 (Magothe et al., 2012b). It was a cockerel exchange programme where farmers took their breeding cocks to the agricultural centers in exchange with a Rhode Island Red cock. This programme was undertaken for a period of 18 years with positive results on the growth rate and productivity of the crosbreeds. Later on, the farmers experienced a challenge since the hens were not becoming broody (reproduction/multiplication) which occasioned a return to the IC ecotypes other than the improved local breeds (Menge et al., 2005). Other than the reproduction problem, there was an improvement in production which concurs to work done in other developing countries which have improved performance of local poultry by crossbreeding with exotic dual purpose breed adaptable to low input production systems (Fassill et al., 2010; Alewi & Teklegiorgis, 2012; Melesse et al., 2013).

The government of Kenya through KALRO, rolled out a strategy to improve indigenous chicken productivity by evaluating the productivity of several ecotypes in Kenya. In the process the researchers imported exotic breeds that can survive in low input production systems (Ilatsia et al., 2016). Support services were offered both by the KALRO Poultry Department and the numerous extension workers in the various regions in Kenya; this involved farmers training in poultry husbandry, vaccination and disease control. The programme is currently on-going at the National Animal Husbandry Research Station (NAHRS) in Naivasha, Kenya and is focused on improvement of egg and meat production (KALRO, 2014). The current study was set to partly evaluate this programme.

2.5.1. Success of previous breed improvement programmes

The present day breeds are as a result of decades of either natural or artificial breeding that has been going on since the domestication of chicken. There has been an increase in demand for the IC products as previously highlighted in this document and efforts have been going on to either intensify IC farming or improve the ecotypes which can survive in the low input systems. An economic analysis of IC under an intensive management system is unjustifiable due to the poor feed conversion efficiency and low productivity (Gondwe & Wollny, 2005). This prompted the quest for a high genetic potential dual purpose breed adaptable to low input production systems. To attain this objective, crossbreeding as a means of genetic improvement has been advocated for by several researchers (Mekki & Yousif, 2005; Ayorinde et al., 2012; Sola-Ojo & Ayorinde, 2011).

Studies on performance of crossbreeds between local and exotic breeds indicate better performance compared to the local poultry (Melesse et al., 2013). Rhode Island Red (RIR), Barred Plymouth Rock (BPR) and their crossbreeds are dual purpose breeds that have been used to improve genetic potential of local chicken in low input production systems (Matiwos et al., 2013; Nthimo et al., 2006; Das et al., 2014). For instance, Mmereole & Udeh (2009) having done a study in Enugu State, southeast of Nigeria, concluded that the crosses of Plymouth Rock and local birds in the tropics performed better than the local breeds therein. Crossbreeds benefit from transmitted sire and dam gene effects although they lack maternal environment effect. While the local poultry transmit adaptability and disease resistance traits the exotic one contribute to the high productivity (Ngeno et al., 2014)

Crossbreeding for egg and meat production with exotic breeds results in increased productivity of the indigenous chicken (Ngeno et al., 2013). For instance, crossbreeding IC with RIR under the NPDP programme improved productivity of the indigenous chicken tremendously with the flock sizes and egg production increasing by 85% and 80% respectively in the surveyed regions (Smith & Tan, 1981; FAO, 2007a).

Breed improvement programme in Uganda by crossbreeding with exotic breeds have also produced excellent results by strategic interventions. It was found out that crossbreeding local hens with exotic breeds and vaccination against Newcastle disease increased productivity per household and had positive economic impacts (Ssewannyana et al., 2008a). Private entrepreneurs and rural development programs import and distribute the exotic dual purpose breeds and their crossbreds to improve on food security in developing countries (Nthimo et al., 2006).

2.5.2. Challenges encountered in the previous breeding programmes

In Kenya, IC productivity through crossbreeding with exotic breeds was unsustainable due to the incompatibility of the crossbreds with low input systems, lack of clear breeding objectives and operational breeding programs that would have ensured constant supply of breeding stock to farmers (Ngeno, 2011). Exotic breeds are ‘food converters’ and not ‘food producers’ and for them to produce they require grain based diets hence competing for the scarce grain resource with human beings which complicates the situation. There are occasions when maize grain is deficient in Kenya as it is used as human food and in several instances the situation has been declared national disaster. Much of the raw materials used in manufacture of poultry feeds in

Kenya comes from the neighbouring countries in form of agroindustrial by-products which is also seasonal in correspondence to the crop seasonality.

For the high out put genetic resources to be maintained within the population, articulate and cost efficient animal husbandry practises are required (Hoffmann, 2010). In the previous breed improvement programmes, instead of improving on productivity, new challenges which included increased production costs, unavailability of inputs due to high costs, market failures as a result of oversupply and erosion of genetic resources due to indiscriminate use of the exotic breeds were promoted (Magothe et al., 2012a; Okeno et al., 2012). These weaknesses and rationale of the past improvement efforts need to be addressed for success of the present and future breeding programmes.

In Ethiopia the Ministry of Agriculture imported exotic cockerels for crossbreeding but the scheme did not succeed (Tadelle et al., 1999). The increase in exotic genes in local chicken reduced broodiness which farmers consider to be of economic value for their flock build up. Though the crosses have a higher productivity than the IC, the flocks diminished progressively due to the inadaptability to the local environment and low reproductive performance leading to low flock build up (Nigussie et al., 2010; Martin, 2000). The crossbreeds had successful results in the research stations but the programme had to be discontinued due to the above reasons among others (Nigussie, 2011).

In other parts of the world efforts to improve IC by crossbreeding has been on two approaches which are crossbreeding with exotic breeds and the cockerel exchange programmes. The efforts have been futile due to unacceptability of the birds by the farmers and their reproductive challenges. Though some genetic progress has been recorded in some rare instances, over time only the change of plumage colour remains as an indicator of the intervention made (FAO, 2008).

2.5.3. Current status in production and raising of improved indigenous chicken in Kenya

In Kenya, there has been an increased demand for the improved indigenous chicken by farmers due to their fast growrth rate, consitent egg laying and high perfomance as compared with the local indigenous chicken. For a long time the source of the impoved IC was KALRO Naivasha but due to the growing demand there was expansion through the establishment of a hatchery in KALRO Kakamega. Additionally, private enterprises in urban and periurban areas have proliferated to supply the increased demand of improved indigenous chicken (Alaru et al., 2017). The county goverments have been promoting the rearing of improved IC and have taken a step further in procuring and distributing the imrpoved IC to farmers at subsized costs (Waineina et al., 2017). The source of the fertile eggs and cocks for the improved IC has been KALRO Naivasha and this has created a constraint in that it is not capable to meet the demand. Consequently, the private enterprises have been having unmonitered activities leading to inbreeding and reduced perfomance of the chicken making the venture unsustainable (Alaru et al., 2017; Waineina et al., 2017). The field data to be obtained from this study will be analysed to provide an indication of what could be happening post KALRO Naivasha.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Study structure

The current study was organized in three parts. The first study was conducted on-station to phenotypically characterize the exotic parent stock in the breeding programme and its F1 progeny and evaluate the production performance of the exotic parent stock, F1 progeny and the IC flock on-station was evaluated. The second part was a follow-up study in the field (on-farm) to evaluate the production and reproduction performance of F1 progeny reared under extensive production system by the farmers. Lastly, third part was an evaluation study of egg quality traits for the on-station and on-farm flocks.

3.2. Study site

3.2.1. The on-station studies

On-station studies were conducted at KALRO Naivasha, which is located in Naivasha town along the Nairobi to Nakuru highway approximately100 Km North-West of Nairobi (Fig 2). It is at an altitude of 1829-2330 m above sea level, in the ecological zone IV experiencing an average rainfall of 680 mm per annum with a temperature and a relative humidity range of 8 ℃ to 26 ℃ and 60% to 75% respectively (Kariuki et al., 2010).

3.2.2. The on-farm study

The on-farm studies were conducted in Lurambi Sub-county located in Kakamega County. Kakamega County is in Western Kenya (Figure 2) and covers an area of 1,395 km^2. The County lies within an altitude of 1,250 - 2,000 m above sea level and receives an average annual rainfall of 1,250 - 1,750 mm (Mbuthia, 2014). Kakamega was chosen since the current study was part of a wider project that covered Kakamega County due to its higher population of IC. Some donor funded projects undertaken in the county had focused on improvement of IC and had provided farmers with F1 progeny chicks from KALRO Naivasha. This county therefore provided a relevant study site for follow up studies on performance of improved IC and the subsequent generations with F1 progeny procured from KALRO Naivasha.

Figure 2: A geographical map of Kenya showing Kakamega and Naivasha study sites. (KNBS, 2010)

3.3. Phenotypic characterization of the parent stock (E_f, E_m) used in the breeding programme and its F1 progeny (on-station flock)

3.3.1. Sampling

A flock of exotic parent breeds; D109 (Dominant CZ, 2014), was housed in a ratio of one male (E_m) to ten females (E_f) and their F1 progeny were used in this study. From each of the two available layer houses with a capacity of 500 birds each, a sample of 120 hens and 12 cocks were randomly selected using the method recommended by FAO (2012).

3.3.2. Data collection

Characterization involves collection of both qualitative and quantitative data on phenotypic traits. The sampled chicken confined in separate cages, were evaluated for both qualitative and quantitative traits.

a. Qualitative traits recorded were; feather morphology, feather distribution, plumage colour, plumage pattern, skin colour, comb type, eye colour, shank colour, earlobe colour and comb size. For accuracy and consistency, a pictorial guide by Cuesta (2008) was used for this characterization (Appendix 1).
b. Quantitative traits assessed in this study were; body weight, body length, shank length, wingspan and chest circumferences as described by Guni et al. (2013).

3.3.3. Data analysis

The qualitative and quantitative traits mentioned above, were analysed using Minitab Version 14 for descriptive statistics.

3.4. Evaluation of egg production performance of the parent stock (E_f), the F1 progeny and IC (On-station flock)

3.4.1. Background of study flocks

Exotic parent stock males (E_m) and females (E_f) were imported from Czech Republic (Dominant CZ, 2014) as day old chicks, brooded for 8 weeks then transferred to grower houses. They were fed on chick and duck mash for 8weeks before being introduced to growers mash up to the 20th week. From thereon they were fed on layer's mash while water was provided *ad libitum* at all stages of growth. At sexual maturity (20 weeks), the males and females were transferred to layer houses in a ratio of 1:10 (male to female) to form the parent stock. Eggs from the parent stock were incubated and on hatching, the same practices as described above were undertaken to raise the off-springs of F1 progeny. Standard disease prevention procedures were observed for vaccinations against Marek's disease, Newcastle disease, fowl typhoid and fowl pox.

3.4.2. Data collection

Egg production records for a period of 64 weeks (20th to 84th week of age) of the layers production cycle from the pure breed parent stock and their F1 progeny were studied. The data included; number of layers housed, daily egg production, egg weight (egg mass), age at first lay, peak production and at 50% lay and age at peak lay. It is important to note that the data was collected from the two flocks of chicken used previously in the phenotypic characterization in KALRO Naivasha. For comparison purposes, data from IC managed at the research station was similarly evaluated for the above indicated production parameters. The IC ecotypes used in this study were developed by KALRO in Naivasha (Ilatsia et al., 2016).

3.4.3. Data analysis

Minitab Version 14 was used for the descriptive statistics on production indices. The egg production parameters were calculated as described by Murad et al. (2003).

The egg production parameters are shown below:

$$\text{Hen-day Percentage egg production} = \frac{\text{Number of eggs produced per day}}{\text{Number of hens in the flock}} \times 100$$

3.5. Evaluation of the productive and reproductive performance of F1 progeny reared under extensive production system (On-farm flocks)

3.5.1. Study Site and data collection

See Section 3.2.2. for the description of the study area. Farmers who purchased F1 day old chicks from KALRO Naivasha research station were identified and contacted for the study. A structured questionnaire (Appendix 2) was then administered to a total of the identified 60 households. These are were all the farmers that had been supplied with day old chicks by KAPAP.

Relevant data on egg productivity, breeding and production system was collected while direct observations were made to determine the management and housing system used by the farmers

3.5.2. Data analysis

Data on egg production was analysed using Minitab Version 14 and described using univariate statistics.

3.6. Evaluation of egg quality traits for the parent stock, F1, F2, and IC

3.6.1. On-station flocks

This study was conducted to determine the egg quality attributes and trends from one generation to the next. Eggs were collected from three different lines; parent stock (E_f), F1 progeny and IC which are maintained at KALRO Naivasha poultry unit. At the time of undertaking the study the E_f and F1 progeny were at the age of 60 weeks, while IC were at the age of 38 weeks. All the birds were under an intensive production system and fed on a standard commercial diet. Eggs laid from the respective layer houses were randomly selected in the following criteria; E_f (90), F1 progeny (90) and IC (60), and evaluated within a period of 72 hours. Evaluation within 72 hours was to enhance accuracy since storage time has an effect on quality.

3.6.2. On-farm flocks

Additionally, 120 eggs were obtained from 3 different flocks' generations from farmers in Kakamega County and evaluated for egg quality traits. From each generation, 40 eggs were evaluated within 72 hours after egg laying. Farmers were categorized into three groups as follows: Group one comprised of farmers who had purchased F1 chicks from KALRO Naivasha for commercial egg production. Group two farmers who had purchased fertile eggs from the first group hatched and reared them as the F2 generation. The third group mated F2 cocks to their IC hens with an objective of improving the productivity. The progeny of F2 by IC was considered as F3 for the purpose of this study.

Eggs were marked for identification before breaking to extract contents, shells were wiped and air dried before weighing and measuring their thickness. Soiled eggs were wiped with a cloth before further evaluation to avoid extra weight on them. A 0.001 g sensitive electronic weighing machine was used to measure egg and shell weight. Egg length and width were determined using a veneer calliper and the measurements used to calculate shape index according to Rayan et al. (2010). Micrometer screw gauge was used to measure the shell thickness (Dasari et al., 2013), while egg surface area was determined using the formula $3.98W^{0.71}$, where 3.98 and 0.71 are constants and W is the egg weight (Nasr et al. 2012). Eggshell percentage and eggshell density were calculated by dividing the shell weight by egg weight and by egg surface area respectively. Other parameters recorded were the shell colour and shell appearance (tinted or plain).

The albumen and yolk weight, height and width were measured separately using methods described by Dasari et al. (2013) and Shabbir et al. (2013).

3.6.3. Data analysis

Univariate analysis statistics were used to describe the internal and external egg traits, their derived indices and the Haugh unit. Minitab Version 14 was used for all the statistical implementations. Egg indices were calculated according to Yakubu et al. (2008) and Thomas (1968), whereas Haugh unit (Hussain et al., 2013), was determined using the formula below.

$$Haugh\ unit = 100\ \log(H + 7.6 - 1.7W^{0.37} \qquad \text{(Equation 1)}$$

where H is the height of the albumen and W is egg weight

Egg volume was calculated according to Teusan et al. (2008) as:

$$0.519 \times \mathrm{Lg} \times \mathrm{Wd}^2 \qquad \text{(Equation 2)}$$

where Lg is the longitudal length, Wd is the transverse width and 0.52 is a specific calculation coefficient. Shape index was determined as described by Rayan et al. (2010):

$$\text{shape index} = \frac{\text{Egg width}}{\text{Egg length}} \times 100 \qquad \text{(Equation 3)}$$

CHAPTER FOUR

RESULTS

4.1. General results

Qualitative traits are as illustrated in Table 2 where all the sampled chicken had a normal feather morphology and distribution. All the sampled birds had large comb size and white skin colour. There was 100% single comb type in E_f, E_m and F1 hens while F1 progeny cocks had a 4% rose comb type. The appearance of rose combs in F1 progeny was puzzling since the parent stock E_f and E_m had single comb types. The distinct characteristics of the parent stock was as follows: E_m had red plumage colour and eye colour with a normal plumage pattern (100%), while E_f had black plumage (100%) with a barred pattern and orange eye colour (99%). Based on all the evaluated traits the parent stock exhibited uniformity in all the characteristics except in ear lobe colour. The F1 Progeny hens had 83% grey shank colour, 99% normal plumage pattern and 64% red/white earlobes. F1 Progeny hens were distinguished by the black plumage colour with brown feathers on the neck (Figure 3).

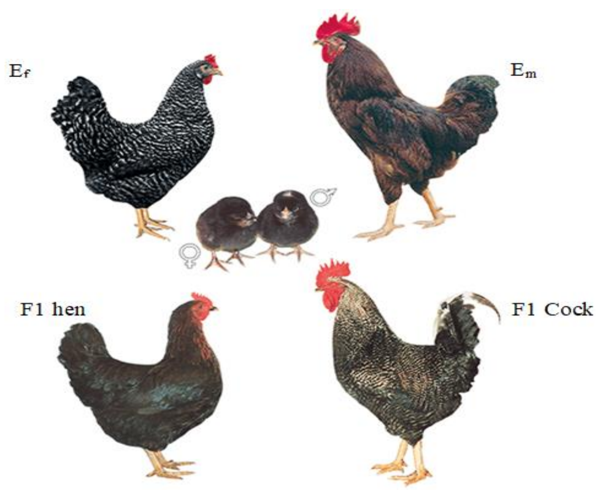

Figure 3:**Morphological expression for E_m, E_f (top) and their F1 Progeny (bottom) used in the the present study. (Source; Author, 2009)**

Table 2: Phenotypic trait expression in percentage for E_m, E_f and F1 Progeny

	Parents		Progeny (F1)	
Parameter	**Cocks (E_m)**	**Hens (E_f)**	**Cocks**	**Hens**
Feather Morphology				
Normal	100	100	100	100
Feather Distribution				
Normal	100	100	100	100
Plumage pattern				
Normal	100	0	54	99
Barred	0	100	46	1
Plumage Colour				
White	0	0	67	13
Black	0	100	4	81
Brown	0	0	4	5
Red	100	0	0	1
Whiten	0	0	25	0
Skin Colour				
White	100	100	100	100
Shank Colour				
White	99	100	96	17
Yellow	0	0	4	0
Grey	1	0	0	83
Ear Lobe Colour				
Red	24	58	75	36
White/Red	76	42	25	64
Comb size				
Large	100	100	100	100
Comb type				
Single	100	100	96	100
Rose	0	0	4	0
Eye Colour				
Orange	99	0	96	100
Red	1	100	4	0

Weights for E_m, E_f and F1 progeny are shown in Figure 4. Cocks and hens weights for parent stock were 2.90 kg and 2.28 kg respectively. On the other hand, F1 progeny cocks and hens weighed 3.09 kg and 2.16 kg respectively.

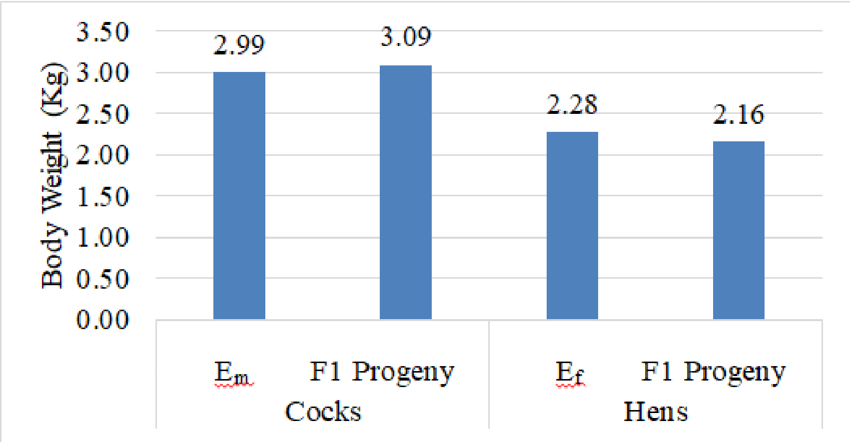

Figure 4: Body weights of E_m, E_f and F1 Progeny

The F1 progeny shank length (12.04 ± 0.72 cm) and wingspan (55.67 ± 2.33 cm) were significantly higher than those of E_m which had a shank length of 11.63 ± 0.88 cm and a wingspan of 53.83 ± 2.29 cm. The F1 progeny males exceeded the parent stock males in most of the recorded measurements. Nevertheless, body length of E_m (49.83 ± 1.75 cm) exceeded that of F1 progeny (46.00 ± 5.52 cm) significantly.

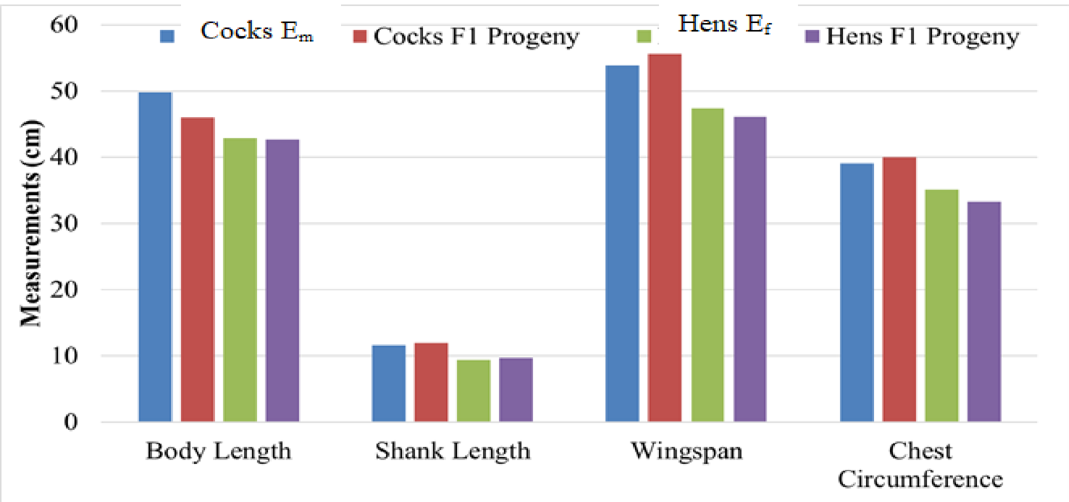

Figure 5: Body measurements of E_m, E_f and F1 Progeny

In the case of chest circumference, E_m had 39.08 cm while E_f had 35.13 cm. The F1 progeny cocks had a chest circumference of 40.00 cm while hens had 33.28 cm. The F1 progeny cocks had larger body weights, chest circumference, shank length, and wingspan compared to the F1 progeny females. The F1 progeny hens had lower body measurements in all the traits than the E_f except for the shank length where the F1 progeny had 9.74 ± 0.55 cm while E_f had 9.41 ± 0.48 cm.

The F1 Progeny recorded better performance by reaching age at first lay in 128 days, age at 50% lay at 161 days and peak lay of 90% at 186 days as shown in Figure 4. E_f started laying at 158 days, attained 50% lay at 177 days and peak lay of 89% at 190 days. In comparison, IC started laying at 152 days and reached 50% lay at 192 days and reached its peak lay of 55% at 194 days.

Table 3: Production parameters of F1 Progeny, E_f and IC

Parameter	IC	E_f	F1 Progeny	Mean
Age at peak lay (days)	194	190	186	190
Egg mass (g)	1885.062	18334.830	16081.490	12100.5
Hen Day Production	40.707	269.781	229.360	179.949
Hen housed production	65.357	237.767	195.217	166.114

The F1 Progeny hens layed their first egg at 160 days on-farm and 120 days on-station; attributable to variations in managerial practices.

Table 4: External egg physical characteristic of E_f, F1 progeny and IC

Egg Parameter	E_f	F1 Progeny	IC	Overall Mean	SEM
Egg Weight (g)	67.96^a	70.11^a	46.31^b	61.46	±7.60
Egg Length (cm)	6.01^a	6.20^a	5.33^b	5.84	±0.26
Egg Width (cm)	4.48^a	4.52^a	4.01^b	4.34	±0.17
Shell thickness (mm)	0.43^a	0.49^b	0.58^c	0.50	±0.04
Shell weight (g)	5.62^a	6.06^b	4.94^c	5.54	±0.33

Values with dissimilar superscripts have significant difference ($p<0.05$)

External egg characteristics are presented in Table 4. Indigenous chicken had the lowest egg weight (46.31 ± 5.36 g), length (5.33 ± 0.29 cm), width (4.01 ± 0.33 cm) and shell weight (4.94 ± 0.76 g). Remarkably, IC had the thickest shell of 0.58 ± 0.11 mm. In comparison, F1 Progeny had the highest egg weight (70.11 ± 7.28 g) egg length (6.20 ± 0.33 cm), egg width (4.52 ± 0.20 cm), and shell weight (6.06 ± 0.83 g).

Table 5: Egg weights for different shell colour and appearances

		IC		**E_f**		**F1 Progeny**	
	Parameter	**Egg weight (g)**	**Proportion (%)**	**Egg weight (g)**	**Proportion (%)**	**Egg weight (g)**	**Proportion (%)**
Shell Colour	Brown	44.67	47	68.19	94	71.13	78
	Cream	48.91	53	64.15	6	67.52	22
Shell appearance	Plain	46.42	100	67.76	59	70.38	84
	Tinted			68.26	41	68.68	16

Results on shell colour and appearance are presented in Table 5. It was observed that brown shells dominated in F1 Progeny (78%) and E_f (94%), whereas cream shells dominated in IC (53%). All eggs from the IC flock had a plain appearance as presented in the table above. Plain shell appearance dominated in F1 Progeny (84%)

and in E_f (59%), although there were more tinted egg shells in E_f than in other chicken. F1 Progeny hens had heavier brown eggs with 71.13 g than cream eggs which had 67.52 g. Similarly, the brown eggs were heavier in E_f (68.19 g) and in IC (44.67 g) than the cream eggs.

Table 6: Internal egg physical characteristics of E_f, F1 progeny and IC

	Breeds				
Egg Parameter	**IC**	**E_f**	**F1 Progeny**	**Overall Mean**	**SEM**
Albumen Weight (g)	24.54^a	40.58^b	40.59^b	35.24	±5.35
Albumen Height (mm)	3.43^a	6.53^b	7.18^b	5.71	±1.16
Albumen Width (mm)	6.61^a	7.16^b	7.23^b	7.00	±0.20
Yolk Weight (g)	14.63^a	18.54^b	19.12^b	17.43	±1.41
Yolk Height (mm)	1.48^a	1.62^a	1.46^b	1.52	±0.05
Yolk Width (mm)	3.82^a	4.20^b	4.33^b	4.11	±0.15

Values with dissimilar superscript have significance difference ($p<0.05$)

Internal egg characteristics are illustrated in Table 6. F1 Progeny had higher internal qualities than the rest of the chicken except for yolk height (1.46 ± 0.73). The albumen width (7.23 ± 0.46 mm) and yolk weight (19.12 ± 1.66 mm) were higher even though they did not differ significantly from the values recorded for the E_f. In general, all internal egg traits, IC had the least measurements while F1 progeny recorded the highest in most of the observed traits.

Table 7: Egg traits parameters E_f, F1 progeny and IC

	Breed				
Egg Parameter	**IC**	**E_f**	**F1 Progeny**	**Mean**	**SEM**
HU	72.78^a	86.23^b	83.02^b	80.68	±4.06
Egg Surface Area (cm^2)	59.48^a	78.02^b	79.73^b	72.41	±6.49
Shell density (g/cm^3)	0.01^a	0.01^a	0.04^b	0.02	±0.02
Egg volume (cm^3)	44.80^a	62.83^b	65.79^b	57.81	±6.56
Egg density (g/cm^3)	1.06^a	1.08^a	1.07^a	1.07	±0.01
Shape index	75.30^a	74.70^a	73.10^b	74.37	±0.66
Shell index	8.15^a	7.20^b	7.60^c	7.65	±0.28

Values with dissimilar superscript have significance difference ($p<0.05$)

There was significant difference between the egg traits recorded in Table 7 in all the 3 groups of chicken with the exception of egg density of F1 Progeny (1.07 ± 0.05 g/cm^3), E_f (1.08 ± 0.03 g/cm^3) and IC (1.06 ± 0.14 g/cm^3). E_f had the highest HU of 86.23 ± 5.38 while F1 Progeny had 83.02 ± 5.71 and IC had 72.78 ± 15.15.

4.2. Egg quality of F1 Progeny

Table 8: Egg quality traits of F1, F2 and F3 generations in on-farm flocks

Parameter	**Crossbreed**				
	E_f× E_m (F1)	**F1 × F1 (F2)**	**F2 × IC (F3)**	**Mean**	**SEM**
Egg Weight	66.29	56.81	47.31	56.80	±5.48
Shell thickness (mm)	0.39	0.41	0.36	0.39	±0.01
Albumen weight	40.99	33.86	23.74	32.86	±5.01
Albumen Height	6.52	5.91	4.47	5.64	±0.61
Yolk weight	18.80	16.53	16.78	17.37	±0.72
HU	84.10	79.50	73.37	78.99	±3.11
Egg Surface Area (cm^2)	76.59	68.68	60.41	68.56	±4.67
Shell density (g/cm^3)	0.01	0.01	0.01	0.01	±0.00
Egg volume (cm^3)	64.48	53.26	44.77	54.17	±5.71
Egg density (g/cm^3)	1.03	1.07	1.06	1.06	±0.01
Shape index	76.30	76.87	73.03	75.40	±1.20

F1 progeny had the highest egg weight of 66.29 ± 8.24 g, F2 had 56.81 ± 7.81 g and F3 had the lowest 47.31 ± 4.58 g (Table 8). The F1 had the highest values in most of the observations except for shell density (0.01 ± 0.01 g/cm^3), egg density (1.03 ± 0.03 g/cm^3), yolk height (1.53 ± 0.15 mm), shell thickness (0.39 ± 0.05 mm) and shape index (0.76 ± 0.04). F3 generation had the least observations in all parameter except for egg density (1.06 ± 0.08 g/cm^3), shell density (0.01 ± 0.01 g/cm^3), yolk width (4.19 ± 0.23 mm) and yolk weight (16.78 ± 1.76 g). All the chicken generations had a high HU ranged from 73 to 84. F2 generation exhibited the highest shell thickness

(0.41 ± 0.04 mm), shape index (0.77 ± 0.05), egg density (1.07 ± 0.06 g/cm^3) and shell density (0.01 ± 0.01 g/cm^3).

CHAPTER FIVE

DISCUSSION

5.1. General discussion

There have been a few characterization attempts in Kenya based on morphology and feather colours, indicating wide variations; which indicate of genetic variability in the chicken population (Magothe et al., 2012b). Phenotypic characterization of the parent stock (E_f and E_m) and their F1 progeny in KALRO research station made it possible to identify breeds used in the breeding programme and the characteristics of the offspring.

The uniform expression seen in the results presented in Table 2 (100%; without variation) in red eye colour, single comb type and white shanks is attributable to prolonged period of artificial selection of the pure breed in E_m. This notwithstanding, it was noted that the earlobe had 58% red colour and 42% red/white colour. It is expected that the purebred exotic breeds would not show such variation unlike the IC. Emebet et al. (2014) observed dorminant ear lobe colors to be; red, red/white and white. In this study, it was observed that E_m cocks had a uniform plumage colour, while their F1 progeny that varied from white, black and brown. This could have resulted from crossbreeding of the red cocks to the black barred hens. Additionally, F1 progeny (cocks and hens) had normal feather morphology and distribution, white skin colour and a large comb size as illustrated in Table 2. Comb and wattle size are highly correlated to male fertility and can be used in selection and culling of sub fertile males in a flock (Gebriel et al., 2009; Ibrahim et al., 2014).

The F1 cocks had plumage colour variation; 67% white, 4% black, 4% brown and 25% whiten. The same variation in plumage colour was observed in the F1 progeny hens that had 13% white, 81% black, 5% brown and 1% red. In controlled breeding, plumage colour and feather characteristics has little variance due to a high gene frequency which is a characteristic of commercial hybrids. In the converse, plumage pattern and colour greatly vary in populations with uncontrolled breeding (Guni & Katule, 2013; Ssewannyana et al., 2008a). For instance, in Bangladesh, the local IC exhibited a variety of plumage pattern and colour ranging from 13.7% red, 13.5% blackish red, 12.67% black, 11.04% white with black spot, 5.55% mixed colour, 4.9% brown, 4.9% blackish white and 0.61% reddish white (Nipa et al., 2014). In Kenya, the common plumage colours are; white, brown, golden, red, yellow and mixed colours (Magothe, et al., 2012b).

Single comb type and white shank colour dominated (96%) over rose comb type and yellow shank colour characteristics (4%) in F1 progeny cocks (Table 2). Furthermore, all the sampled birds had white skin and shank colour; with exception of F1 progeny females which had 83% grey and 17% white shanks. Shank colour may be because the flocks did not have access to green forage material, which could have influenced pigmentation. Lack of pigmentation can partly be attributed to low xanthophyll in the diets. Skin colour is often the result of deposition of melanin pigments in the epidermis and dermis under the influence of genes and nutrition (Duguma, 2006). Feeds with high xanthophyll result to yellow pigmentation although some birds are genetically incapable of utilizing and depositing the carotenoid pigments (Guni & Katule, 2013). The IC reared under extensive system forage around the homesteads and may have access to carotene hence yellow shank and skin colour dominates (Emebet et al., 2014; Firda et al., 2014). Orange eye colour dominated (96%) in F1 progeny cocks, F1 progeny hens and E_m in this study. This concurs with a study in Uganda in which most of the evaluated chicken had a dominant orange eye colour (Ssewannyana et al., 2008b). Contrasting findings were reported by Duguma (2006) who observed black eye colour in Horro, Tepi and Jarso ecotypes in Ethiopia.

The IC exhibit large variations in qualitative traits and have been reported by different authors to vary on plumage colour and plumage pattern. The possible explanation for the variation reported is the extensive interaction of genes influencing the traits and lack of artificial selection (Apuno et al., 2011). Artificial selection results to high gene frequencies and minimizes variation within breeds. The small variation in phenotypic traits of F1 progeny indicate less interactions of genes influencing the traits due to defined crossbreeding in the programme.

The highest quantitative measurements (Figure 3) except for body length were observed in the F1 progeny cocks. The F1 progeny hens had lower weights than the cocks which is similar to findings by Guni et al. (2013) who reported that cocks were generally heavier than hens. This difference may be attributed to the effect of testosterone hormone, which influences muscles build up in males. When the chicken are reared for meat production, males are preferable in realization of better returns than the females of the same age.

Farmers preferred the F1 progeny to the IC. This can be attributed to the body weight (2.16 ± 0.22 kg), chest circumference (33.28 ± 2.55 cm), and wingspan (46.14 ± 5.75 cm) of the F1 progeny. The hens were heavier than their contemporary IC reported by Egena et al. (2014) of 1.69 kg and Ukwu et al. (2014) of 1.45 kg. This poor productivity traits could be explanined by the measurements recorded for Gaga chicken in Indonesia studied by Sri et al. (2013). which had smaller body weight (1.71

± 0.37 Kg), chest circumference (17.00 ± 2.60 cm) and wingspan (24.20 ± 2.30 cm) This may be because the F1 progeny evaluated is a crossbreed of exotic breeds that have a higher growth potential than the IC. The other reason for the small body sizes in IC may be because they were reared under extensive production system characterized by poor nutrition and inappropriate husbandry practises (Ngo et al., 2006).

The high body measurements in the F1 progeny and their parents in the current study might have resulted from gene-environment interaction since they were reared under an intensive production system where their feeding was on premium commercial feeds. The E_f and E_m are exotic breeds that have been selected over many decades for fast growth and big mature body size. Being pure breeds and receiving adequate nutrition, they are capable of attaining even greater weights as reported by Machal et al. (2004).

The IC had eggs with the smallest weight compared to F1 progeny and E_f (Figure 4). Poor IC performance was observed in the intensive production system at the research station. This implies that putting IC in intensive production would be uneconomical based on poor peak production (55%) and long duration before reaching peak laying (194 days). Gondwe and Wollny (2005) also reported that it is uneconomical to rear IC under intensive production system due to their poor genetic potential. The IC egg weight was in the same range between 42 g and 48 g although smaller egg sizes of between 33g and 39 g have also been reported in IC flocks as that reported by other authors (Kingori, 2004; 2010; Mengesha, 2012). In the current study the age at first lay was at 152 days which is later than the range of 126 to 140 days reported in Benin (Youssao et al., 2011). When IC were reared in an extensive system they exhibited poor perfomance due to poor nutrition and management. Similar results have been reported in Sudan (Issa et al., 2013) which had a first lay at 157 days and in Tanzania which was between 168 and 224 days (Mwalusanya et al., 2002). The IC in the current study had higher egg production indices than reported in literature (Msoffe et al., 2004; Olwande et al., 2010), since the local poultry herein were managed in an intensive system, while much of the existing literature is based on extensive management systems.

Age at first egg is the maturity age of the flock and therefore F1 progeny reached maturity earlier (128 days) than the maternal parents E_f (158 days). This can be attributed to heterosis that crossbred animals have over the purebred animals. The heterotic effect of crossbred animals is well documented in breeding programmes. For instance, the maturity age of a cross between Rhodes Island Red and Fayoumi breeds decreased from 167.60 ± 2.70 days to 151.50 ± 1.90 days. When the Leghorn was crossbred to the Fayoumi, the maturity age also decreased from187.10 ± 2.30 days to 153.10 ± 2.30 days (Dottavio et al., 2001). A similar reduction of age at first lay following crossbreeding was reported in Ethiopia by Fassill et al.(2010).

The F1 progeny had a higher egg laying peak (90%) at 165 days while E_f had a lower peak lay (89%) at 190 days in the current study with the egg weight in E_f being less than that of F1 progeny. The heavier eggs in the crossbred chicken is attributable to heterosis. Different values were obtained in the study carried out by Islam et al. (2002; 58.04g) and Monira et al.(2003; 64g) for the E_f eggs. This may be explained by the genotype x environment interaction noting that the environment in which the E_f were reared was different.

The F1 progeny in the field environment in this study attained age at first lay later (160 days) than those in the breeding station at KALRO, Naivasha. The F1 progeny hens did not exhibit broodiness and hence farmers incubated the eggs with foster IC hens and the egg hatchability corresponded to other studies which recorded 82-84% under natural incubation of (King'ori et al., 2010; Okeno et al., 2012; Addis & Aschalew, 2014).

The F1 generation in the current study had the highest egg weight and the best egg quality based on the HU measures when compared with F2 progeny. This is because it is a crossbreed between two exotic pure breeds chicken while the latter is a product of single line cross. When F2 was crossbred with IC, the egg weight and HU reduced to 47.31 ± 4.58 g and 73.37 ± 7.77 respectively. There was an observed decreasing trend in egg quality from F1 to F3 generations. This can be explained by the fact that there was progressive loss of heterotic effects between one generation to the next. Fassill et al. (2010; 43.7g) and Alewi and Teklegiorgis (2012; 44.2g) reported low egg production performance when IC was bred with F2 generation cocks/hens.

Phenotypic expression is a factor affected by both genes and the environment. F1 progeny produced lighter eggs in the semi intensive system than in the intensive system in Naivasha where they had 70.11 ± 7.28 g; this may be due to the change in production system. Conversely, the HU slightly increased from the recorded 83.02 ± 5.71 to 84.102 ± 10.40 in the different systems.

The second and third generations, egg’s quality traits reduced when compared to the first generation. When F2 cocks were crossbred with IC hens, the performances were low because of the poor maternal effects. In crossbreeds where the dam is involved in the rearing of the offspring, there is a tendency for the progeny phenotype to resemble the dam than the sire. In chicken, there is a high correlation between egg weight, hatching weight and weight at 4 weeks due to maternal effect as reported by Egahi et al. (2013). The small egg sizes in the IC led to decreased overall perfomance of the subsequent generations. The F3 had better HU and higher egg weight than IC reared in an intensive production system.

The F1 progeny in this study attained age at first lay later (160 days) than the counterpart in the breeding station in KALRO Naivasha which could be attributed to the change in feeding and general management. The egg hatchability corresponds to other studies that recorded 82-84% under natural incubation (King'ori et al., 2010; Okeno et al., 2012).

5.2. External egg quality traits

The physical characteristics indicated that the F1 progeny had higher means for all eggs traits tested except for shell thickness when compared to other research groups. The IC had the least observed means compared to those of F1 progeny and E_f in all the characteristics except for shell thickness. The E_f eggs had a weight of 67.96 ± 5.67 g whereas the same breed is reported to have 64.00 g in Bangladesh (Monira et al., 2003). The F1 progeny had the highest egg weight while IC had the lowest. The low mean weight of IC eggs is attributable to the factor of age of the birds and the genetic composition as previously noted by Hussain et al. (2013) and Yakubu et al. (2008). The egg weights for Rhode Island Red (55.56 ± 1.79) and White Bovans (50.91 ± 2.03) in this study contrasts with the findings reported in Niraj et al. (2014) for the breeds reared in intensive management system in Ethiopia (Niraj et al., 2014).

The Eggshell quality has been reported to affect hatchability and recommendations made of a thickness ranging between 0.33 mm to 0.35 mm to be the ideal minimum thickness for incubation eggs (Niraj et al., 2014). The eggs obtained from different chicken groups used in this study fell in that range and are therefore suitable for hatching to production and hatching of viable chicks. The small differences observed in shell thickness in the current study could be explained by breed differences and age of the birds, the older flocks of E_f and F1 progeny had thinner egg shells than the IC which were in the mid egg production stage (Monira et al., 2003).

The brown shell colour dominated the eggs obtained from F1 progeny and in E_f (94%), while in IC the most abundant egg shell colour was cream. The white shell was second at 30% and finally the brown shelled eggs at 17%. The crossbreed of E_m and E_f (Dominant Black) is reported elsewhere to produce brown eggs (Dominant CZ, 2014)In all cases, plain shelled eggs were more than tinted ones and their difference in weights was not significant ($p<0.05$). The brown eggs in F1 progeny were heavier than the cream eggs in the same flock and in IC. Similar results are discussed in other studies with brown egg strains having heavier eggs compared to light colour egg strains (Rayan et al., 2010).

Eggs can be graded based on the shape index into three categories; sharp (<72), standard (72-76), and rounded shape (>76) (Niraj et al., 2014). The E_f hens reared in intenisve manangement system in Pakistan had a shape index of 73.080 ± 2.260 (Ali & Anjum, 2014). Shape index in this study contrasted the findings reported by Rajaravindraa et al. (2015) in broiler chicken (77 ± 0.01) Niraj et al. (2014) in Rhode Island Red (77.28 ± 3.21) and Bovans White (78.43 ± 2.88) under intensive manangement system. Shape index and egg weight can be used to predict the sex of the chicks to be hatched (Khushid et al., 2003). These results only strengthen the point that IC has poor egg quality performance even at optimum management system.

5.3. Internal egg quality traits

The albumen and yolk characteristics of IC were significantly lower than those of F1 progeny and E_f. Monira et al. (2013) reported 8.92 mm of albumen height in E_f in contrast to the 6.53 mm recorded for the same breed in this study. Albumen weight of the F1 progeny (40.59 ± 6.13 g) and E_f (40.58 ± 4.39 g) was higher than the one reported on Isa Brown (33.37 ± 5.85 g), Bovan Brown (34.54 ± 5.67 g) and Potchefstroom Koekoek (25.54 ± 3.94 g) from a study carried out in Ethiopia (Desalew 2015). However, the IC had a low albumen weight of 24.54 ± 3.70 g that had a significant difference from the other eggs, which compares well with albumen weights of IC eggs in other studies (Hussain et al., 2013;Yakubu et al., 2008). Low egg weights are unappealing to the consumers and when incubated result to low hatching weights and poor egg hatchability.

The HU is used as a measure of albumen quality with many consumers prefering 'sound' albumen hence a conventional standard was developed for egg grading (Aboonajmi et al., 2010; Desalew et al., 2015). The HU of the F1 progeny eggs, E_f and IC was above average. Eggs with HU values of 70<HU<80 are considered to be of good quality while H>80 are of excellent quality (Desalew et al., 2015). Other studies have also reported fair quality eggs (70 to 80) of IC based on the above HU standards (Momoh et al., 2010; Niraj et al., 2014; Rajaravindra et al., 2015).

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

- The resultant crossbreed of E_f and E_f exhibited high potential for meat production based on the large body weight and measurements. Phenotypic characterization showed that it is possible to differentiate the hens due to their black plumage colour and the cocks due to their barred plumage pattern.
- The F1 progeny hens reached sexual maturity days earlier than either the parents and the IC. They also reached 50% lay earlier and performed better in all the performance indices.
- Egg quality traits decreased with an increase in loss of hybrid vigour. The F1 progeny did not improve the productivity of the IC at village level nor maintain the high egg quality in subsequent line breeding.

6.2 Recommendation

- Farmers should be encouraged to replenish the F1 progeny flocks so as to reap the full benefits of heterosis.
- Further research should be carried out on breed selection of IC for the egg quality traits and productivity. This will conserve genetic diversity of the unique genes in IC for disease resistance and self-propagation.

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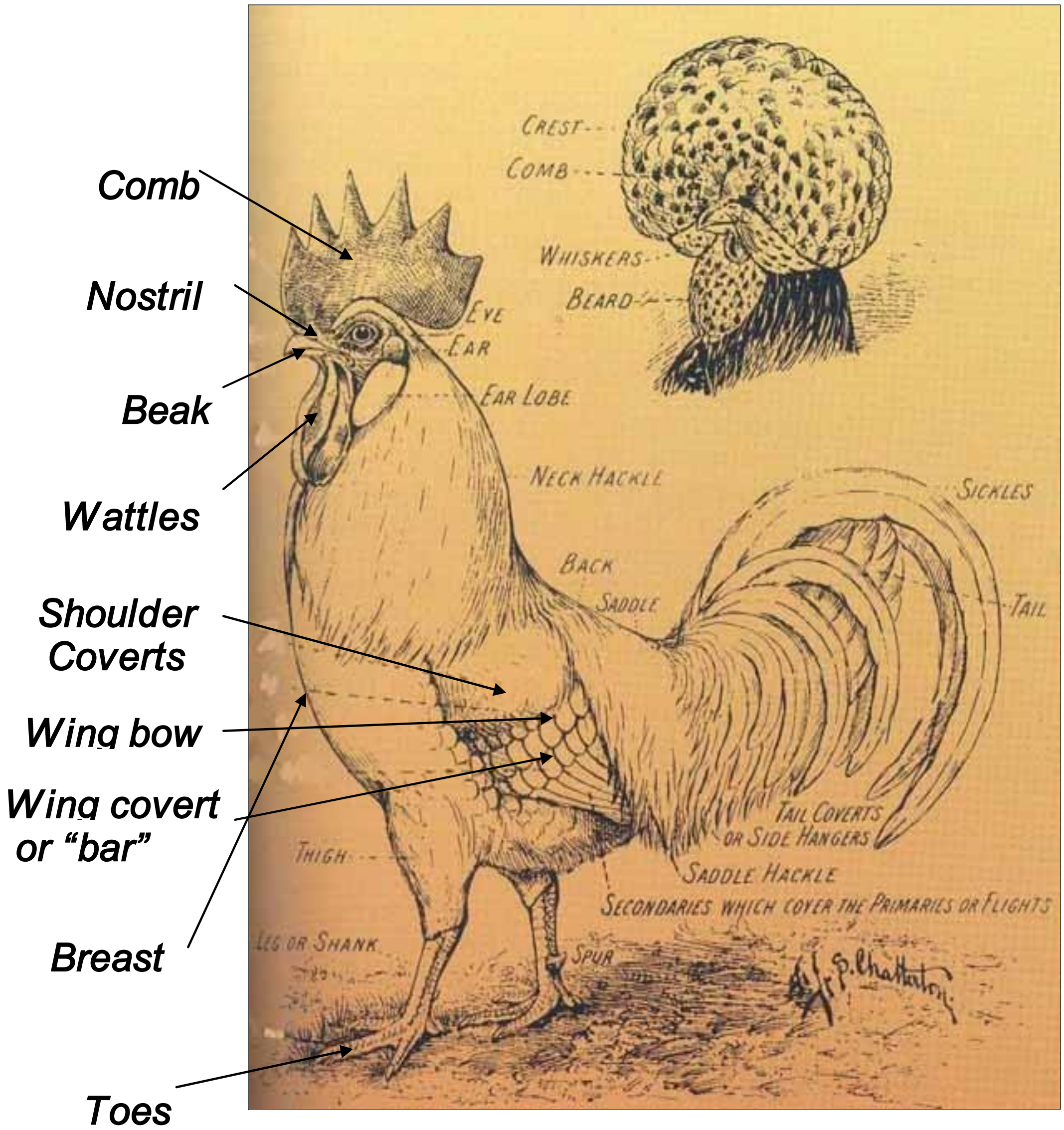
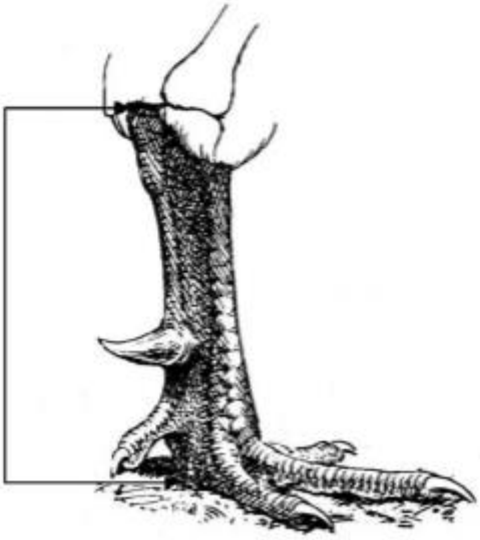
APPENDICES

Appendix I: Pictorial guidance for phenotypic characterization of chickens and ducks (cuesta, 2008)

GENERAL TERMS FOR POULTRY



SHANK LENGTH



SHANK CHARACTERISTICS - COLOURS

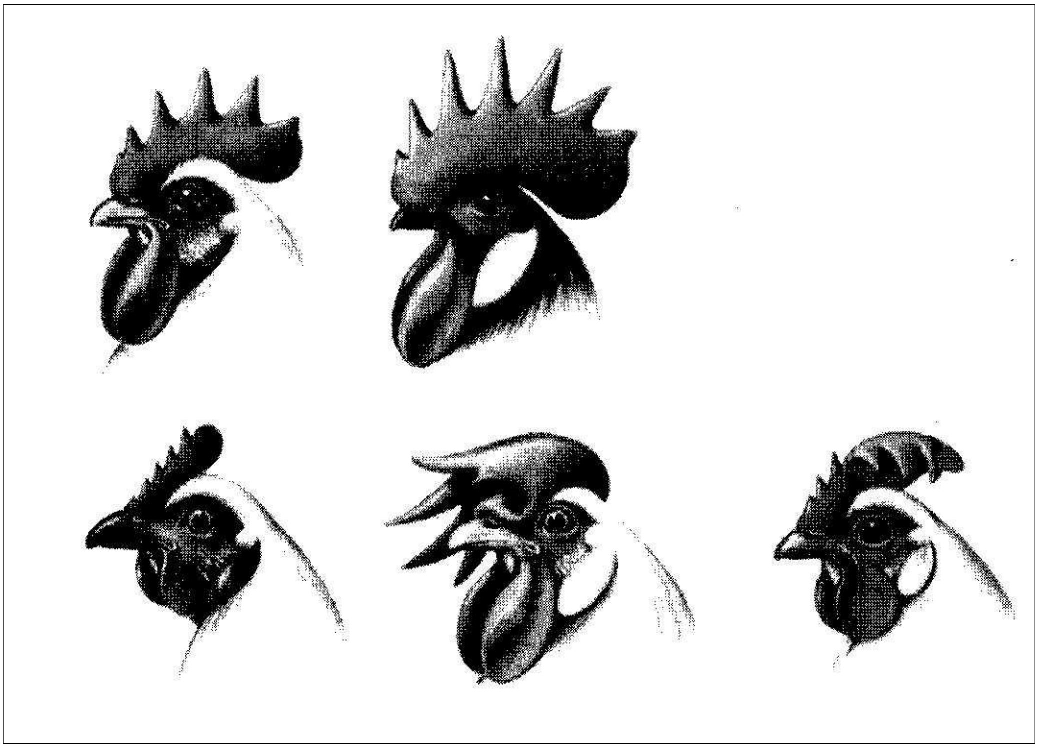
White Variety

Green Variety

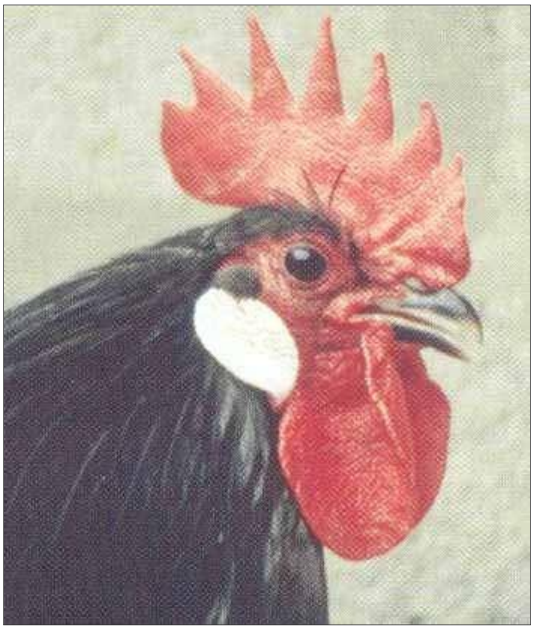
White variety Green variety (above)

Grey blue variety (below)

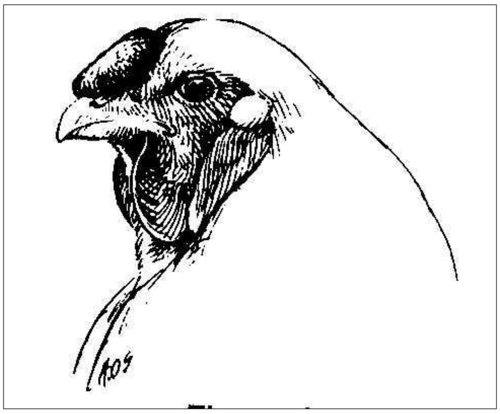
COMBS TYPES



Single comb



Pea Variety



Cushion Variety

Rose varieties

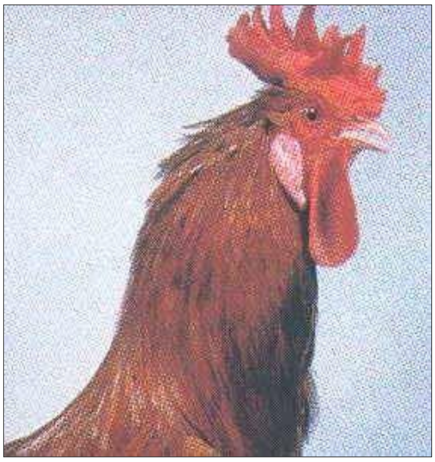
Double Varieties

EAR-LOBE COLOUR

Red

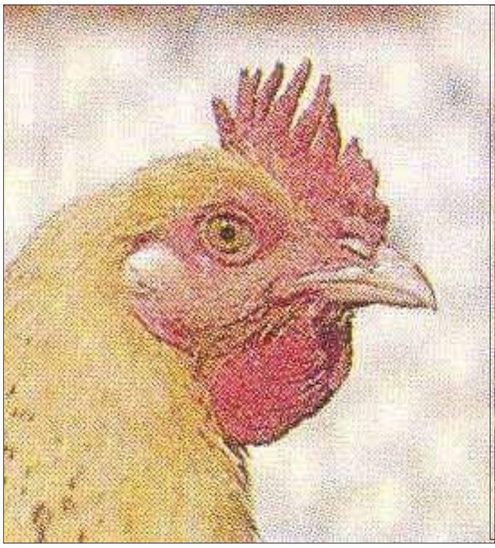
White

Blue



Red-white

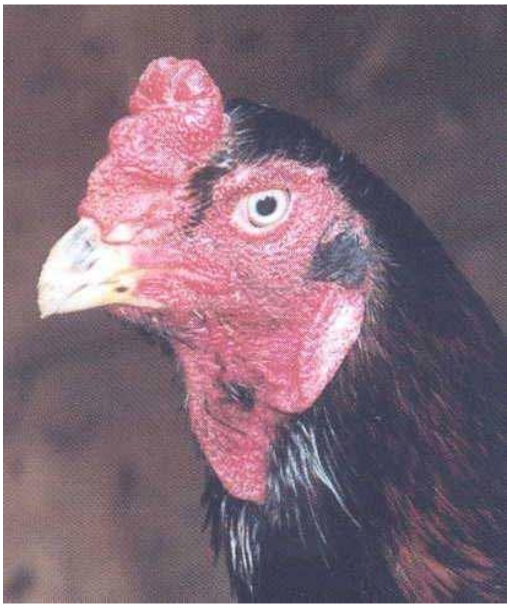
EYE COLOURS



Orange

Brown

Red



Pearl

OTHER CHARACTERISTICS

Crest

Naked
neck

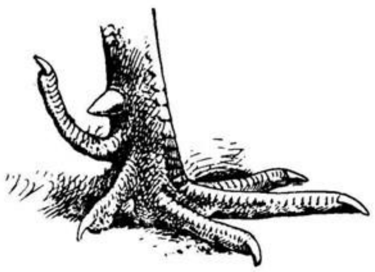


Illustration showing fifth toe in five-toe breeds

Polydactil

Frizzled Feathered

Silk Feathers

Appendix II: Local poultry breeding and production in Kenya questionnaire

All information provided by interviewee will be treated as STRICTLY CONFIDENTIAL for mutual benefit of both the researcher and the respondents.

Questionnaire number…………………………..
Date……………………………..

1. Personal information…………………………………………..

2. Name of the village …………………………………………………………………..

A. General information

1.

Male	Female

2. What is the number of livestock in your farm?

Cow	Sheep	Pigs	Poultry	Goats

3. How long have you been keeping chicken?

6months	1 year	Over a year

4. What are your reasons for keeping chickens?

Income generation	Visitors	Custom	Home consumption	Any other reason

B. Feeding

1. Do you feed your chicken?

Yes	No

2. Among the family whose responsibility is it to feed chickens.

Yourself	Your partner	Other family members	Hired labour

3. How often do you feed your chicken in a day?

Once in the morning	Twice in the afternoon	Once in the afternoon	Twice in the afternoon	Whenever feed are available

4. Where do you get the feeds that you give to your chicken?

Locally	Purchase

C. Breeds

1. How many types of breeds do you keep?

1	2	More than two (specify)

2. Which breed do you prefer and why

1	2	Others

Reason…………………………………………………………..

3. Do you practice breeding?

Yes	No

If yes, how?
If No, why?

G. Fertility

1. Does the chicken sit on the eggs?

Yes	No

2. How many eggs does the hen incubate per sitting?

3. How many times do you put the chicken on the eggs in 6 months?

4. What proportion of the eggs hatch out of those incubated by the hen?

5. What is the proportion of chicks that survive to maturity from those hatched?

No

D. Housing

1. Do you house your chicken?

Yes	No

2. If housed, describe the housing type

Simple on-farm construction	Simple construction with purchased material	Improved construction

E. Disease and mortality

Do you take note of the mortality of your chickens	Yes	No

<table>
<tr><td rowspan="2">Have you ever experienced disease outbreak of your chicken?</td><td colspan="2">Yes</td><td>No</td><td></td></tr>
<tr><td colspan="2"></td><td></td><td></td></tr>
<tr><td rowspan="2">What is the major cause of losses</td><td>Disease</td><td>Accident</td><td>Predator</td><td>Unknown</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table>

When your chickens are sick what type/s of medication do you give them?	Traditional medicine	Pharmaceutical	Others (specify)

Where do you get your medicine	Veterinary officer	Forest	Others (specify)

How do you get the medicine/..?

At what age does your flock die most?	Up to 1 month	1-6 months	Laying onwards

G. Productivity

1. How many eggs do your chicken lay per clutch?

2. How many KARI chicken do you keep?

3. How many clutches do you have per year form the KARI chicken?

Appendix III: Similarity report

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