EFFECTS OF TARGETED PHASE SUPPLEMENTARY FEEDING ON PERFORMANCE OF SCAVENGING ECOTYPES OF INDIGENOUS CHICKENS IN KENYA

GAKIGE JESSEE KAGAI

A Thesis Submitted to the Graduate School in Partial Fulfillment for the Requirement of the Award of the Master of Science Degree in Animal Nutrition of Egerton University

EGERTON UNIVERSITY

MAY 2015

DECLARATION AND RECOMMENDATION

DECLARATION

This thesis is my original work and has not, wholly or in part, been presented for the award of a degree in any University.

Signature: ………………………………   Date: ………………………..

Mr. Jessee Kagai Gakige

KM11/3042/11

RECOMMENDATION

This thesis is the candidate's original work and has been prepared with our guidance and assistance; it has been submitted with our approval as the official university supervisors.

Signature: ………………………………   Date: ……………………….

Dr. A.M. King'ori

Animal Science Department

Egerton University

Signature: ………………………………   Date: ……………………….

Prof. Bockline Omedo Bebe

Animal Science Department

Egerton University

DEDICATION

This work is dedicated to my parents, siblings and supervisors for their unmatched support.

ACKNOWLEDGEMENT

I take this opportunity to thank the almighty God for giving me the strength to take me through the entire study period despite the many challenges I faced. I wish to acknowledge Egerton University, especially the entire staff of the Department of Animal Sciences, for the great support they offered during my study period. I am sincerely grateful to my supervisors Dr. A.M. King'ori and Prof. B.O. Bebe for their guidance and support during my course work and research. I sincerely thank Prof. A.K. Kahi and the entire InCIP team for their financial and technical support during my research period at the InCIP poultry research unit. I am grateful to the laboratory technologists at Chiromo campus of University of Nairobi for their support during the histology work.

ABSTRACT

Indigenous chicken (IC) depend on nutrients they scavenge for growth and egg production. Scavenging alone does not provide sufficient nutrients for both maintenance and high production. Feeding interventions to improve on productivity have been applied uniformly without considering the different growth phases though IC exhibit points of low and high rates of growth along their growth curves. A study was designed to provide a scientific basis for feeding strategies that exploit the physiological adaptations induced by the requirements for improved growth rates. The objectives were to determine the effect of supplementary feeding at exponential growth phase on mature weight, feed intake, feed conversion ratio (FCR) and ecotypes on weight gain and gut morphological characteristics at different growth phases. Feeding trials were run for a period of 21 weeks with supplementation at three growth phases (5-8weeks (TRT2), 9-14weeks (TRT3) and 15-21weeks (TRT4)) while leaving the chickens to scavenge for the rest of the growing period. The control group (TRT1) was left to scavenge for the entire study period. Three chickens in each phase were randomly selected for examination of histology of digestive system. The weight of the gizzard, length of the small intestines, and number of the villi per cm^2 in the three sections of the small intestines were measured. Cost benefit analysis of each treatment was done to identify the feeding regime with the highest mature body weight at the least cost. The results showed a significant difference ($P< 0.05$) between the treatments where the highest mature body weights were recorded in treatment four (TRT 4) of 1021g for Kakamega (KK) and 1123g for Bondo (BN) ecotypes. However, FCE was highest for TRT3 at 0.241 but the group was not able to maintain high body weights after they were put on scavenging treatment. Treatment significantly affected the intestinal morphology in the duodenum section only but it had no effect on the jejunum and ileum. The villi population was highest in the duodenum section suggesting that this was the most active section in nutrient absorption. The control group (TRT1) had the highest gizzard weights (10.71g/100g live weight). The study recommended that IC should be supplemented during the final growth phase so as to achieve high body weights while minimizing the cost of supplementation. This feeding strategy can enable the resource poor farmers of IC achieve increased profits from keeping chicken.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

IC	Indigenous Chicken
INCIP	Indigenous Chicken Improvement Program
MOALD	Ministry of Agriculture and Livestock Development
MOLD	Ministry of Livestock Development
KALRO	Kenya Agriculture and Livestock Research Organization
CP	Crude protein
FCE	Feed Conversion Efficiency
ADG	Average Daily Gain
TRT	Treatment
IL	Intestinal length
LW	Live weight

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

1.1 Background information

Indigenous chicken (IC) are highly adaptable birds mainly reared under free-range conditions. The advantages of free range scavenging include availability of free feed resources in the surrounding environment and kitchen leftover and preserved ability to incubate and brood naturally (Swai *et al.,* 2005). However, their nutrient intake from the scavenging material is only sufficient for maintenance and low production (King'ori *et al.,* 2007). To improve productivity, nutrient supplementation is necessary during the various growth stages.

In Kenya, supplementation is done during wet season and little or no supplementation during the dry season (Magothe *et al*., 2012). This is because during the wet season, there is enough food left over unlike during the dry season when food is scarce. Supplementation with cereals is the most common practice, but this leads to increased competition for food with humans. Scavenging alone may provide adequate nutrients to the IC but this is dependent on the stage of growth, area of scavenging per bird, quality of the scavenge material and the production stage (Birech, 2002). Energy requirement between the ages 5 to 8 weeks is approximated at 12.6MJ/kg ME, 10.9MJ/kg ME from 8 to 14 weeks period which decreases to 10.1MJ/kg ME for weeks 14 to 21 (Chemjor,1998). Due to the potential of the IC to improve rural livelihoods in Kenya (Magothe *et al*., 2012), efforts to improve productivity through improved nutrition have been explored. However, many of these attempts have not succeeded but instead presented new challenges such as increased cost of production. Considering the high cost of supplementation in feeding indigenous chicken, there is need for feeding strategies that match the growth phases of the ecotypes.

Ng'eno (2011) showed that growth curves of two IC ecotypes exhibited slowed initial phase followed by rapid exponential growth phase and a final slow growth phase, which suggests that supplementation at the different growth phases may have different effects on performance of the ecotypes. The large phenotypic variation in production performance between the ecotypes is evidenced by a wide range of variation in annual egg production of 20 to100 eggs; mature live weight in females of 0.7 to2.1 kg and in males 1.2 to 3.2 kg (Tadelle *et al.,* 2003). A study by Laverty *et al*. (2006) on exotic breeds showed a great difference in the intestinal morphological distinctions between broilers and White Leghorns which suggests there is a greater absorptive area leading to the higher growth rate in broilers. The broilers had more developed, larger villi, wider microvilli at the apices of villi and more active extrusions of epithelial cells at the tip of the villi surface than the White Leghorn. Currently, there is no information available on the comparative anatomical appearance of the digestive system at the different growth phases and different ecotypes of IC in Kenya.

1.2 Statement of the problem

Indigenous chicken depend on nutrients they obtain from scavenging for growth and egg production. However, scavenging alone does not provide nutrients sufficient for both maintenance and optimum production. Feeding interventions to improve on productivity have been applied uniformly without considering the different growth phases. However, IC exhibit points of low and high growth rates along their growth curves. This may be contributing to the low production attained with the feeding interventions. It is likely that phase feeding has a positive effect on the feed utilization efficiency and mature weight of the chicken and can therefore impact on the cost of feeding.

1.3 Objectives

1.3.1 General Objective

To improve productivity of IC by developing a feeding strategy that improves the feed conversion efficiency and increase mature body weight of scavenging indigenous chickens.

1.3.2 Specific objectives

1. To determine the effect of supplementary feeding at exponential growth phases on mature weight of IC ecotypes.
2. To determine effect of feed intake, FCE and ecotypes on weight gain of IC.
3. To determine the relationship of the gut morphological characteristics with the ecotypes, mature body weight, feed intake and FCE at different growth phases.
4. To perform a cost-benefit analysis on supplementing at different growth phases

1.4 Null hypotheses

1. Mature body weight is not significantly affected by Phase feeding.
2. Weight gain is not significantly associated with feed intake, FCE and ecotype.
3. Gut morphological characteristics at different growth phases are not significantly related to the ecotype, mature body weight, feed intake and FCE.

1.5 Justification

Indigenous chicken ecotypes exhibit growth patterns with a slowed initial phase followed by rapid exponential growth phase and a final slow growth phase. Weight gain varies depending on the growth stage in the scavenging ecotypes of IC, suggesting a possible variation in nutrients utilization between the different phases. Phase feeding will target the growth phase that has high FCE therefore maximizing on the average body weight gain to increase the maturity weight of the IC and to attain improved productivity. Phase feeding will aim at maximizing on the exponential growth phase to achieve the highest productivity. To reduce cost of feeding, supplementing will be at the rapid exponential growing stage and leave the chicken to scavenge at the slow growing stage.

CHAPTER TWO

LITERATURE REVIEW

2.1 Domestication and early use of chickens

Kenya is a country with heavy human population and this population is continuously on the rise. This increase has led to the high demand for the available animal and poultry products in all parts of the country (Menge, 2008). Among the cheapest and highly affordable protein source for this Population is mainly the poultry products. Poultry, particularly IC are very important and has been recognized as an important genetic resource among the avian species.

Chicken were domesticated in East Asia about 7500 years ago (Colin *et al.,* 2004). They were domesticated for food (eggs and meat), for religious or ceremonial purposes, and for cock fighting. They belong to the order *Galliformes*, family *Phasianidae*, and genus *Gallus* (Menge, 2008). The ancestral stock for the chicken is the red jungle fowl (*Gallus gallus*) from South East Asia (most likely North East China). Other species of the jungle fowl include the Java or the green jungle fowl (*Gallus varius*), Ceylon or the Lafayette's jungle fowl, and the grey jungle fowl (*Gallus sonneratii*). Chicken then spread from North East China to Europe then Africa. The spread was facilitated by colonists who moved with chicken to Africa (Colin *et al.*, 2004).In Africa, chicken were first discovered in Egypt, where they were reared as foreign pets and game cocks (Adomako, 2009).

However, in the year 650BC they became common and economically important. They then spread from Egypt to sub-Saharan Africa during the first millennium AD (Adomako, 2009). The prevalence of the indigenous chickens long after the introduction of the exotic strains shows that these chickens still possess the potential to form the basis for improved indigenous poultry production (Natukunda *et al.,* 2011). They can be transformed from subsistence to commercial production to increase food security and income in the rural areas. Several terms have been used to refer to these local fowls. These include "family chicken", "African chicken", "bush chicken", "runner chicken", "scavenging chicken", "native chicken", "village chicken", "local chicken" or "indigenous chicken" (Magothe, 2012). However, distinct local varieties have been reported in some African countries, such as Egypt, Cameroon, Burkina Faso, Morocco and Sudan (Gueye, 1998). Despite being disregarded through limited provision of shelter, feeds, limited protection against predators and above all against infectious and parasitic diseases which cause high mortalities, indigenous chickens have invaluable characteristics that are not found in the exotic strains(Natukunda *et al.*, 2011).

2.2 Value of IC.

The indigenous chicken meat industry has undoubtedly been the most successful of any of the animal industries, and the egg industry is now making strides in new product development (Leeson, 2008).Production of IC is a well-known livestock enterprise in Kenya where virtually every household keep small flocks of between 5-20 chickens (Okitoi *et al.*, 2007a). IC are robust and well adapted to survive and reproduce in unfavorable environmental conditions such as fluctuating weather, feed shortages, chronic diseases, heavy parasitic infestations and predators (Gueye, 1998). They are said to be appropriate in the rural areas especially due to the fact that they require minimum inputs which rural farmers can easily afford. Unlike other birds and mammals, chicken farming is neither suppressed, challenged, frustrated nor influenced by taboos. Previously, farmers themselves regarded rearing of indigenous chickens as a secondary activity but in the recent past, the enterprise has earned recognition in the rural socio-economy because it provides readily harvestable animal protein (meat and eggs) and revenue (Okitoi *et al.*, 2007a, Okeno, 2011).

Poultry can be raised by farmers for many different reasons, from the need to create an income to the simple pleasure that some farmers take in watching their healthy birds walk around their houses (FAO, 2002). In general, rural poultry provide scarce animal protein in the form of meat and eggs. But they are also a kind of 'credit card', instantly available for sale or barter in societies where cash is not abundant. Village poultry also fulfill a range of other functions for which it is difficult to assign a monetary value. They provide manure, are used in special festivals and to meet social obligations, and are used for pest control. In communities where food shortages are common, chickens are kept to supplement the meals where they provide cheap high quality protein. In other communities, they are used to honor guests and for recreation while in others, they are used to perform funeral rites and spiritual cleansing (Maina, 2000).

Little wonder, therefore, that development of family poultry systems is a key strategy in many developing countries special programs for Food Security. FAO (2002) points out that the productivity of most family poultry is very low compared to that of high input systems. A scavenging hen, for example, lays only 30 to 50 eggs a year or up to 90 eggs a year with improved feeding and husbandry, while a commercial hen will produce 280 eggs under optimal conditions. The improvement of rural poultry production requires introduction of appropriate management skills, husbandry inputs such as supplementary feed and shelter, development of effective marketing strategies and, above all, better disease control (FAO 2002).

The IC enterprise is rarely the sole means of livelihood for the family but is one of the integrated and complementary farming activities contributing to the overall well-being of households. Over the last decade, the consumption of poultry products in developing countries has grown by5.8 percent per annum, faster than that of human population growth, and has created a great increase in demand (FAO, 2004). IC meat and eggs are more preferred and often do fetch higher prices than the exotic commercial poultry products because they are organically produced (Ndegwa *et al.*, 1998). Currently, an indigenous chicken egg is selling at ksh 15 and a hen or a cock at ksh 1,000 (Cheburet, 2010) especially during the festive seasons. As reported by Ndegwa *et al*., (1998) delicious taste, texture of carcass, little fat content and flavor make indigenous poultry meat a highly appreciated and marketable product. This makes the price of IC meat to be almost twice the price of meat from exotic breeds. Meat and eggs from IC are rich nutritionally, depending on what they feed on, as they offer proteins with some fats, minerals and vitamins (King'ori, 2012). Therefore, IC are a good source of affordable nutrition for the rural families. IC production improves the health of the children and alleviates protein malnutrition as well as economically empowering rural women and youth. Income from sales of eggs contributes 15.1% while that from live birds contributes up to 57.9% of the total family income in most rural households (Kimani, 2006).

Women are the main decision makers in IC industry (Nyaga, 2007) in most Kenyan communities where ownership is predominantly by women estimated at 63% (Okitoi *et al.*, 2007b). They control most of the income from eggs and live birds. Generally, eggs and meat produced are reserved for the family own consumption, in addition to the direct sale of live animals. Some of the eggs produced are used for brooding to produce chicks for stock replacement. Depending on the location of the farm dwelling, birds and eggs are taken by the farmer to the local market and sold to traders, other farmers or directly to consumers. Traders from urban areas buy eggs in village markets to sell in big cities or to owners of restaurants. The price of eggs and live chicken is directly related to supply and demand as well as seasonal demand (holidays and fasting seasons), lack of infrastructure, plumage, color, size, age, weight, sex, market site and the health status of the birds (Bett *et al*., 2011).These attributes are used by traders as a form of grading IC at the different market levels. The plumage colour influences positively and significantly the IC prices. This means that the physical attractiveness of the IC to the buyers significantly improves its marketability. However, weight has the highest preference in both secondary and terminal markets (Bett *et al*., 2011), where heavy and healthy birds have higher acceptance in the market and therefore attract favourable prices. The IC weights at most of the rural markets in the study area are based on approximations. This is mainly done manually and depending much on the experience of traders. However, at the terminal markets weighing scales are used.The income derived from the sale of chickens and eggs is used to purchase consumable food items, for school fees, grain milling services, purchasing of improved seeds of maize, wheat and other expenses

Poultry is a source of self-reliance for women since, poultry and egg sales are decided by women (Mereset *et al.,* 2011) both of which provide women with an immediate income to meet household expenses and sources of food. A report by FAO (2007) showed that women are involved in rearing of chicken and marketing of eggs and live birds where they are highly responsible for many activities like provision of water and supplementary feed to chicken (100%), selling of chicken (94%) and cleaning chicken's waste in their night time resting areas (91%). A study by Ndegwa *et al.,* (2012) showed that rearing of indigenous birds is mainly by women all over sub-Saharan Africa, as it is lowly rated in terms of its importance in the farming systems. It provides an area for rural women to generate some income. Indigenous chicken production should therefore be improved as a strategy to empower the rural women who mainly bear the effects of the extreme poverty prevailing all over the sub-Saharan Africa region. There is a growing recognition of the contribution of women to agricultural production. Okitoi (2007b) reported that women provided 46 percent of agricultural labor, produced approximately 70 percent of its food and did at least half of the tasks involved in raising animals. It is for these reasons that it is felt that in order for rural poultry improvement programs to have a positive impact on household economies and gender equity, women's concerns have to be integrated in the programs as a gender variable. An IC enterprise initial capital requirement is minimal and many smallholder rural farmers, including women and youth, find it among the manageable business ventures. Other factors that make IC suitable for the rural farmers include faster recovery of the poultry flocks after disasters like drought, adaptability and tolerance to the local environment and diseases (Menge *et al*., 2005). High demand and low supply of the IC meat indicates a potential niche market for the indigenous chicken in Kenya (Magala *et al*., 2012).This market can be tapped by improved nutrition and management of the IC (King'ori*et al*., 2007) which have potential for better performance in terms of growth rate. Eggs from indigenous birds are similarly preferred due to their taste and color of yolk. Kenyan consumers are increasingly interested in IC products that they perceive as organic or naturally produced (King'ori*et al*., 2010), environmentally friendly, tasty, safe with no contaminants and nutritious qualities (Ochieng' *et al*., 2007). Interest is growing in quality aspects rather than quantity of meat and eggs and this provide opportunities for IC market growth in Kenya (Degelo, 2011). Producers get better price both for live birds and eggs during holidays and festivals.

2.3 Production systems

Indigenous chicken production systems are broadly classified as subsistence and commercial based on scale of production, production objectives, husbandry practices and levels of input (Gueye, 1998). There are three systems of production depending on household's land availability, and the value attached to the IC enterprise. These systems are: free-range system, semi-intensive system and intensive system.

In free range system, a small flock of less than 30 chickens are reared. The birds are left to scavenge on their own around the homestead and are never provided with health care or feed supplements (Ndegwa *et al.,* 1998). They usually scavenge on green forages, insects, earth worms, kitchen wastes, various seeds and any other consumable feed resource (Birech, 2002). Night shelters may be provided which include coops, stores and kitchens but in some instances the birds may roost outside, usually in trees, and nests in bushes (FAO, 2004). This is a low input-low output production system where cost of production per unit of egg or meat is negligible but return for land, capital and labor is high (Menge *et al.,* 2005). Farmers attempt to balance stock numbers according to the scavenging feed resources available in the environment in each season. Under the free-range, feed supplies during the dry season are usually inadequate for any production above flock-maintenance level (FAO, 2004).

Semi intensive system of production is common in urban, peri-urban as well as rural areas. They are confined part of the time especially during cropping seasons and supplemented with crop residues, grains, kitchen wastes, small quantities of commercial feeds and any other available feed resources (Kitalyi, 2002). Under this system, all the nutrients required by the birds must be provided in the feed, usually in the form of a balanced feed purchased from a feed mill (FAO, 2004). As these are often expensive and difficult to obtain, smallholders use either unconventional feedstuffs or “dilute” the commercial feed by supplementing it with grain by-products which supply energy and some protein. A well-balanced feed however is difficult to achieve, as grains and plant protein sources are becoming increasingly unavailable for livestock, and premixed trace minerals and vitamins are usually too expensive for smallholders. Level of inputs range from low to high depending on the economic value attached to the chicken. They are provided with housing but no medication except traditional herbal medicine.

In intensive production system, flocks of 100-500 birds are either totally confined in deep litter houses or partially confined in fenced runs with night shelters (Ndegwa *et al*., 1998). This system is mainly for commercial purposes and crossbred chicken are mainly reared. They are provided with commercial rations, medication and vaccination against endemic diseases. (Menge *et al*., 2005)

2.4 Population and distribution of IC in Kenya

Kenyan IC is a heterogeneous population with no standardized characteristics and performance. They vary in size, plumage color, comb type and skin color. Plumage color varies widely with black, brown, light orange, yellow, grey and white laced and molted (King’ori *et al*., 2010). Variation is also seen in comb type, length and color of wattles, ear lobes and beaks (King’ori *et al*., 2010). Characteristics such as naked neck, frizzled feathers and single, pea, rose and walnut combs are common in flocks of the IC (Adomako, 2009). The naked neck mutation originated from Romania and spread across Europe centuries ago. They were then introduced to Africa by sailors and traders (FAO, 2004). Local chicken of today resulted from centuries of cross-breeding with exotic breeds and random breeding within flocks of local birds. As a result, it is not easy to standardize the characteristics and performance of indigenous chicken in Kenya (FAO, 2012). Indigenous chicken are the dominant variety of chicken raised in developing countries like Kenya especially in rural areas (Chemjor, 1998). Of 21 countries in Africa reported, IC comprised more than 70% of the total chicken population in 18 of them.

Table 1: Chicken population and distribution in Kenya.

Region	Indigenous Chicken	Exotic Chicken
Nairobi	279,397	342,788
Central	3,039,786	2,489,837
Coast	1,599,696	521,864
Eastern	4,107,618	544,812
North Eastern	422,899	71,313
Nyanza	5,605,478	501,056
Rift Valley	6,557,262	1,339,395
Western	4,144,351	259,977
Total	25,756,487	6,071,042

Source: Central Bureau of Statistics 2009.

Despite the introduction of exotic chicken in the 1920s, IC still make up more than 74% of all the chicken raised in Kenya (Cheburet, 2010). Kenya has an estimated poultry population of over 31 million birds (FAO, 2012). Of these over 25 million are local or indigenous chicken, which are kept by 90% of rural communities (King'ori *et al*., 2010) under free range conditions. Most homes in Kenya have at least 10 indigenous birds but there is large variation in the flock size ranging from 1 to 81 (Okeno *et al*., 2011) with a mean size of 22 chicken. Chicks form the largest proportion (35.6%) of the flock while cocks are the least (9%). Nyaga (2007) reported that there were an estimated 3.1 million layers, 2.1 million broilers and 31.4 million indigenous chickens. The balance is comprised of other poultry species such as ducks, geese, ostriches, pigeons, turkey, quails etc. Under improved housing, disease control and feeding, egg production from these local birds can be increased to 150 eggs/bird/year (King'ori*et al.*, 2004).

Commercial birds consisting of hybrid broilers and layers that are kept in the peri-urban areas of the major towns such as Nairobi, Nakuru and Mombasa. This is mainly for ease of marketing and procuring of inputs. These commercial birds make up to 26% of the poultry population. Most commercial farmers keep from 300 to 2,000 broilers and 100 to 1000 layers per batch (Nyaga, 2007).

2.5 Nutrition

Chicken need enough feed to grow and lay eggs (Adomako, 2009). They find their own food if allowed to scavenge; but extra feed should be given in order to cater for their energy and protein requirements. Provision of adequate clean water and feeding of birds in a clean dry place must be ensured (Ndegwa *et al*., 2012). Feed resources are a major input in poultry production systems. They are estimated to account for 60 percent of total production costs in the poultry sector (Adomako, 2009). In indigenous chicken production systems, it is difficult to estimate the economic and physical value of feed input because there is no direct method of estimating the scavenged feed resource which constitutes most of the feed input.

The scavenging feed resource base depends on household food status (Gondwe *et al.*, 2005). The nature of the area available for scavenging influences strongly the feed intake pattern of the chickens when these have free access to both energy and protein rich supplements. The scavenging system places a limit on the expansion of IC within village settlement (Sonaiya, 2000). Whenever the carrying capacity of the scavenging area is exceeded, morbidity and mortality ensue, particularly the chicks and growers. Although a variety of scholarly papers and books classify chickens and turkeys as granivores, they are omnivores and do not have the food preferences, digestive anatomy, or nutritional strategies that would classify them as granivores (Sonaiya, 2000). Their wild relatives consume a very wide variety of food items of both plant and animal origin, and seeds are not often a primary component. Intake of insects by jungle fowl chicks and wild turkey poults exceeds 50% of their diet, and adult females increase their intake of insects at the time of reproduction. In the case of jungle fowl, termites and bamboo mast are preferred foods in the area of Southeast Asia where domestication likely occurred (Sonaiya, 2000). The percentage mean crude protein (CP) level of the scavenging diets is 11.2. The crude protein (CP) Metabolizable Energy (ME), Ether Extract (EE), Crude Fiber (CF), Ash, Nitrogen Free Extracts (NFE), Starch and Dry Matter (DM) intake is similar for growers and layers in medium high and low potential agricultural areas (Birech, 2002). It has been reported that the nutrition of scavenging local chicken is improved during the harvest period when there is availability of post-harvest residues, green grass, earth worms, and insects (Mwalusanya *et al* 2002). Sometimes, selective supplementation (e.g. of laying hens alone) is adopted as well as use of creep feeders which allow the chicks preferential access to supplemental feed and additional protection from predators (Sonaiya, 2005). However, in addition to environmental constraints, poultry production is challenged by the escalating prices of feed ingredients, such as maize and soybean due to seasonal fluctuation in the supply of conventional feed ingredients. It is therefore imperative to search for alternative feed resources particularly energy sources and come up with new feeding strategies to ensure optimum performance of the birds all over the year. Malnutrition in terms of avitaminosis A is a serious killer particularly in young chicks and growers during prolonged dry season and at the beginning of rain season due to lack of green vegetation, which serve as important sources of vitamin A to the scavenging birds (Mbyuzi *et al*., 2012). The condition has emerged to be a threat to both intensive and extensive chicken production systems in various parts of the country especially during the dry spell. During that period, hens lay eggs with severe deficiency of vitamin A and consequently new hatches are also deficient of the vitamin. Vitamin A functions to maintain epithelial tissues and a lack of this vitamin reduces the integrity of the epithelial barrier and eventually leads to easier penetration of a pathogen into the epithelium which is its proliferation site.

2.5.1 Feed resources

IC main feed source is scavenged from the surrounding environment and household refuse with low levels of supplementation with by-products of local crops. The major components of the scavenged materials are household refuse, crop waste and the gleanings from gardens (Samang, 1998). IC has always served farming communities by gleaning the fields for grains dropped by the wayside during the processes of threshing, drying and transportation; and are known to make productive use of household leftovers. They are important in controlling insect pests and weeds. This emphasizes the importance of the scavenging feed resource base as it gives the scavenging birds the opportunity of meeting any nutritional deficiency in the feeds offered as supplements.

Potential scavenging feed resources (SFR) can be categorized into four main groups: (1) household wastes (including the waste from households which do not keep chickens); (2) materials from the environment, such as, protein sources (worms, snails, termites insects, grasshoppers and frogs), grain products from cultivating, harvesting and processing (rice, maize and rice and maize bran), green leaves and seeds; (3) cultivated and wild fodder materials such as grasses, herbs, fodder trees and aquatic plants (Lemna, Azolla, duckweed, water spinach etc); and (4) non-conventional feeds and agro-industrial by-products (brewery and alcohol residues, soybean residues, molasses, shells, etc) (Roberts, 1997). The scavenging feed resource base is not constant, and the proportion that comes as a supplement and from the environment varies with activities such as season, land preparation and sowing, harvesting, and grain availability in the household, and the life cycle of insects and other invertebrates (Dessie, 1996). Soil fertility, water availability for irrigation, and rainfall are other factors that determine the
SFR (Samang, 1998). The composition of SFR is below the nutrient requirements of IC for optimum performance, and varies with season and the type of bird. The SFR are often, but not always, deficient in protein rather than energy, and it was concluded that protein supplementation is usually more important than energy supplements in scavenging poultry production systems in Bangladesh (Samang, 1998). The protein required in
supplements for scavenging chickens depends on the quantity and balance of available amino acids, and for poultry, evaluation of protein sources is based upon the amounts of the three major limiting amino acids, lysine, methionine and tryptophan (McDonald *et al.*, 2002), and especially methionine is necessary for chicks.

Scavenging birds require ME in varying amounts for all metabolic purposes, including scavenging activities (Kingori *et al*., 2014) Deficiency of energy affects most aspects of their productive performance. Energy was found to be limiting during the rainy season in Ethiopia (Dessie, 1996). Therefore, energy supplementation is usually also considered necessary for scavenging chickens for optimum performance.

2.5.2 Nutrient requirements of IC

For birds to be productive, they need feeds that will give them the necessary nutrients for body function, including growth and meat production (Adomako, 2009). Under scavenging conditions, protein content is too low in relation to energy, which places a heavy nutritional burden on the chickens. Birds have defined requirement for nutrients, which scavenging rearing conditions do not meet adequately.

Ndegwa *et al*., (2012) defined nutrient requirement as the amount of nutrients needed by animals to maintain their activities, maximize growth and feed utilization efficiency, improve laying capacity and hatchability and optimize fat accumulation. These nutrients include carbohydrates, lipids and protein. Growth involves deposition of bones, muscle and fat, each exhibiting an individual pattern of development. Poultry usually consume just enough food to meet their energy requirements since the control of feed intake is believed to be based primarily on the amount of energy in the diet (Adomako, 2009). Increasing the dietary energy concentration leads to a decrease in feed intake and vice versa, thus affecting growth. However, feeding animals below their energy or protein requirements thus reduces growth and efficiency of nutrient utilization.

2.5.3 Energy requirement of IC

When formulating poultry diets, the nutrient requirements of chickens have frequently been expressed per unit of dietary metabolizable energy (Larbi *et al*., 2013). Leeson *et al.* (1996) showed that broiler chickens fed up to 25 day and 49 days of age were able to adjust their feed intake to a constant energy intake over a range of dietary metabolisable energy levels from 11.29 to 13.80 MJ ME/kg DM, which indicated that broiler chickens retain an innate ability to eat to a fixed energy requirement rather than to physical capacity. The importance of energy level in the diets for indigenous chicken breeds is similar to that of broiler chicken breeds. That is, dietary energy level has an effect on feed intake, feed conversion ratio, growth and carcass quality. However, limited information indicates that indigenous chickens have lower energy requirements than the broiler chickens (Tadelle, 2000). The author reported that the energy requirement of indigenous chickens as determined from the chemical analysis of the crop contents is 11.99 MJ ME/kg DM of feed. NRC recommended that the required energy in growing indigenous chicken diets should be 12.14 MJ ME/kg DM of feed.

2.5.4 Energy Sources

Corn is the most important and widely used. Also wheat, barley, and oats are being used, but not as common compared to corn in the relative value (FAO, 2012). Grain by-products include various milling by-products e.g., corn gluten & bran, and wheat processing by-products and brewery by-products. Molasses is also used as a source of energy but have an adverse laxative effect, thus should be limited to not more than 2% of the diet. Vegetable and animal fats are used as energy sources, but also reduce feed dustiness, increase palatability, and improve texture and appearance of the feed.

2.5.5 Protein requirements in chickens

Proteins are the most expensive components of chicken diets (Mwalusanya *et al.*, 2002). However, the amounts of proteins that should be supplied in supplements for scavenging birds are different from those needed for confined birds, because scavenging birds can get part of their requirements for proteins from scavenging feed resources such as grains, insects and worms. The dietary status of scavenging birds varies with season, climate, production type and age of birds. The amino acid profiles of the crop contents will give information on the intake of these nutrients, which is the basis for supplement policy of scavenging chickens (Mwalusanya *et al.*, 2002).

Proteins have been described as complex organic compounds of high molecular weight composed of 22 different amino acids or derivatives that are linked by peptide bonds to form a primary chain structure. (Ndegwa *et al.,* 2001). They are made up of amino acids. The amino acids are classified as 'essential' or 'non-essential' amino acids. Essential amino acids are defined as those amino acids in which animals are unable to synthesize. Non-ruminants must receive these amino acids via the diet. Non-essential amino acids are defined as those amino acids which animals are able to synthesize by themselves (Mwalusanya *et al.*, 2002). The basic function of dietary protein is to supply adequate amounts of required amino acids. Thus, the quality of a feed protein depends not only its nitrogen content, but also on its constituent amino acids, their digestibility, and physiological utilization of specific amino acids after digestion ((Mwalusanya *et al.*, 2002)).

Because body Proteins is in a dynamic state, with synthesis and degradation occurring continuously, an adequate intake of proteins is required. The effect of protein density in indigenous chickens is similar to that of broiler chickens. Studies have revealed that indigenous chickens responded significantly to different feed protein density and husbandry environment. Kingori *et al.* (2003) compared the effect of varying crude protein levels of 100, 120, 140, 160 and 180 g/kg DM on the feed intake, feed conversion ratio and live weight of growing indigenous chickens raised intensively between 14 and 21 weeks of age. Results from this study indicate that feed intake per bird increased with increasing dietary protein levels. Live weight gain increased with increasing protein levels while feed conversion ratio decreased with increasing dietary protein levels. Thus, growth was better with a diet having a higher protein density. Contrary to the above results, reported no effect of varying dietary crude protein levels on growth and feed intake of indigenous chickens.

2.5.6 Protein Sources

Plant sources include Soybean meal, which is the most widely used because of its ability to provide indispensable amino acids; high in digestibility and low in toxic or undesirable substances. Cottonseed meal is generally not used for layer diets because of gossypol, which can cause a greenish color to egg yolks, and cyclopropenoic fatty acids, which can impart a pink color to egg whites.

Other sources include Linseed meal which can be used at a limited amount. It should not exceed 3 to 5% of the poultry diet. Fish meal is often used at 2 to 5% of the diet, but tends to create a fishy flavor in meat and eggs when used in larger amounts.

2.6 Productivity levels

Sexual maturity of IC is attained at 5 months for hens and at 6 months for cocks. The age at first laying ranges between 5-6 months (Larbi *et al*., 2013). The number of eggs per female per clutch ranges between 7 and 18. The reproduction is not seasonal and there is no evidence of a peak period for laying throughout (Sonaiya, 2000). The choice of the breeding stock (cocks and hens) is made essentially at random making it very difficult for farmers to express any breeding objectives, which could be considered in a breeding program involving selection within local populations or crossing with exotic breeds or commercial lines (Okeno *et al*., 2012). Most IC farmers keep their chicken mainly for meat as illustrated by the fact that over 50% of the farmers leave the eggs for hatching, while the other 50% are either consumed by the household or sold for income (Nyaga, 2007). Most of the birds are sold at the age of 5-6 months weighing between 1.3-1.8 kg live weights (Degelo, 2011). The average cold dress weight of IC is estimated at 72% as compared to 75 to 80% for culled layers and broilers respectively (MoALD, 1994). The difference in dressing weights is due to production system where the IC are reared under free range system with minimal supplementation whereas culled layers and broilers are reared under intensive production system on commercial. Indigenous chicken meat is the most popular among poultry species in Kenya (MoALD, 2008).They contribute 47 and 55% of the national egg and meat production respectively (King'ori *et al*., 2010). Research work on local chicken carried out in Kenya and elsewhere in Africa shows that the number of clutches per year is 2 to 4; eggs per clutch is 15; egg weight is 44 to 49g; hatchability is 78% and chick mortality is 32.6% (Swai *et al.,* 2005). The low productivity is also influenced by diseases, poor genetic potential, poor bird management practices, predators and low level of literacy among farmers. The estimated poultry meat production is 26,900 metric tonnes with indigenous chicken producing 15,602metric tonnes per year (FAO, 2012).

2.7 Marketing of poultry products

Marketing is an important component of indigenous chicken value chain (Bett *et al.,* 2012). The willingness of IC producers to increase productivity is dependent on the existence of efficient marketing system of their produce. In Kenya, IC marketing component is entirely a private sector business driven by the high demand for IC products (Upton, 2000). In the free range production system, the marketing of eggs and live chicken is informal where producers depend on middle men to buy their products and later sell to the urban markets (Upton, 2000). Prices of eggs are relatively constant while that of live chicken fluctuates, being low during grain shortage and high during festive seasons (Bet *et al.,* 2012). The price of live birds further varies based on body weight, feather color, comb type, age and sex. Heavy and healthy birds have higher acceptance in the market and therefore attract favourable prices. The IC weights at most of the rural markets in the study area are based on approximations (Bett *et al.,* 2011). This is mainly done manually and depending much on the experience of traders. However, at the terminal markets weighing scales are used.Live birds and eggs are carried on foot and pieces of cloth, plastic shopping bags and basket are used to transport eggs to the markets, all of which could result in breakage and deterioration in egg quality (Meseret *et al.,* 2011). Moreover the live bird markets are characterized by small unhygienic selling space and lack of shelter, feed and water. Market decision is dictated by households' need for cash, disease outbreaks and need for de-stocking. Some of the IC farmers sell off some of their chicken before they reach market weight (1.5-2.0 kg) to avoid total loss in case of disease outbreaks, thereby obtaining lower profits (Okeno *et al*., 2012).

The farmers directly sell their chicken to consumers and/or to small retail (traders) who take them to large urban centers. Live chickens and eggs are sold either at the farm gate, small village market (primary market) or at larger markets (Secondary market in towns). There is exchange of commodities throughout the week with one regular market day at the centers of most villages (Meseret *et al.,* 2011). Both eggs and chickens pass through different individuals before reaching consumers. In most of the cases, the sale and purchase of live chickens and eggs is the responsibility of women. The household poultry is therefore a source of self-reliance for women, since live bird and egg sales are decided by women, both of which provide the women with an immediate income to meet household expenses. Unstable price and demand seasonality are the problems of egg and live chickens marketing in Kenya.

Traders have more access to market information than the farmers (Bett *et al.,* 2011). This is a disadvantage to the farmers since it limits their marketing decisions and consequently affecting production and sales decision. On the contrary, the well informed traders are able to exploit the presence of information asymmetries or lack of information by charging high prices at different markets for their IC sales and paying lower for the purchases from the farmers who accept whatever they are offered. Upton (2000) acknowledges that the lack of information results in poor integration of spatially dispersed markets and cyclical fluctuations in production and prices. However, the relatively high margins for the intermediaries reflect opportunities present at the market (Bett *et al.*, 2011). These opportunities can therefore be effectively utilised by the farmers if they are provided with adequate and reliable information as well as through group marketing.

In intensive and semi-intensive systems, most farmers market their eggs and live chicken through middle-men, shops, hotels and supermarkets while others market directly to consumers and processors (Njenga, 2005). This marketing channel is relatively organized and stable. Decision to market is based on the availability of stock for sale and the economies of profits and loss (Njenga, 2005).

2.8 Improvement intervention

Sustainable rural poultry programs in Kenya should build on what already exists and match technological interventions with local situations. FAO (2002) cites the success in Bangladesh of a smallholder poultry program that targeted illiterate and destitute women with no land and no assets apart from their labor. Village groups of 30-40 women received training in savings and credit management, and learnt the basic techniques of poultry feeding, housing and disease control. Through a credit scheme, the women were provided with improved chicken breeds adapted to village conditions and capable of laying up to 200 eggs a year. At the same time, the program funded a network of supporting village-based enterprises - chick-rearing units, feed suppliers, mini-hatcheries and egg collectors and trained village-based para-veterinarians who provided house-to-house vaccination of the groups' birds against major diseases. The women's welfare improved substantially, with 28% of family incomes rising above the national poverty line within 18 months and school enrolment rates increasing from 86% to 99% in beneficiary households.

In South Africa, the National Agricultural Research Council sponsored a chain of poultry supply centers, owned and managed by members of resource-poor communities, which supplied all the materials needed by poultry producers, including birds, feed, health care supplies and materials to build chicken runs (FAO, 2002). Prospective producers who complete training courses received certificates that secure accreditation with development banks or local government subsidiaries, an essential step toward future loans. They also received, at a nominal fee, poultry first-aid kits. The program identified indigenous chicken breeds that are adapted to survive under harsh, low-input conditions, as long as shelter, feed, water and hygiene are satisfactory. Kenyan IC industry can learn from these two countries and come up with interventions that will help improve the profitability of the indigenous chicken enterprise.

2.8.1 Housing

Housing is essential to chickens as it protects them against predators, theft, rain, sun, cold wind and dropping night temperatures. Moreover, it provides shelter for egg laying and broody hens. In this study, the birds were mostly left to scavenge for feeds during the day and confined at night. In the extensive system, birds of all ages live and scavenge together (Larbi *et al.*, 2013).

In other homesteads, chicken are kept generally with other animals such as sheep, goats and cattle or other animals in the backyard. In many countries, production systems for IC vary widely from large stationary houses with yards, to small portable houses (coops) that are moved frequently to new pastures (KARI, 2010). Most common types of indigenous chicken houses include saddle roofed houses, round thatched huts, boxes and basket types (Adomako, 2009). The traditional houses are small in size and, therefore, difficult for a person to go in and clean up. This would definitely not provide a healthy environment (Kitalyi, 1999). Most of the houses are made from locally available materials such as wood, mud bricks, sugarcane stems, bamboo and cereal stovers (Sonaiya *et al*., 2004).

In Kenya, some of the resource poor small scale farmers share their residential houses with their chickens. The chickens are housed overnight in the kitchen (Nyoni *et al*., 2012). Others construct a chicken house attached to the kitchen which is built on the outside. Young chicks are housed in the kitchen, as they are more vulnerable, to assure their security due to the threat of cold, thieves and predators. Saw dust is used as the main bedding material for the chickens in the houses (Nyaga, 2007) where they sleep for the night. Other farmers use soil, sacks or mats as bedding/litter. This enables them to clear the droppings every morning. A woven basket is the most common housing for confinement of chicks overnight. Its use may be because farmers do not want to invest in chicken houses or they cannot afford to.

2.8.2 Health and disease management

The common causes of death of chicken are seasonal disease outbreaks specifically Newcastle Disease followed by predation (Halima *et al*., 2007). The highest disease outbreak is observed during the rainy season. However, there is a problem identifying the real causes and type of diseases since there is minimal veterinary service offered/sought for. Halima *et al*., (2007) reported that only 6.7% of IC farmers have any access to extension service related to chicken disease and health management. The majority chicken mortalities reported are not properly examined and no health management services are provided. The common diseases and disorders of free-range poultry may be either infectious or non-infectious, and are caused by a wide range of organisms or deficiencies (FAO, 2004). Viral diseases are some of the most important infectious diseases affecting poultry. They are characterized by not being able to be treated, but most can be prevented with vaccines. Poultry health is also affected by nutritional and environmental factors, such as insufficient feed or feed deficiencies (Nyaga *et al*., 1985). A high mortality rate among chicks during the first days or weeks after hatching may be caused by insufficient feed and water. A high mortality in adult birds may be due to nutritional problems, such as mineral deficiency. Energy and protein deficiencies and imbalances can arise when the feed contains insufficient quantities of these nutrients, resulting in poor growth in young stock and a drop in egg production and egg weight in laying hens (FAO, 2004). Mineral and vitamin deficiencies may result in poor growth, low production or death. Vitamin D deficiency if combined with a calcium deficiency causes rickets (bone deformities) in chickens of all ages. A lack of manganese results in deformities of the feet of older chickens.

A major weakness in village chicken farming is on disease control measures. Losses caused by mortalities due to diseases alone have been overshadowed by devastating pressure of Newcastle disease (ND). Nyaga *et al.* (1985) indicated that Newcastle disease outbreaks are reported during the cold and dry periods of the year with peaks in April-July and September-November periods meaning that antibody to the virus can be found in birds all year round. Management practices, including confinement, mode of disposal of poultry waste and carcasses and recovery rates of chicken from disease outbreaks also favour maintenance of virus in village populations. This has led to underestimation of other factors whose contribution to chicken losses is huge (Mbyuzi *et al*., 2012).

Chicken disease symptoms vary and are composed of cough, diarrhea, dizziness, ataxia, sudden death, apathy, swollen head and shanks, pendulous crop, scabies on eye lids and comb (Larbi *et al.,* 2013). Endoparasites (worms) and ectoparasites are equally economically important in village chicken farming. They reduce weight gain, egg production and hatchability and are responsible for significant deaths in young birds (Muhairwa *et al.*, 2008). Conventional disease prevention methods are geared towards birds in confinement and not free range in an indigenous poultry production system. However, the existing indigenous technical knowledge inherited from past generations has sustained the local poultry production system (Okitoi *et al*., 2007c). This knowledge is passed on verbally and is hardly documented. Diseases are a major constraint of indigenous poultry production in Kenya; where Indigenous poultry farming is an integral part of mixed farming. The birds are raised mostly on low input extensive free-range system of production.

Due to lack of simple veterinary knowledge, clinical symptoms are regarded as diseases themselves. Mixing with other animal species (dogs, cattle, wild birds etc) as they scavenge for food, (Petrus *et al*., 2011) may create an opportunity for spreading of disease pathogens between species. Newcastle Disease is the most prevalent and fatal disease in IC farming in Kenya leading to high mortality rate (King'ori *et al*., 2010). The mortality rate in some cases is close to 50%, but falls to 10% when the flock is properly managed. During disease outbreaks, mortality is highest in the dry seasons of August, November and December (Chemjor, 1998) due to limited scavenging material leading to poor nutrition that suppresses disease tolerance. Disease patterns vary according to the season. Newcastle Disease is more serious during the dry season (FAO, 2004). As for Fowl Pox, more outbreaks occur in the rainy season and about 60 percent of the outbreaks affect young chicks. Chickens under two months of age (normally a rapid growth-rate phase), and those over six months of age (in the process of becoming sexually mature) are more susceptible to infectious diseases (Chemjor, 1998). Few farmers seek the services of the veterinary officers or the agricultural extension officers in their regions. Due to high cost of conventional medicines and vaccines coupled with the lack of knowledge on their use (Okitoi *et al*., 2007c), these drugs are usually out of reach of the small-scale farmers. Therefore, there is need for affordable, easy to use and sustainable local poultry disease control programs.

Treatment methods vary but most farmers use alternative remedies also known as ethno-veterinary medicines (Nyoni *et al*., 2012). Farmers mix different herbs depending on the individual farmer's knowledge but there is no analysis on the amount of ingredients contained in the plants (Okitoi *et al.*, 2007c), which means the birds may receive an over or under dose. The most common plants used are *aloe vera,* croton leaves, milk weed and hot pepper (Nzioka, 2000). Others combine *Aloe vera* with Neem, *Sanchusspp,* pepper, red *Amaranthusspp* and guava leaves (Nyaga, 2007), a concoction reported to protect flocks against New Castle Disease. According to famers, the leaves are harvested, cleaned with water, and crushed before they are mixed with drinking water for chickens. Sometimes the concoctions are offered in drinking water regardless of whether the birds are sick or not. There is no age consideration when administering the concoctions. These interventions by farmers could in a way be blamed for the high mortality rate experienced (Petrus *et al*., 2011).However, the effectiveness of herbs as a way of disease treatment was reported in Zimbabwe by Mapiye *et al*., (2005). The authors observed that rural farmers who used traditional medicine (herbs) in that country had large flock sizes in comparisons with those who did not use any form of treatment.

Extensive management systems where chickens have access to outdoor areas, and not confined, predispose them to a greater diversity of parasite infestations (Muchadeyi *et al.,* 2007). Meanwhile parasitism has been known to be a big constraint to chicken productivity (Mungube *et al*., 2008). Helminths are among the important internal parasites in free range chickens affecting all ages. On the other hand fleas, lice and mites feature in most of the ecto-parasitic infestations, chicks and growers being commonly affected. Chicken losses have been reduced significantly in areas where disease identification and control strategies have been communicated to chicken keepers as compared to areas where no extension measures have been put forward. Knowing that most losses occur in chicks has been of crucial importance to establish the different causes, their magnitude and contributing factors. This will give a direction on where greater efforts should be directed.

2.8.3 Losses due to poor management

Although the study by Alfred *et al*. (2012) shows that in free ranging chicks predation causes more losses than any other problem, still chicken keepers are justifiably more concerned about the illnesses than predation. The values of chickens to the farmer increases as the chicken grow and since predation is less common in adult chicken, then diseases are of more concern. Although illnesses might kill more chicks than adults, still chicken keepers observe more diseases in valuable adults than due to predation or any other cause of loss. Deaths due to diseases and parasites contribute to 44%on flock reduction while predation leads to 8% loss. Stock reduction is due to many other factors apart from mortality. These include home consumption 21.5%, sales for income 17.1%, donations 4.4% and exchange 5.5% (Okeno, 2011). The challenges in brooding are diseases, predators, poor housing and poor quality and quantity of feeds which cause mortality of the chicks when they hatch. Poor chicken management especially feeding and watering leads to the highest production losses.

During the dry seasons, green vegetation and insects are scarce contributing to high mortality rates of chickens in the rural areas. Mortality is highest during the first and second week after hatching. A study by Petrus *et al*., (2011) reported mortality of chicks to be the highest (85%) compared to 40% for adults. This can be due to the fact that chicks as young as one day old are left to scavenge together with their mothers leading to starvation. At this age, chicks do not have enough competence and experience in scavenging. Lack of adequate nutrients lead to chicks with low physical defensive mechanism, weak and under-developed immune system (Petrus *et al.,* 2011). Mwalusanya *et al*, (2002) reported a survival rate of 59.7% in village IC chicks (1-10 weeks old) in Morogoro. It is evident that chick losses under the free range management system could be reduced significantly if chicken keepers would pay attention in protecting chicks from predators in addition to controlling Newcastle disease (Alfred *et al.,* 2012). Proper housing of young chicks during their first few weeks of age will prevent them from being preyed on and will also make it easy to attend to any health problems that may arise. The use of early chick shelters such as the hay box brooders and other such equipment may assist in reducing preventable chick losses. Furthermore, identification of specific causes of illnesses in chicks in the free range management system is vital to IC production.

2.8.4 Genetic improvement of IC

Breeding programs need to be well organized to increase the productivity of indigenous chicken with respect to the ability to lay more eggs, grow faster and to have high feed conversion efficiency (Menge, 2008). This should be achieved without losing important genetic characteristics related to product qualities, disease resistance and adaptability. These breeding programs should be set on the basis of their influence on the overall profitability of the IC enterprise (Menge, 2008). The programs targeting improvement of IC should focus on within-breed selection rather than crossbreeding with commercial chicken breeds (Okeno *et al*., 2012). This will help to maintain the IC unique attributes which are appreciated by producers and consumers and elude genetic erosion and dilution hence their conservation. However, implementation of these breeding programs in developing countries are always constrained by numerous challenges including small flock size, poor infrastructure, organizational issues, financial constraints, lack of technical personnel and poor communication networks between researchers, extension agents, farmers and markets (Kosgey *et al.,* 2011).

In Kenya, distinct indigenous chicken ecotypes have been identified and named. They vary in body size, conformation, plumage color and performance. They have been named according to their phenotypic descriptions. These names used to describe common phenotypes in Kenya are; frizzled feathered, naked neck, barred feathered, feathered shanks, bearded and dwarf sized (King'ori *et al*., 2010). The study by Larbi *et al*. (2013), showed that most farmers do not buy birds from outside to improve their flocks; replacement is exclusively with their own birds but some of them purchase chickens from outside, and from neighbors. This pattern is common to all villages of the country. They use only local breeds of chicken. Farmers usually prefer to purchase adult birds rather than young ones. Breeding is relatively an individual affair and the farmer decides what characteristics to propagate. Most farmers prefer colors that are not bright for purposes of camouflaging the chicken from airborne predators as they scavenge (Menge, 2008). Other farmers have shown preference for prolific chicken among other characteristics. In all villages, the most important selection criteria for purchasing birds are body size, weight, followed by number of eggs laid and disease resistance.

Improvement of IC productivity has become the main focus for developing countries for the last several decades (Okeno *et al.*, 2012). However, most of these projects collapsed as soon as the development partners left. In Kenya for instance, attempts at genetic improvement of IC were first made in 1976 (Magothe *et al*., 2012) through National Poultry Development Program (NPDP), a bilateral program funded by the Kenyan and Netherlands governments. The program had three phases where phase one and two had six components, namely; the egg production pilot project, broiler production pilot project, the cockerel exchange pilot program, training, research and marketing surveys (Menge, 2008). Phase three aimed at increasing production and consumption of cheap eggs and meat products among the subsistent rural households (Menge, 2008). This is when the cockerel exchange program was emphasized as a means of achieving the objective. In the cockerel exchange program (CEP) of the NPDP, a hybrid cock was exchanged for the local cock (Nyaga, 2007) and then all the local cocks were killed. The program used cockerels and pullets of Rhode Island Red, White Leghorns, Light Sussex and Black Australop breeds with an aim of improving eggs and meat production of the IC (Otieno, 2013). Government farms were set up where the exotic varieties were raised for sixteen to twenty weeks before being supplied to farmers in exchange for their indigenous chicken. This was meant to increase farmer's income and protein consumption through commercialization of IC. The program was terminated in 1994 after 18 years of implementation. However, this intervention did not succeed because the exotic breeds could not survive the harsh environmental conditions such as high temperatures, drought and disease. The program used a top-bottom approach with minimal farmer input which led to farmers not owning the program.

There was inability to select the IC at the farm level due to lack of breeding goals (Menge *et al*., 2005). For improvement of IC to succeed, breeding goals must be well defined. Breeding goals are linear combinations of traits that have influence on profitability of a given species. When emphasis is put on the wrong traits or when important traits are left out of the breeding goals, genetic change is likely to be in the wrong direction. Currently, some types of IC may be threatened by extinction and this has prompted attempts to maintain some IC in various parts of the country (Menge. 2008). This is done through Kenya Agriculture Productivity Project (KAPP) maintained by KARI and Indigenous Chicken Improvement Program (INCIP) started in 2006 at Egerton University.

Genetic variation within Bomet and Kakamega ecotypes is low. The coefficient of variation estimates in these ecotypes (Ng'eno, 2011) indicates that there is close genetic uniformity within the ecotypes. At the fifth week of age, it is reported to be 11.68 and5.3%, 12.85 and 10.83% at 8 wks and 10.0 and 8.68% at 14 wks for Bomet and Kakamega respectively. This variation is close to 6.5% reported for exotic hybrid layers (genotype well known) at growing stage (Ponsuksili *et al*., 1998).

2.9 Morphology of the digestive system

The intestines serve as an integrating segment for mixing and modification of both urinary and intestinal inputs. Much of the transport activity in the lower intestines is regulated by the hormone aldosterone which varies inversely with the dietary salt content. Low salt diets increases cell numbers, microvillus density, length and the proportion of mitochondria-rich cells (Laverty *et al*., 2006). The functions of the intestinal epithelial cells may change or adapt in the response to a wide number of demands or challenges. These include evolutionary forces, genetic selection either natural or artificial, response to altered physiological status, environmental challenges or constraints upon nutrient availability and dietary composition (Mitchell *et al*., 2006).

Chicken small intestines go through morphological, cellular and molecular changes towards the end of incubation. The weight of the intestines, as a proportion to the embryonic weight, increases from approximately 1% at 17 days of incubation to 3.5% at hatch. After hatching, the growth rate of the intestines relative to body weight is reported to be greatest at 5-7 days of age of chicks (Uni, 2006). Although the digestive capacity begins to develop a few days before hatch, most of the development occur post hatch when the chick begins to consume feed. During the post hatch period, the weight of the small intestines increases at a faster rate than body mass. In addition, the intestinal crypts, which begin to form at hatch are clearly defined several days post-hatch (Sklan, 2001), increasing in both number and size. Villi increase both in size and volume giving them a greater absorptive surface per unit of intestine. The rapid morphological development differs in the duodenum, jejunum and ileum. Duodenum villi growth is almost complete by day 7 while jejunum and ileum go beyond 14 days.

Studies have shown that feeding immediately after hatch accelerates the functional development of the small intestines, while delayed access to external feed hinders the development of the small intestine's mucosal layer (Sklan, 2001). Furthermore, birds denied access to feed within the first24 to 48 hrs exhibited decreased villus length, decreased crypt length and decreased enterocytic migration rate. The difference in growth rates between the ecotypes subjected to the same conditions suggested that the growth rate is related to genetic increases in feed intake and utilization. It may also be assumed that such increased feed intake and efficient feed utilization have also altered intestinal functions, which could influence intestinal morphology (Koh-en and Yutaka, 2007). Therefore, possible morphological differences in the small intestines are of considerable interest. Currently, there is no information available on the comparative anatomical appearance of the intestinal surface of the different ecotypes in Kenya.

Gross and comparative anatomical measurements of each intestinal segment found that birds with heavier body weights had greater intestinal area as broilers had larger and more villi per unit area than the White leghorn in all intestinal segments (Koh-en *et al*., 1991). The broilers had more developed, larger villi, wider microvilli at the apices of villi and more active extrusions of epithelial cells on the tip of the villi surface than the White leghorn. Such morphological distinctions suggest a greater absorptive area leading to the higher growth rate in broilers. These characteristics are thought to be induced by genetic selection for rapid growth rate in broilers leading to increased feed intake and utilization. However, this research has not been done on indigenous chicken and therefore the findings of this study will be useful in explaining the difference in growth rates between ecotypes in Kenya, and will help in selection towards high growth rates.

2.9.1 Gompertz growth model

Growth is an important trait in indigenous chicken industry (Magothe, 2012). It is defined as increase in size such as length, width and weight with age and it is affected by both genetic and non-genetic factors. Nutrition is one of the important non-genetic factors that influence growth in chicken. To describe growth patterns and characteristics, mathematical functions that summarizes growth into biologically interpretable parameters are used (Magothe, 2012). Growth patterns and characteristics are useful in developing standard management and feeding regimes important for achievement of innate growth potential (Cooper, 2005).

The mathematical functions can be useful for optimizing the management and efficiency of animal production and can be used to relate BW to age of the animals, to determine efficiency of nutrient utilization, or to predict daily energy, protein, and mineral dietary requirements (Darmani-Kuhi *et al*., 2010).As described by Duan-Yai *et al.* (1999), the function can be used in two methods, one based on mature weight (BWa) and the other based on initial weight or hatch weight (BW0). The BWa form is based on the knowledge of mature weight of chicken where such data is sometimes not available due to high mortality (Duan-Yai *et al*., 1999). The BWa growth curves have therefore relied mostly on the early part of growing period and assumed on the mature weight value using regression analysis. The BW0 form of Gompertz function that does not rely on mature weight may be more suitable for this study. A useful growth function should describe data well and contain biologically and physically meaningful parameters. The literature on poultry and other animals traditionally defines the relationship between age and live weight as a nonlinear, S-shaped function (Sengul and Kiraz, 2005). As described by Thornley and France (2007) growth functions can be broadly classified into 3 categories: those that describe diminishing returns behavior, those related to sigmoidal behavior with a fixed point of inflexion, and those related to sigmoidal behavior with a flexible point of inflexion. Among the growth functions with sigmoidal behavior and a fixed point of inflexion, the Gompertz equations have been the most used in poultry.

Gompertz growth model is used by Biologists interested in the description of biological growth and in trying to understand its underlying biological process. It is based upon a model given by Gompertz in 1825 for the hazard in life table, then used as growth model. Its initial formulation was largely empirical, but later derived as a growth model for the heart of a chicken (Ismail *et al.*, 2003). The Gompertz model is very popular and used in various fields such as population studies and animal growth in situations where growth is not symmetrical about the point of inflection.

The assumptions underlying the Gompertz equation are that nutrient supply is non-limiting; the quantity of growth is proportional to BW, and rate of growth decays exponentially with time according to decay constant. Inflexion in this sigmoidal growth function is fixed and occurs at a proportional level of final weight. The specific growth rate decays log-linearly (Thornley and France, 2007).There are two main approaches in using this model, namely biological and statistical approach. This model can be useful in providing predictive information especially if the data has been collected over a limited period of growth cycle. In this study, a statistical approach was used where polynomial curves were fitted to the data using multivariate models. The curves fitted have the following characteristics: an accelerating phase of growth from hatching, a point of inflection in the growth curve at which the growth rate is maximum, a phase where growth rate is decelerating, and a limiting value (asymptote) mature weight (Roush and Branton, 2004).

2.9.2 Cost-Benefit analysis

The Ministry of Agriculture and Livestock Development (MOLD) promotes poultry production and emphasizes on production of indigenous chickens. The MOLD (2012) reported that indigenous poultry production is a fast growing industry in the country. The indigenous poultry farmers have been encouraged to commercialize in order to improve their livelihoods in terms of food security, poverty alleviation, income generation and as a drive towards selfsufficiency in poultry and poultry products. Menge et al. (2005) argued that IC production is of great importance to smallholder farmers, but they face the challenge of improving productivity of their flock which could have financial benefit and promote food security as well as achieve market potential.

Currently, consumers opt for organically produced meat from indigenous chickens (Olwande et al., 2010) than meat from broiler chickens. The demand for exotic chickens is declining worldwide due to a majority of the consumers opting of meat for indigenous chickens. According to Olwande et al. (2010), commercialization of IC production is therefore timely in terms of meeting the unmet market demand. Commercial IC production is a fast supplementary income-generating enterprise for rural farmers. Though, there are opportunities for exports of indigenous poultry products, the traditional poultry marketing channels need to be clearly defined (Menge, 2012). Indigenous chickens are ready for marketing at six to eight months and they do not require high financial and technical inputs. There is no formal or organized market for indigenous chickens and as a result, farmers of indigenous chickens compete unfairly with broiler chicken farmers, thus forcing indigenous chicken farmers to lower their prices. However, the demand for indigenous chickens is still high. Many restaurants and food outlets now serve indigenous chicken meat though, only in limited amounts (MOLD, 2012).

In a study of the key market dynamics and profit drivers of the IC industry in Kenya, it was noted that profitability was affected by four key drivers, namely: vaccination costs, transportation costs, costs of supplementary feed and the selling price per unit of an IC. These key drivers vary from one farmer to the other. The study emphasized that overspending on supplementary feed eroded more than 50% of the revenue generated by the producers and more than 25% of the revenue were spent on transport costs.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Source of birds

Flocks of IC were from a collection of eggs of two ecotypes of IC from Kakamega (KK) and Bondo (BN) which were chosen because there have been minimum exotic genetic dilution in these regions. One hundred and twenty eggs were collected from each area and each of the area represents an ecotype sample.

The research was carried out at a poultry research unit of the Indigenous Chicken Improvement Program (InCIP), at Egerton University, Njoro Sub County, Nakuru County, Kenya. Njoro sub County lies on the longitude 35.9449 ^{0} East of Greenwich Meridian and Latitude 0.3316 ^{0} east of the equator. It is about 25km west of Nakuru town. The altitude is between 1800 and 2423meters above sea level (ASL) with a mean annual temperature of between 17 to 22 ^{0}C and mean annual rainfall range of 700 to 1200mm.

3.2 Experimental design

Layout 1 illustrates the experimental design involving five week old chicks subjected to treatments in a 2 x 3 x 4 factorial arrangement with each of the two ecotypes under three growth phases assigned four treatments. Each treatment was replicated two times with thirty birds per treatment. This was meant to capture the effect of treatment on the two ecotypes and the three growth stages.

PHASE (WKS)	**5-8**				**9-14**				**15-21**			
ECOTYPE	**BM**		**KK**		**BM**		**KK**		**BM**		**KK**	
FEEDING REGIMES.	**SCV**	**Sup** 12.56 MJ	**SCV**	**Sup** 12.56 MJ	**SCV**	**Sup** 10.89 MJ	**SCV**	**Sup** 10.89 MJ	**SCV**	**Sup** 10.05 MJ	**SCV**	**Sup** 10.05 MJ

KEY: SCV – Scavenging. SUP – Supplementation

Layout 1: Experimental design

The birds were offered a chick starter diet *ad libitum* from 0 to 5 weeks of age. Clean water was provided *ad libitum* daily. After5 weeks of brooding, each ecotype was divided into four groups of twenty chicks. The first group, which was the control, was left to scavenge with no supplementation up to 21 weeks. The second group was supplemented from week 5 to 8 with a diet formulated to provide 160g CP/ kg and 12.6 MJ/kg ME then left to scavenge without supplementation up to week 21. The third group was left to scavenge without supplementation up to week 8 then supplemented with a diet containing 160g CP/kg and 10.9 MJ/kg ME up to 14 weeks then left to scavenge without supplementation up to week 21. The fourth group was left to scavenge without supplementation up to week 14 then supplemented up to week 21 with a diet containing 160g CP/kg and 10.1 MJ/kg ME. The variation in energy was as per the energy requirements at every growth stage (King'ori *et al.,* 2007).

3.3 Management of experimental birds

The eggs were numbered for tracking identification then simultaneously incubated. At hatching, each chick was weighed and wing tagged with an identification number. Brooding was from hatching to 5 weeks. All birds were vaccinated against Marek's disease at 1 day old, Gumboro at 18, 24 and 30 days old, Fowl Typhoid at 5 and 18 days old, Newcastle at 24 days, 6 wks, 13 wks and 15wks old and Infectious Bronchitis at 6, 13 and 15 wks old as per veterinarian's recommendations. Any other incidence of disease condition was treated promptly by resident veterinarian. Age-weight data was recorded weekly for each bird until 21 weeks of age. Disinfection of brooding and rearing pens was done one week before arrival of the birds. Wood shavings were used as litter material at about 5 cm initial thickness.

Brooding of chicks was done in deep litter brooders fitted with infra-red electric bulbs. At the beginning of the 6^{th} week, chicks were retransferred to deep litter rearing pens (1m × 3m), within the same house. Each pen was provided with two-5 ft. feeders with a capacity of up to 10 kg of feed and two-5 liter water drinkers. The pens were designed to allow the chickens to move out and scavenge freely during the day and get back to the pens in the evening. The chickens were allowed to scavenge together for uniformity of scavenging materials then move back to their respective pens in the evening. There was group feeding where feed was given *ad lib* in each pen. Feed was offered at 8.00 hrs where the chicken were allowed free access up to 10.00 hrs and then released to scavenge. Feeding was done in the morning only as per the practice with most farmers.

3.4 Data collection

The feed intake was recorded daily and weight gain weekly from which the FCR was calculated as total feed intake divided by weight gain. Regression analysis of the data was done to determine the effect of ecotype, feed intake and FCR on average daily weight gain of the KK and BN ecotypes.

Three chickens at every growth phase were randomly selected and killed by decapitation under a light anesthesia. The digestive system was excised for histology. The intestinal segment from the gizzard to pancreatic and bile duct was labeled duodenum, from the duct to Meckel's diverticulum was jejunum, and from the diverticulum to the ileo-caecal-colonic junction was the ileum (Yamauchi *et al.*, 2006). The tissue samples, 4cm segments, was taken from the middle part of each intestinal segment and placed in a 10% buffered formalin solution which was then dehydrated by increasing ethanol concentration (70, 80, 95, and 100%), cleared by two changes of xylene, and embedded in paraffin.

From each chicken, 6 transverse sections (5 μm), i.e. two from each section, were cut by rotary microtome, mounted on glass slides, stained with haematoxylin-eosin and examined with a light microscope. Villus number per cm^2 was determined for the three intestinal sections. Villus height was measured from the top of the villus to the villus-crypt junction. An average of the three birds per phase was taken for the villus number and height in the three sections, i.e. duodenum, jejunum and ileum. The means of these values was used for analysis. The length of the intestines from the pylorus to the ileo-ceacal junction was compared between the ecotypes. The gizzard weights relative to the body weight was measured. All data from these measurements were calculated and expressed as g/100g BW and intestinal length was express as cm/100g BW.

3.5 Statistical analysis

The PROC GLM of SAS (1998) was used for analysis of variance of body weights at each age. The fitted model accounted for the fixed-effects of ecotype, treatment, phase and interaction between ecotype and treatment, ecotype and phase, phase and treatment, phase ecotype and treatment. Least square means were separated using the probability differences option. The model fitted was:

$$\mathbf{Y_{ijk} = \mu + \alpha_i + \beta_j + r_k + (\alpha\beta)_{ij} + (\alpha r)_{ik} + (\beta r)_{jk} + (\alpha\beta r)_{ijk} + \varepsilon_{ijk}}$$

where: Y_{ijkl} = body weight of the ith bird at a particular age; μ=overall mean; α_i =fixed effect of ith treatment (i=1, 2, 3, 4 treatments); β_j =fixed effect of jth phase (j= 1, 2, 3 phases); r_k = fixed effect of kth ecotype (k = KK and BN); $\alpha\beta_{ij}$ = interaction between treatment and phase; α_{rik}= interaction between treatment and ecotype; β_{rjk} = interaction between ecotype and phase; $\alpha\beta_{rijk}$ = interaction between treatment, ecotype and phase; and ε_{ijk} = error term associated with each body weight at a particular age.

3.6 Growth patterns

The growth of an animal is measured as body weight on a longitudinal time frame and the characteristic growth curve is obtained in the sigmoid shape by plotting the body weights as a function of time (age). The sigmoid shape first shows a self-accelerating phase in which the specific growth rate starts at a value of weight (hatch weight) and then a linear phase follows, which turns into a growth rate to a maximal value in a certain period. Finally, growth curve reaches a decelerating phase in which the growth rate decreases and approaches zero which means animal nears mature weight asymptotically. The growth curves of the different groups were drawn by use of non-linear regression model procedures (nlin) of the Statistical Analysis System (SAS, 2003). The Gompertz –Laird function was chosen to fit the data on body weights, as described in literature. The growth model had been found to meet convergence criterion both with IC population in an earlier study (Duan-Yai *et al.*, 1999). It has been shown to represent the growth of chicken accurately with the best fit when compared to other non-linear polynomial functions (Duan-Yai *et al.,* 1999). The function can be used in two methods, one based on mature weight (BWa) and the other based on initial weight or hatch weight (BW0). In this study, it was based on hatch weight (BW0) and the model (Gompertz) expressed as:

BWt=b1exp (-exp (-b2 (t-b3)))

Where:

BWt= live body weight at age t; b1= estimated body weight at hatch; b2= initial specific growth rate; b3= exponential rate of decay of the initial specific growth rate; and t= age in weeks.

The assumptions underlying the Gompertz equation are that nutrient supply is non-limiting, the quantity of growth is proportional to body weight (BW), and rate of growth decays exponentially with time according to a decay constant (Ng'eno, 2011). Recorded body weights from hatch to 21 weeks of age were fitted into equation 1 and growth parameters b1, b2 and b3 estimated for each treatment using PROC NLIN of SAS (SAS 1998). The initial parameter estimates were b1= 2500, b2= 4.5 and b3 = 0.1 as described by Ndegwa *et al* (1996). The estimated parameters were fitted into the function so as to model body weights at particular ages for each treatment. Analysis of variance for modeled body weights and for each parameter was performed according to equation 1. The least square means for each treatment were then plotted against age to obtain growth curve patterns.

Data on intestinal length, gizzard weight and light microscopic examination (villi number per square centimeter) were analyzed with analysis of variance (ANOVA) using the SAS statistical software package to determine whether there is a relationship with digestive system, FCE and growth rates in the two ecotypes. Differences among the treatments were analyzed by Tukey's range test and significance considered at $p<0.05$.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Effect of supplementation at different growth phases on body weight

The overall mean body weights for each treatment are presented in Table 2. Treatment one (TRT1), treatment two (TRT2) treatment three (TRT3) and treatment four (TRT4) were 267.40, 308.40, 333.10 and 310.3g respectively. TRT2 and TRT3 were not significantly different ($P< 0.05$) but there was significant difference between TRT1 and TRT2, TRT1 and TRT3, TRT1 and TRT4 and TRT3 and TRT4. The influence of treatment on body weights was highest on TRT3 which had heavier mean body weight (333.12 g) compared to ($P<0.05$) other treatments.

Table 2: Mean body weights of KK and BN ecotypes under the four treatments.

	Mean body weights(g)	
Treatment	KK	BN
Treatment 1	265.54±19.49^{a}	276.06±17.75^{a}
Treatment 2	306.43±12.84^{b}	319.88±20.63^{b}
Treatment 3	341.71±13.66^{c}	355.37±19.36^{c}
Treatment4	301.11±19.26^{b}	323.19±20.10^{b}

^{abc} Means in a row with one or more letter superscripts in common are not significantly different ($P<0.05$)

The results show that the control group (TRT1) had the lowest growth rate (Table 2). This was due to the limited source of nutrients in the scavenging materials as compared to the groups under supplementation. These results were consistent with Birech, (2002). The Bondo ecotype seemed to adapt better in scavenging than Kakamega ecotype. Bondo ecotype showed the highest body weight in the control treatment. Loss of weight was observed during transition period from one growth phase to another where most chicken showed slowed growth rate after transition from a supplementation phase to a scavenging phase but recovered after one week to a steady positive growth rate. This loss of weight could have been due to lower nutrients availability in the scavenging material as compared to commercial feeds used in supplementation. It could also be as a result of the time taken (one week) for the chicken to adapt from supplementation to scavenging. Likewise, sudden weight gain was observed during transition from scavenging to supplementation. This stabilized after one week to a steady weight gain.

The overall mean body weights observed for both ecotypes were lower than those reported by Ng'eno, (2011). This difference could be a genetic influence in the parental stock (Ng'eno, 2011). The lower body weight recorded for BN and KK ecotypes may be due to changes in the management regime, which shifted to a low input system of scavenging whereas Ng'eno (2011) used intensive production system for the same ecotypes throughout his study period. Fluctuations in growth performance as a result of limited management interventions are common especially at early stage of growth from 1 to 8 weeks (Tadelle *et al*., 2003). The growth performances of ecotypes studied underlined the differences between ecotypes with BN having remarkably higher growth performance levels than KK which may be attributed to differences in feed conversion efficiency (FCE) and scavenging ability. This is in agreement with results of Nge'no (2011) and Tadelle *et al.* (2003).

The indigenous chicken ecotypes under this study were reared under the free range production system where they were occasionally supplemented using commercial feeds depending on the growth stage. They were put under high level health management corresponding to practices in commercial rearing of hybrid poultry with which farmers achieve high productivity levels. Under this management practice, the chicken showed variation in growth patterns. This is consistent with results from other countries like Tanzania, Malawi and Ethiopia (Ng'eno, 2011).

The mean hatching weights observed for BN and KK were 32.79g and 34.56g respectively. Despite lower hatch weight, the BN ecotype had higher growth rates during the early stages and demonstrated better scavenging habits than KK ecotypes, which can explain the higher mean body weights observed in Table 2.However, the hatching weights were heavier than those reported under intensive production system in Nigeria (24.3 to 26.5g) by Adedokun and Sonaiya, (2001), in Ethiopia (28 to 30.8g) by Dessie and Ogle, (2001) and by Tadelle *et al*., (2003) and in Tanzania (26 to 30g) by Msoffe *et al*, (2004).This was consistent with egg weights at incubation where the variations in hatch weights follow the egg weight pattern at incubation.

A study by Tadelle *et al*, (2003) showed a positive correlation between egg weight at incubation and body weight at hatch where 1 gram egg weight difference translates to 1.5 g body weight difference at hatch. Magothe *et al*., (2012) also reported a positive correlation between the egg weights and the age at lay in the parental population. Pinchasov, (1991) reported that hatch weight was not affected by the age of the hen at lay but he found a close correlation between egg weight and hatch weight. He reported chick to egg weight ratio at hatching to be 0.71 and independent of the hen age. One day after hatching, chick weight decreased by 1.5g. This decrease in weight was due to transitional period between the yolk as the major nutrient supplier and the time chicks start feeding on exogenous feeds (Tadelle *et al.,* 2003).The study also showed that the correlation between egg weight and chick weight decreased markedly during post-hatch growth, becoming insignificant five days after hatching.

From these studies by Tadelle *et al*. (2003), Magothe *et al*. (2012) and Pinchasov, (1991), it is also evident that the advantage of high hatching weights attributed to large eggs diminished after hatching, which suggest that feed intake has influence on growth rate and final body weights. According to Witt *et al.* (2004), the hatch weight is determined primarily by egg weight and secondarily by weight losses during incubation, shell and residue weight, strain, incubation time, breeder age, gender of chick and time after hatching. Chick weight normally represents 62 to 76 % of initial egg weight (Witt *et al.,* 2004). This study concludes that the correlation between egg weight and chick weight decreased with age of the chick, and at the end of 8^{th} week, no significant correlation was observed. Results of the mean mature weights for the two ecotypes subjected to the different treatments are shown in Table 3. Mature body weights at week 21 were significantly different between the four treatments where treatment four (TRT 4) had the highest weight in the two ecotypes (1021.88 g and 1143.00g for KK and BN respectively).

Table 3: Mean body weights and SE KK and BN birds at week 21.

Treatment	Mature Weight (g)	
	Kakamega	Bondo
Treatment 1	625.67±70.02^{c}	677.00±64.72^{c}
Treatment 2	696.67±65.91^{b}	753.18±30.28^{b}
Treatment 3	750.00±24.53^{b}	771.67±42.87^{b}
Treatment 4	1021.88±36.20^{a}	1143.00±38.35^{a}

^{abc} Means in a row with one or more letter superscripts in common are not significantly different (P<0.05)

4.2 Modeled body weights

Growth curves in poultry are very useful for setting commercial strains, defining ages and/or weights for selection and setting management procedures because they enable determination of the lines that have diverse genetic background and early predictors of adult body weight for designing feeding programs (Forni *et al*., 2007; Sezer, 2005). The growth curve parameters in this study provide an opportunity to develop feeding strategies for indigenous chicken in Kenya.

The modeled growth curves showed a disrupted progression along the sigmoid-shaped growth curve (Figure 1 a, b, c & d). This is due to what is known as compensatory growth, also referred to as catch up growth, rebound growth or rehabilitative growth (Zubair, 2007). This occurs when the chicken are deprived food for a period of time then followed by a period of food abundance. This causes accelerated growth rate that exceeds that achieved by animals fed continuously. The chicken seems to ‘store’ growth potential where they are able to contend with fluctuations in feed supply. This phenomenon is important economically for indigenous chicken farmers as it enables them to plan feeding schedules so that maximum use of supplements is done when the market conditions are favorable. The results did not show any interaction between the variables in the regression model.

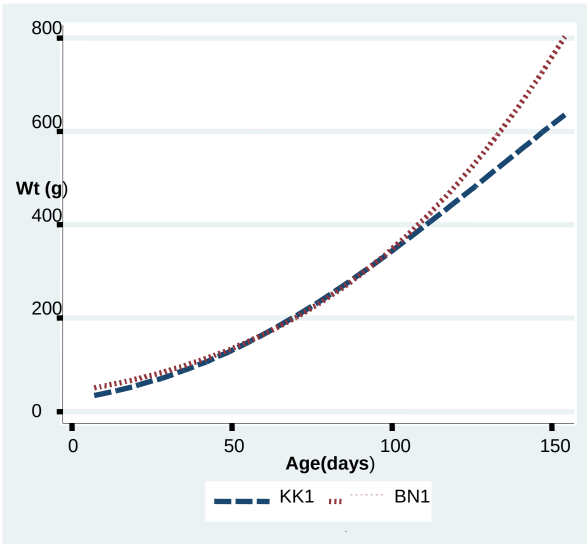

Figure 1 (a)

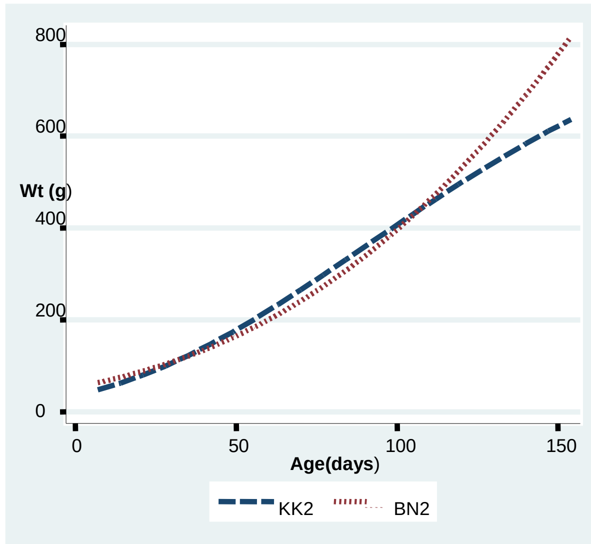

Figure 1 (b)

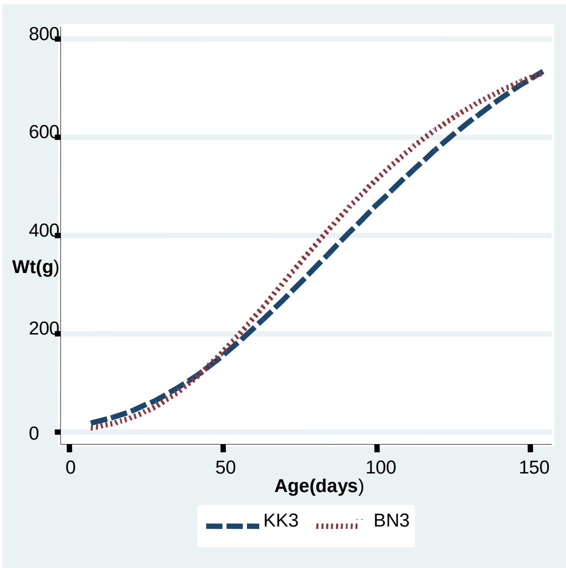

Figure 1 (c)

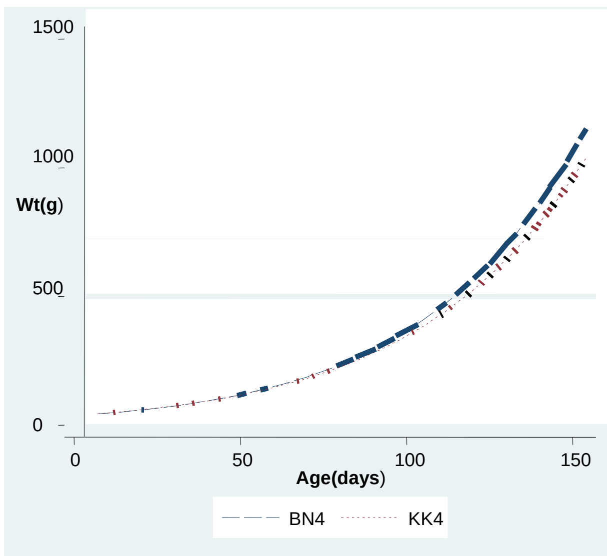

Figure 1 (d)

Figure 1: Modeled body weights of the two ecotypes under the four treatments.

The non-linear model for the growth process have some advantages in not only mathematically estimating the growth curve parameters and explaining of the growth but also in estimating the relationship between size at maturity and maturing rate, which play a crucial role in feed formulation (Ng'eno, 2011).

4.3 Effect of feed intake, FCE and ecotype on weight gain

Table 4 presents the results of a regression analysis that was run on the data obtained from the feeding period. The model was significant (P<0.05) and it explained 92.8% of the data. Ecotype and phase were not significant to the model. Other variables (age, intake and FCE) were significant to the regression model.

Table 4: variable coefficients and standard errors of regression analysis.

Variable	coefficient	SE
Constant	-12.143	2.71
Age	0.976	0.42
Intake	0.027	0.007
FCE	50.403	9.92
R^2	92.8	

In both ecotypes, growth phase significantly affected the FCE (P< 0.05) where the second growth phase (9 -14wks) showed the highest FCE (0.432) which coincided with treatment TRT3 that had the highest average body weights in earlier reported results of this study. This agrees with Ng'eno, (2011) whose study showed that the self-accelerating growth phase estimated by Gompertz models reached the maximum between the 10^{th} and 14^{th} week in all the ecotypes. He therefore suggested that considerable attention and targeted feeding at this stage is required in order to support the rapid growth.

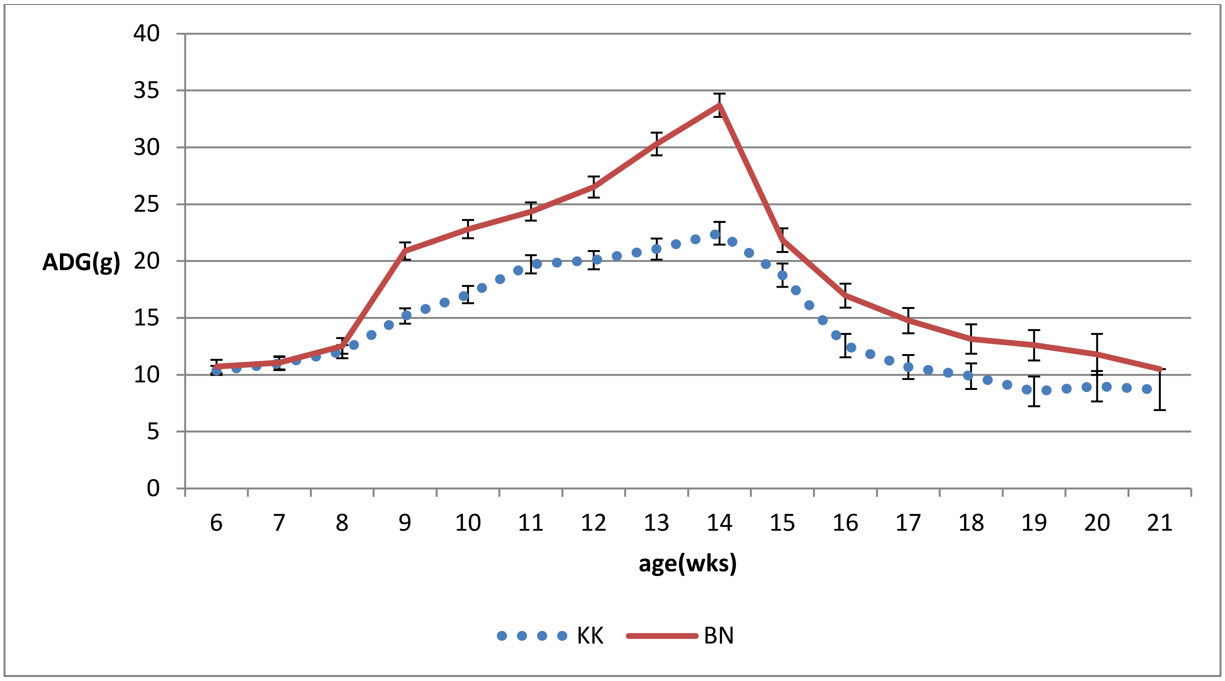

Figure 2: Average daily gain (ADG) for Kakamega and Bondo ecotypes up to week 21.

Ecotype did not significantly (P< 0.05) affect the average daily gain. However, Bondo ecotype showed a higher mean in ADG than Kakamega ecotype (Figure 2). ADG was highest between week 9 and week 15 of the growth period. Week 14 recorded the highest ADG. There was significant difference (P< 0.05) in mean ADGs between week 12, 13 and 14 as compared with the rest of the growth period.

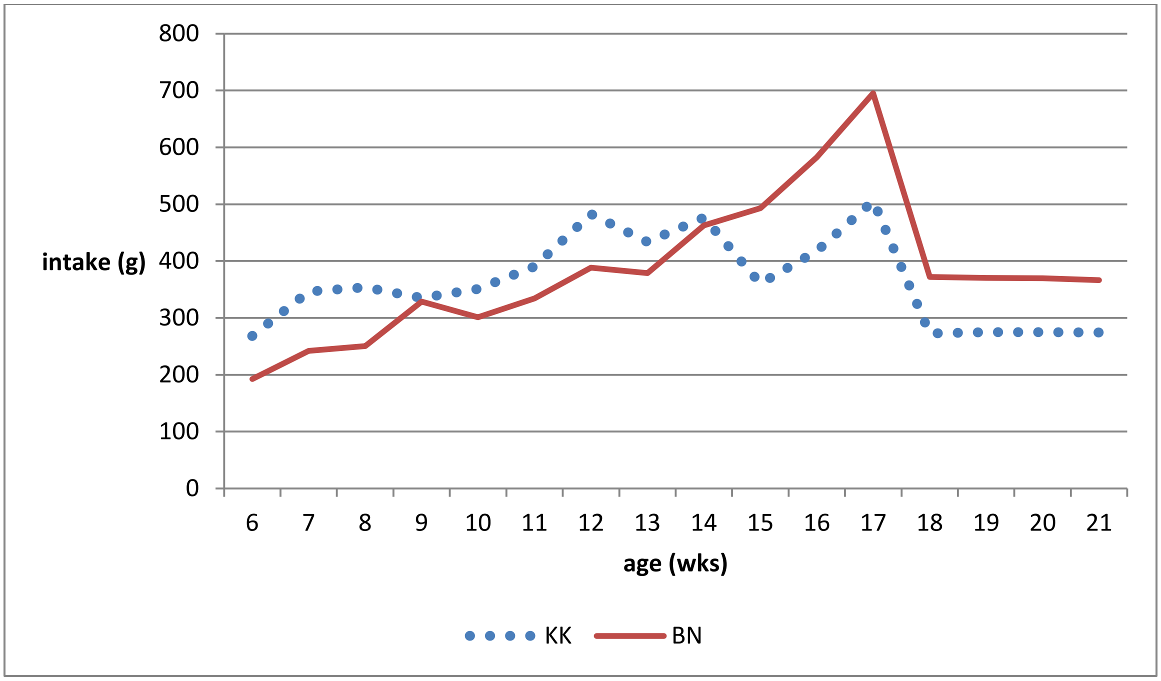

Figure 3: Average feed intake for Kakamega and Bondo ecotypes.

Results on feed intake and conversion efficiency (Figure 3&4) showed a large variation in growth and feed utilization between the three growth phases of the two ecotypes which agrees with other previous findings from Kenya and elsewhere in the world (Ng'eno, 2011, Tadelle, 2001, Sonaiya *et al*., 1999). This offers an opportunity to use phase feeding as a feeding strategy to improve on IC productivity.

In this study, age significantly affected feed intake (P< 0.05). The chicken consumed more feed as they grew older with the highest intake recorded at week 17 of the growing period (Figure 3). This was consistent with the phase where the growth phase significantly (P< 0.05) affected feed intake. The third growth phase (15-21 wks) showed the highest mean feed intake (53.56g/bird/day and 42.80g/bird/day for BN and KK respectively).

Growth phase two had the highest FCE as compared to the other phases (Figure 4). This is explained by the results on villi population where growth phase two had the highest villi population as compared to other growth phases, which led to better feed utilization. Ecotype did not have significant effect on feed intake where the two ecotypes seemed to take almost the same amount of feed in all stages of the growth period. However, ecotype significantly (P< 0.05) affected FCE. The Bondo ecotype showed a significantly higher overall mean FCE (0.43) than Kakamega ecotype (0.20).

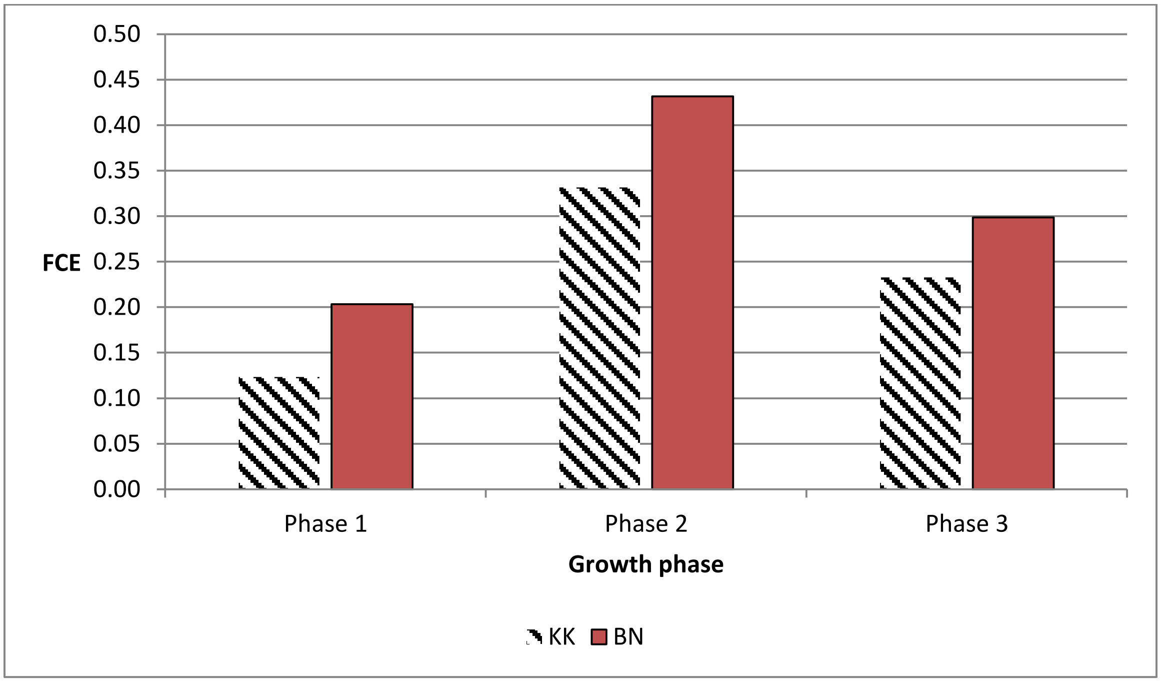

Figure 4: Feed conversion efficiency (FCE) at different growth phases of KK and BN ecotypes.

4.4 Relationship of the gut morphological characteristics with the ecotype, mature body weight, feed intake and FCE

Table 5 shows the results of the gizzard weights and intestinal length of chicken sampled for histology in the four treatments. In ecotypes, intestinal length (IL) and gizzard weights (GW) were expressed per 100g live weight. This was meant to cater for the differences in live weights (LW) in the different chicken sampled for histology.

The control group (TRT1) had the highest mean gizzard weight 104.36g and 113.95g for KK and BN respectively. This was followed by TRT4 with 93.89g and 94.33g for KK and BN respectively with TRT2 having the least in both ecotypes. This was due to adaptation to feed restriction in TRT1 and TRT4 where the chicken intestinal morphology adapted to utilizing the little available nutrients in the scavenging material.

Table 5: Intestinal lengths and gizzard weights of KK and BN ecotypes.

Ecotype	Treatment	Intestinal length(cm)	Gizzard weight(g)
KK	Treatment 1	104.36±21.12[a]	11.13±3.90[a]
	Treatment 2	68.11±19.79[b]	5.26±1.40 [b]
	Treatment 3	73.69±22.12[b]	6.64±0.93 [b]
	Treatment 4	93.89±23.47[ac]	10.52±3.58 [ac]
BN	Treatment 1	113.95±6.72 [a]	10.71±2.73 [a]
	Treatment 2	60.42±22.46 [b]	5.31±1.70 [b]
	Treatment 3	62.78±17.34 [b]	6.13±0.85 [b]
	Treatment 4	94.33±12.23 [ac]	10.50±2.43 [ac]

[abc] Means on a column with one or more letter superscripts in common are not significantly different ($P<0.05$)

The scavenging material was mainly grass, grains and insects which require grinding in the gizzard leading to highly masculine gizzard thus higher weights. TRT2 was supplemented in the first growth phase with commercial feed which was easily digestible and did not require grinding by the gizzard and therefore the digestive organs did not have to adapt for food restriction. This could be the reason why TRT2 recorded the least gizzard weights and intestinal lengths in both ecotypes. However, there was no significant difference in mean gizzard weights and intestinal lengths between the two ecotypes

In both ecotypes as shown in Table 5, treatment significantly ($P<0.05$) affected the intestinal length. The control group (TRT1) had the highest mean intestinal length. This was lower than in other treatments with TRT2 having the lowest. This, as in the case of the gizzard, was due to adaptation to scavenging where the small intestines elongates to help in absorption of the scarce nutrients in the scavenging material.

Silva *et al.*, (2012) indicated that early feed restriction strategies increased the growth rate and feed efficiency with reduced carcass fats. The study showed that early growth retardation resulting from feed restriction in broiler chicks induced an accelerated growth rate (compensatory growth), when feed was given *ad libitum* after a 14 days period of restriction. However, some studies have shown that though in general growth was compensated, final body weight of the restricted birds could be lower (Silva *et al.*, 2012) compared to ad libitum fed counterparts. This is because the birds are not able to regain their full growth potential after re-feeding. Increased weights of liver (Mateos *et al*., 2012), gizzard and intestinal length due to restricted feeding have been reported. This increase in size is due to the organs adapting to efficiently utilize the limited supply of nutrients. The report further suggested that supply organs such as the digestive tract compared to whole body respond more quickly to *ad libitum* feeding regime after a period of feed restriction.

In this study there was a trend of decreased live weight gain during scavenging period. At the same time, there was a trend of increasing digestive organ weight especially the gizzard. These observations suggest that even at the later stage of growth when nutrients are limited; priority is given for the growth of supply organs such as intestines and gizzard than to whole body. Mateos *et al* (2012) reported that length of the small intestines, in relation to live weight, increased when chicken was left to scavenge. This is consistent with the findings of this study where the control group under scavenging had the highest gizzard weights and intestinal lengths in relation to the body weights.

Poultry adapt quickly to changes in dietary fiber content by modifying the intestinal length and weight of digestive organs as well as the rate of passage through the different segments of the GIT. Increasing the dietary fiber content in poultry resulted in increased length of the small intestines, decreased proventriculus weight and increased gizzard weight which is an indication of improved functioning of the GIT (Mateos *et al*., 2012). This could be the reason why both the group under TRT3 and TRT1 showed increased organ weight due to their long period of scavenging at an early growth stage.

The results suggest that the chicken under control (TRT1) adapted to scavenging. This led to increased gizzard weights, due to the nature of the scavenging material available. The gizzard became more muscular than in TRT2 where the chickens were exposed to supplementation at an earlier stage of growth. This muscularity is as a result of the gizzard being active in grinding grains and fibrous materials from scavenging (Mateos *et al.*, 2012).

Reports of gross anatomical changes of the gut owing to the type of diet and striking alterations of villus shape in broilers fed a no-fiber diet have been published by Yamauchi (2002). The small intestine, especially the intestinal villi and absorptive epithelial cells, play significant roles in the final phase of nutrient digestion and assimilation. In starved-re-fed trials, the values of villus numbers, height, cell area and cell mitosis were low after starving but clearly increased when the animals were re-fed the formula diets. The epithelial cells on the villus tip also showed a smooth surface after starving but changed to a rough surface after re-feeding (Yamauchi, 2002). These results seem to suggest that the morphological changes of the intestinal villi are dependent on the presence of digested nutrients in the small intestinal lumen.

4.4.1 Intestinal villi

The small intestine is the most important site of nutrient absorption. Intestinal absorptive cells originate at the base of the crypts as immature proliferative cells, differentiate as they migrate up the villus tip, and are finally extruded from the villous tips (Yamauchi *et al.*, 2009). It has been suggested that increased villus numbers result in increased surface area and are capable of greater absorption of available nutrients (Yamauchi 2002). High population of long villi was reported in chickens that showed an increased body weight gain (Yamauchi 2002).

Table 6: Villi population in the three sections of the small intestines of KK and BN ecotypes.

		Villi population		
Ecotype	**Treatment**	**Duodenum**	**Jejunum**	**Ileum**
BN	Treatment 1	16.35±1.93	13.50±1.32	11.51±1.44
	Treatment 2	23.00±5.00	14.00±2.00	10.50±3.50
	Treatment 3	33.00±7.00	17.50±1.50	11.00±1.00
	Treatment 4	19.20±1.02	15.60±0.68	10.60±0.60
KK	Treatment 1	14.80±1.89	13.40±1.52	10.80±0.49 ^{b}
	Treatment 2	19.00±0.58	13.67±0.58	11.00±0.50 ^{b}
	Treatment 3	26.00±2.00	14.33±3.22	11.00±1.53 ^{b}
	Treatment 4	15.40±1.83	16.20±1.30	12.40±0.81 ^{b}

The results of this study (Table 6) show that treatment significantly affected the villi population in the duodenum section in the two ecotypes. TRT3 showed the highest mean number of villi in the duodenum section as compared to other treatments as shown in Table 6. This agrees with results in Figure 5 where Phase 2 under TRT3 showed the highest FCE/ADFI. This may have been due to the high number of villi in the duodenal section which is the main site of nutrient absorption. These results suggest that the villi responded better to supplementation in the second growth phase (9 -14 wks). However, results in Table 2 indicate that the villi reduce significantly once the supplementation is stopped. This could be because the villi are 'not in use' when feed is scarce unlike during supplementation. This is shown by the lowered mature weights recorded for the group under TRT3 (750g and 771g for KK and BN respectively) as compared to TRT4 (1021g and 1143g for KK and BN, respectively, in both ecotypes as shown in Table 3.

The results also suggest that the villi responded positively to supplementation and negatively to scavenging unlike the intestinal length and gizzard weight that seem to increase (Table 5) as a result of adaptation to restricted feed supply in the scavenging group. The reduced number of villi could be due to feed restriction during the scavenging phase and therefore only a fewer number of villi are needed in absorption, unlike during supplementation where a larger number of villi are needed. However, as presented in Table 6, treatment did not significantly affect the morphology of the jejunum and the ileum. This suggests that the two sections do not have as much significance as duodenum in nutrient absorption. This concurs with an earlier study by Yamauchi *et al.,* (2009) who reported that the ileum and the jejunum did not show morphological change after fasting and concluded that the two sections are not actively involved in nutrient digestion and absorption.

4.5 Cost-Benefit analysis

Figure 5 shows the results of a cost benefit analysis conducted on the three different phases. Growth phase 3 (week 15-21) showed the highest return to capital in the two ecotypes with BN and KK having ksh 13.1 and 12 on every one shilling used in supplementing respectively. Growth phase 1 had the lowest of Ksh 7.2 and 6.6 for BN and KK respectively. This concurs with the previous findings in this study where the third growth phase has the highest market weight translating into higher profits.

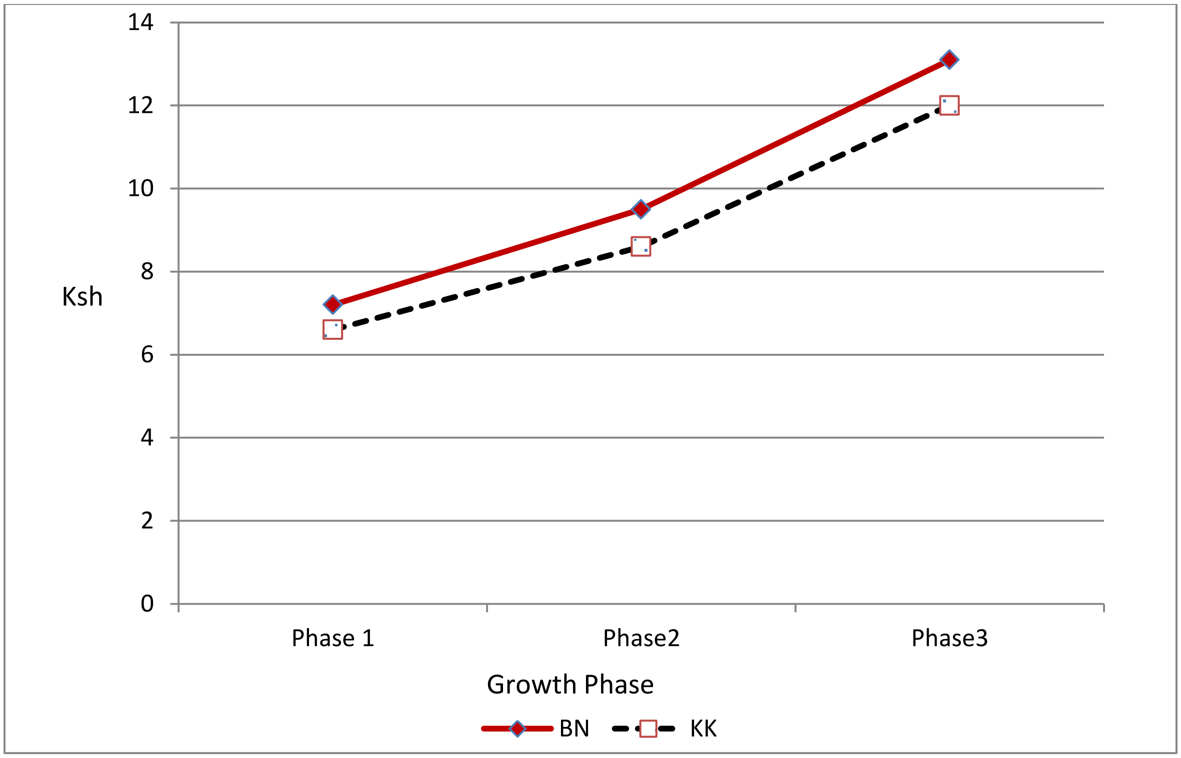

Figure 5: Cost-Benefit analysis for supplementing at different growth phases.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

1. Supplementation during the third growth phase (15-21 wks) leads to the highest mature body weight. Results showed that there were significant differences in the mature body weights in the chicken offered supplementation during the different phases of growth.
2. The chicken consumed more feed as they grew older with the highest intake recorded at week 17 of the growing period. The second growth phase (8-14 wks) had the highest FCE.
3. Scavenging increases the gizzard weight and intestinal length of IC. The control group (TRT1) had the highest mean gizzard weight and intestinal length. This was lower than in other treatments with TRT2 having the lowest.

5.2 Recommendation

1. IC should be allowed to scavenge and then supplemented just before reaching maturity to achieve high market weights.
2. The IC farmers should plan their flocks in such a way that 21 weeks age coincides with festive seasons so as to earn high profits from the high demand during these festivities.
3. Further research on feeding strategies should be done on other ecotypes in Kenya and IC kept for purposes of egg production. A study should be done on long-term feeding strategy which seems to be a reliable method of examining intestinal histological changes.

REFERENCES

Adedokun, S.A. and Sonaiya E.B. (2001). Comparison of the performance of Nigerian indigenous chickens from three agro-ecological zones. *Livestock Research for Rural Development*. (13) 2.

Adomako, K. 2009. Local domestic chickens: their potential and improvement. PhD Thesis, Kwame Nkrumah University of science and technology.

Alfred, B., Msoffe, P. L. M., Kajuna, D., Bunn, A. P Muhairwa and C. J. Cardona. (2012). Causes of losses in free range local chickens following control of Newcastle disease in three villages in Morogoro, Tanzania. *Livestock Research for Rural Development.*24:212.

Bett, H. K., Peters, K. J. and Bokelmann, W. (2011). Hedonic price analysis to guide in breeding and production of Indigenous chicken in Kenya. *Livestock Research for Rural Development.23:142.*

Bett, H. K., Peters, K. J., Kahi, A.K. and Bokelmann, W. (2012). Linking utilization and conservation of indigenous chicken genetic resource to value chains. *Journal of animal production advances*. 2:33-51.

Birech, E. K. (2002). Feed and Nutrient Intake of Local Scavenging Chickens in Nakuru District, Kenya. *M.Sc. Thesis*. Pp. 3-17.

Central Bureau of Statistics. (2009). Kenyan population and housing census report. Pp 30-31.

Cheburet, J. (2010). Improve indigenous chicken. *The Organic Farmer, December*. 67:1-2.

Chemjor, W. (1998). Energy and protein requirements of growing indigenous chicken of Kenya. MSc. Thesis, Egerton University, Njoro, Kenya. Pp. 5-10.

Colin, S. and Esminger, M. E. (2004). *Poultry science.* New York: Oxford University Press. Pp. 104-105.

Cooper, R.G. (2005). Growth in the ostrich. *Animal science journal*. 76:1-4

Darmani-Kuhi, H., T. Porter, S. Lopez, E. Kebreab, A. B. Strathe,A. Dumas, J. Dijkstra, and J. France. (2010). A review of mathematical functions for the analysis of growth in poultry. *Poultry Science journal*. 66:227–239.

Degelo, S. (2011). Quality feeds for Indigenous chicken. *The Organic Farmer, June*. 82: 3-4.

Dessie, T. and Ogle M. (2001). Studies on village poultry production systems in the Central Highlands of Ethiopia. *M.Sc. thesis*. Swedish University of Agricultural Sciences, Uppsala, Sweden.

Duan-Yai, S., Young, A., and Lisle, A. (1999). Growth data of broiler chicken fitted to Gompertz model. *Asian- Aus journal of animal sciences*. 8: 1177-1180.

Food and Agriculture Organization of the United Nations (FAO). (2002).World agriculture towards 2015/2030. Rome, Italy.

Food and Agriculture Organization of the United Nations (FAO). (2004) small-scale poultry production technical guide.

Food and Agriculture Organization of the United Nations (FAO). (2007). Animal production and health division. Emergency center for trans-boundary animal diseases, socio economics, production and biodiversity. Poultry sector country review- Kenya. Pp. 3-13.

Food and Agriculture Organization of the United Nations. (FAO). (2012). Small livestock, big impact. Accessed in April 2012.

Forni, S., Piles, M., Blasco, A., Varona, L. (2007). Analysis of beef cattle longitudinal data applying a non-linear model. *Journal of animal science.* 85:3189-3197.

Gondwe, T.N.P. Ambali, F.C. Chilera, H. and Lwesya, (2005). Rural poultry biodiversity in Lilongwe and Mzuzu Agricultural Development National Statistical Office Divisions (ADD), Malawi. Malawi Journal of Science Technology. 5: 17-21.

Gueye, E.F. (1998). Village egg and fowl meat production in Africa. *World poultry science journal*. 54:73-86

Halima, H. and Neser, F.C. (2007). Village based indigenous chicken production system in North-west Ethiopia. *Tropical Animal Health Production*. 39:189-197.

Katalyi, A.J. (1998). Village chicken production systems in rural Africa: Household food security and issue. Animal production and health paper No. 142, Food and Agriculture Organization of the United Nations, Rome, Italy.

Ismail Z., Azme, K. and Yunus, J. (2003). Fitting Nonlinear Gompertz Curve to Tobacco Growth Data. *Pakistan Journal of Agronomy*. 2: 223-236

Kenya Agricultural Research Institute (KARI). (2010). Annual report. Pp.1-3

Kimani, T., Obwayo, M. and Muthui, I. (2006). Avian flu threat: Socio-economic assessment of the impacts on poultry- related livelihoods in selected districts in Kenya. Pan-African program for the control of epizootics (PACE), Nairobi. Pp. 106-107.

King'ori, A. M., Tuitoek, J. K., Muiruri, H. K., Wachira, A. M. and Birech, E. K. (2007). Protein intake of growing indigenous chickens on free-range and their response to supplementation. *International Journal of Poultry Science.* 6:617-621.

King’ori, A. M., Tuitoek J. K., Muiruri, H. K. and Wachira, A.M. (2004). Demand-driven agricultural research for sustainable natural resource base, food security and incomes; proceedings of the 8th KARI biennial scientific conference. KARI, Nairobi (Kenya). Pp. 598-599.

King’ori, A.M. (2012). Influence of poultry diet on the fatty acid, mineral and vitamin composition of the egg. A review: *Journal of Animal Sciences Advance*. *2***:** 583-588

Kingori, A.M., Wachira, A.M. and Tuitoek, J.K. (2010).Indigenous chicken production in Kenya. *International Journal of Poultry Science. 9*: 309-316.

A.M. Kingori, A.M. Wachira and J.K. Tuitoek, 2014. Influence of Energy Intake on Egg Production and Weight in Indigenous Chickens of Kenya. *International Journal of Poultry Science, 13: 151-155*

Kitalyi, A.J. (1998) *Village chicken production systems in rural Africa: household food security and gender issues*. FAO Animal Production and Health Paper 142, Rome, Italy.

Koh-en,Y. and Yutaka, Y. (2007). Scanning electron microscopic observations on the intestinal villi in growing white leghorn and broiler chickens from 1 to 30 days of age. *British Poultry Science.32*:67-78.

Kosgey, I.S., Mbuku, S.M., Ojango, J.M.K. (2011). Intuitional and organizational frameworks for dairy and beef cattle recording in Kenya. *Animal genetics resources.* 48:1-11.

Larbi, M., M’hamdi, N. and Haddad, B. (2013).Indigenous chicken production systems in villages in the south of Tunisia. *Livestock Research for Rural Development.25:99.*

Laverty, G., Elbrod, V. S., Arnasons, S. and Skadhauge, E. (2006). Epithelial structure and function of the hen lower intestine. Cab International 2006: avian gut function in health and disease. Pp. 1-2.

Leeson, (2008).Predictions for Commercial Poultry Nutrition. *Journal of Applied Poultry Research*. 17:315–322.

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

Magothe, T. M., Okeno, T. O., Muhuyi, W. B. and Kahi, A. K. (2012). Indigenous chicken production in Kenya. *World's Poultry Science Journal.68*: 310-315.

Maina, J.O. (2000). Morphological and molecular characterization of Indigenous chicken in Kenya. PhD thesis, Egerton University Njoro Kenya.

Mapiye, C. and Sibanda, S. (2005). Constraints and opportunities of village chicken production systems in the smallholder sector of Rushinga district of Zimbabwe. *Livestock Research for Rural Development.*17:115.

Mateos, G.G., E. Jiménez-Moreno, M.P. Serrano, and R.P. Lázaro. (2012). Poultry response to high levels of dietary fiber sources varying in physical and chemical characteristics. *Journal of Applied Poultry Research*. 21:156-174.

Mbyuzi, A. O., Komba, E. V. G. and Mulangila, R. C. T. (2012). Integrating interventions against village chicken diseases to reduce mortalities of chicks and growers in southern zone, Tanzania. *Livestock Research for Rural Development. 24:23.*

Menge, E. O., Kosgey, I. S. and Kahi, A. K. (2005). Bio-economic model to support breeding of indigenous chicken in different production systems. *International Journal of Poultry Science.4:*827-839.

Menge, O. E. (2008). Breeding goals for production systems utilizing indigenous chicken in Kenya. MSc. Thesis, Egerton University, Njoro, Kenya.

Meseret, M., And Tadelle, D. (2011). Marketing System, Socio Economic Role and Intra Household Dynamics of Indigenous Chicken in Gomma Wereda, Jimma Zone, Ethiopia. *Livestock Research for Rural Development*. 23:6

Ministry of Agriculture, Livestock Development (MOALD) and marketing, (1994).Animal production division, Kenya. Annual report. Pp. 37-39.

Ministry of Livestock Development (MOLD). (2004, 2005, 2006, 2007 and 2008). Annual report.

Mitcheii, M. A. and Moreto, M. (2006). Absorptive functions of the small intestines. Adaptations meeting demand. CAB international 2006. Pp. 2-3.

Msoffe, P.L.M., Mtambo, M.M.A., Minga, U.M., Olsen, J.E., Juul-Madsen, H.R., Gwakisa, P.S., Mutayoba, S.K., Katule, A.M. (2004). Productivity and reproductive performance of the free-range local domestic fowl ecotypes in Tanzania. *Livestock Research for Rural Development.*16:67.

Muchadeyi, F. C., Wollny, C. B. A., Eding, H., Weigend, S., Makuza, S. M., Simianer, H, (2007). Variation in village chicken production systems among agro-ecological zones of Zimbabwe. *Tropical Animal Health and Production*. 39: 453-461.

Muhairwa, A.P, Msoffe, P.L.M, Mtambo, M.M.A, and Ashimogo, G. (2008). Fundamentals of indigenous chicken rearing in rural áreas of Tanzania.*Journal of animal science.*1:36.

Mungube, E. O., Bauni, S. M., Tenhagen, B. A., Wamae, L. W., Nzioka, S. M., Muhammed, L. Nginyi, J. M. (2008). Prevalence of parasites of the local scavenging chickens in a Selected semi-arid zone of Eastern Kenya. *Tropical Animal Health and Production*. 40:101-109.

Mwalusanya, N. A., Katule, A. M., Mutoyoba, S. K., Mtambo, M. A., Olsen, J. E. and Minga, U. M. (2002). Productivity of local chickens under village management conditions. *Tropical Animal Health and Production.34*:405-416

Mwalusanya, N. A., Katule, A. K., Mutayoba, S. K., Minga, U, Mtambo, M.A. and Olsen, J. E. (2002). Nutrient content of crop contents of rural scavenging local chickens in Tanzania. *British Poultry Science*. 43: 90-95.

Natukunda, K., Kugonza, D. R. and Kyarisiima, C. (2011).Indigenous chickens of the Kamuli Plains in Uganda: Production system and flock dynamics. *Livestock Research for Rural Development.23:220.*

Ndegwa, J. M., Tchombe, T., Kabuage, L. W., Mukkibi-Muka, G. and Kosgey, I. S. (1998). Improvement of indigenous poultry production in sub-saharan Africa. A paper presented at the international course on intensive poultry production held at the Centre for International Agricultural Development Co-operation (CINADCO), Israel. Pp. 43-44.

Ndegwa, J.M., C.W. Kimani, D.N. Siamba, C.N. Ngugi and B.M. Mburu. (2005). On-farm evaluation of improved management practices on production performance of indigenous chicken. Oct-Dec. quarterly report, NAHRC, KARI, Naivasha, Kenya.

Ndegwa, J. M., Mead, R., Norrish, P. and Shepherd, D. (2012). Growth characteristics of six reciprocal crosses of Kenyan indigenous chicken. *Journal of Agricultural Science.4:* 208-212.

Ng'eno, K. (2011). Genetic analysis of growth patterns of different ecotypes of indigenous chicken in Kenya. MSc. Thesis, Egerton University, Njoro, Kenya. Pp. 4-19.

Njenga, S.K. (2005). Production and socio-cultural aspects of local poultry phenotypes in coastal Kenya. MSc thesis Danish institute of agricultural sciences, Tjele, Denmark.

Nyaga, J. M., Nyaga, P. N. and Kariuki, D. P. (1985). Epidemiology of Newcastle disease in Kenya. Animal health and production in Africa. 33: 249-251.

Nyaga, P.N. (2007).The structure, marketing and importance of the commercial and village poultry industry: an analysis of the poultry sector in Kenya. FAO *Poultry sector country review*.1*:*15- 50.

Nyoni, N. M. and Masika, P. J. (2012). Village chicken production practices in the Amatolabasin of the Eastern Cape Province, South Africa. *African Journal of Agricultural Research.***7*:***26-47

Nzioka, M. (2000). Netherlands support to the national agricultural research project phase; Kenya Agricultural Research Institute, Nairobi. Pp. 384-385.

Ochieng, J., Owuor, G. O., Bebe, B. O. and Ochieng, D. O. (2007). Effect of management interventions on productive performance of indigenous chicken in western Kenya. *Livestock research for rural development.*23:5-6.

Okeno, T. O., Kahi, A. K. and Peter, S. I. (2011). Characterization of indigenous chicken production systems in Kenya: household flock structure, dynamics and breeding practices. Pp. 24-26.

Okeno T.O., Kahi A.K. and Peter K.J. (2012). Evaluation of breeding objectives for purebred and crossbred selection schemes for adoption in indigenous chicken breeding programs.

Okitoi, L. O., Kabuage, L. W., Muinga, R. E. and Badamana, M. S. (2007a). The potential of morning and afternoon supplementation of scavenging chickens on diets with varying energy and protein levels. *Livestock Research for Rural Development.*19:2-3.

Okitoi, L. O., Ondwasy, H. O., Obali, M. P. and Murekefu, F. (2007b).Gender issues in poultry production in rural households of western Kenya. *Livestock research rural development.*19**:**23-24.

Okitoi, L. O., Ondwasy, H. O., Siamba, D. N. and Nkurumah, N. (2007c).Traditional herbal preparations for indigenous poultry health management in western Kenya. *Livestock research rural development.*19:5-7.

Olwande, P.O., Ogara, W., Muchemi, G. (2010). Assessing the productivity of indigenous Chicken in an extensive management system in southern Nyanza, Kenya. *Tropical animal health and production.*42:283-288.

Otieno, T.O. (2013). Productivity systems, breeding objectives and selection schemes for indigenous chicken genetic resources in Kenya.

Petrus, N. P., Mpofu, I. and Lutaaya, E.(2011).The care and management of indigenous chicken in northern communal areas of Namibia. *Livestock research for rural development.* 19:8-9.

Pinchasov, Y., (1991). Relationship between weight of hatching eggs and subsequent early performance. *British Poultry Science*. 32: 109-115.

Ponsuksili, S., Wimmers, K. and Horst, P. (1998). Evaluation of genetic variation within and between different chicken lines by DNA fingerprinting. *Journal of Heredity*.89:17–23.

Roush W.B. and Branton, S.L. (2004). A Comparison of Fitting Growth Models with a Genetic Algorithm and Nonlinear Regression. *Poultry Science Association.*23:6-8.

SAS institute. (2003). SAS® user's guide: statistics version 9.1. SAS institute Cary, N.C, USA.

Sengul, T., and S. Kiraz. (2005). Nonlinear models for growth curves in Large White turkeys. *Journal of Animal Science.* 29:331–337.

Sezer, M., S. (2005). Model parameters of growth curves of three meat-type lines of Japanese quails. *Journal of animal science.* 50:22-30.

Silva, P.H.G and Kalubowila, A. (2012) influence of feed withdrawal on growth performance and carcass parameters later stage of broilers. *Iranian journal of applied animal science.*191-197

Sklan, D. (2001). Development of the digestive tract of poultry. *World's Poultry Science Journal*.**57**:512 -514.

Sonaiya, E.B. (2000). Family poultry and food security: research requirements in science, technology and socioeconomics. *Proceedings XXI World's Poultry Congress*, Montreal, Canada, 20-24 August, 2000.

Sonaiya, E.B. (2004).Direct assessment of nutrient resources in free-range and scavenging systems. *World's Poultry Science Journal.* 4: 523 – 535.

Sonaiya, E.B. (2005). Fifteen years of research and development in Obafemi Awolowo University on family poultry. *Ife Journal of Agriculture, Special 40th Anniversary Issue*, 21:116–131.

Swai, E.E., Karimuribo, E.E., Kyakaisho, P.F., and Mtui, P. (2005). Free-range village chickens on the humid coastal belt of Tanga, Tanzania: their roles, husbandry and health status *Livestock Research for Rural Development 19:8.*

Tadelle, D., Kijora, C. and Peters, K. J. (2003). Indigenous chicken ecotypes in Ethiopia: growth and feed utilization potentials. *International Journal of Poultry Science.*2:144-152.

Thornley, J. H. M., and J. France. (2007). Mathematical Models in Agriculture: Quantitative Methods for the Plant, Animal and Ecological Sciences. 2nd edition. CABI Publishing, Wallingford, UK.

Uni, Z, (2006). Early development of small intestinal function. Cab international. Avian gut function in health and disease. Pp. 23-25.

Upton, M. (2000). The Livestock Revolution-Implications for Smallholder Agriculture: A case study of milk and poultry production in Kenya. FAO. Livestock Information and Policy Branch, AGAL

Witt, F and Schwalbach. (2004). The effect of egg weight on hatchability and growth performance of New Hampshire and Rhode Island Red chicks. *South African journal of Animal science*. 34:62-64.

Yamauchi, K., H. Kamisoyama and Y. Isshiki. (2002). Effects of fasting and re-feeding on structures of the intestinal villi and epithelial cells in White Leghorn Hens. *British Poultry Science.* 37: 909-921.

Yamauchi, T., Buwjoom, K., Koge and Ebashi, E. (2006). Histological alterations of the intestinal villi and epithelial cells in chickens fed dietary sugar cane extract. *British Poultry Science.*47: 544-553.

Yamauchi and Thongwittaya. (2009). Intestinal villus histological alterations in broilers fed dietary dried fermented ginger. *Journal of animal physiology and animal nutrition*. 37: 909-921.

Zubair, A.K. (2007) Compensatory growth in the broiler chicken: a review. *World's Poultry Science Journal*. 52:186-201.

Appendices

Author's publications

1. **1.** Effects of Targeted Phase Supplementary Feeding on Gut Morphology of Scavenging Ecotypes of Indigenous Chickens in Kenya: paper submitted to *Livestock research for Rural Development (LRRD) Journal* currently under review.
2. Performance of scavenging ecotypes of indigenous chickens on targeted phase supplementary feeding: Paper presented in the 9th Egerton University international conference on 25th March, 2015 and ready for submission to *Asian-Australasian Journal of animal Sciences*
3. Vines of the Sweet Potato (I. *Batatas*): a Valuable Feed Supplement for Ruminants in Small Holder Systems: paper to be presented in Tropentag Berlin, Germany September 16-18, 2015.